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Designing Innovative and Equitable Curriculum, Instruction, and Assessment Resources Aligned with the Next Generation Science Standards: Transfer and Alignment as a Means of Overcoming Design Challenges

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Abstract

Educators today are questioning the viability of instructional approaches and assessments that do not directly support students to flexibly transfer their learning to new contexts. It is important to develop educational resources that align instruction with assessment, which in turn enable students to think as scientists and engineers as they encounter phenomena and design solutions to problems. To overcome these challenges, Principled Assessment Design (PAD) and Understanding by Design (UbD) frameworks have been used to show how clarity and coherence within and across standards-based assessment and classroom contexts can be achieved. However, there are challenges in mapping the two approaches due to the domain-specific nature of PAD as opposed to the more comprehensive nature of the UbD process. In this paper, we discuss how transfer and alignment to learning goals informed design decisions that were made to integrate the benefits present in each model. The resultant resources are geared at providing equitable and accessible learning opportunities and assessments for all students. Further recommendations about the quality and usefulness of these resources are made based on feedback received from parents, educators, and administrators across several states.

Introduction

Since their introduction in 2013, twenty states have adopted the Next Generation Science Standards (NGSS). An additional 24 states have also adapted rigorous and challenging science standards influenced by A Framework for K-12 Science Education (Openscied, n.d). However, many educators are struggling to teach the required knowledge, skills, and abilities in a way that incorporates students' prior learning opportunities and engages them in local phenomena that encourage sensemaking (Schwarz et al., 2017; Haverly et al., 2022). Through the SIPS ((*Stackable, Instructionally-Embedded, Portable Science Assessments*), we have developed the necessary foundation for an integrated instruction and assessment approach by creating tools that educators, students, and parents need to leverage high-quality assessment to achieve the following goals:

1. Establish a collection of instructionally-supportive science assessment tasks aligned with clearly defined learning goals.
2. Use the developed resources to build state and local educators' capacity to offer high-quality science instruction, evaluate students' learning, and make data-based instructional decisions; and
3. Engage educators, students, and parents in a partnership for student success in science across a range of implementation circumstances.

This paper is focused on the resources that were developed through the SIPS project. Table 1 and Table 2 describe these resources, and the relevant terminology from the NGSS. The project produced year-long model coursework grounded in phenomena and NGSS topic bundles at grades 5 and 8, as well as process guides articulating the design approach and process. All the resources are freely accessible via a web-based resource center (SIPS, 2021). The goal is to facilitate collaboration and communication among teachers at the local level to share best practices and useful resources.

Table 1 – SIPS Resources

Type of Resource	Description
Range Performance Level Descriptors (PLDs)	Developed for each topic bundle, range performance level descriptors (PLDs) describe a continuum of less sophisticated to more sophisticated three-dimensional performances of achievement in science across four levels. PLDs support assessment design and evidence-based interpretations of student scores by defining clear expectations about students' levels of knowledge and skills.
Student Profiles	A student profile describes what students should know and be able to demonstrate prior to, during, and at the culmination of a unit. Designed as a key communication and instructional tool for teachers, the profile builds educators' understanding of the targeted student learning outcomes and how they are situated in the context of year-long instruction. The profile also informs the intentional selection of instructional materials and learning opportunities to support student achievement.
Measurement Targets	A measurement target is a narrative description that integrates the NGSS dimensions into a single statement representing what is to be assessed. The measurement target bridges the gap between the claim and the design of individual assessment tasks.
Instructionally Embedded Assessments	For each instructional segment, descriptions of informal and formal instructionally-embedded assessments are included based on the acquisition goals and evidence statements deemed critical to assess along an instructional plan.
End of Unit (EOU) Assessment	Each EOU assessment is designed to assess the topic bundle at the culmination of each unit. Only the dimensions within the unit bundle are assessed, but they may be assessed in any combination.

Table 1 continued	
Performance Claims	A claim describes what students should know and be able to do in a particular domain such as science. It provides a shared definition of what should be measured and the evidence that should be gathered by assessments to substantiate the claim. Establishing a claim is the first step in designing a system of assessments with the end goals for students in mind.
Assessment Design Tools: • Unpacking Tool • Design Pattern • Task Specification Tool	• An Unpacking Tool provides a clear focus for what is to be measured and helps educators to plan for assessment. • A Design Pattern guides task designers by describing the features of the task necessary to elicit evidence of student proficiency. • A Task Specification Tool defines key elements needed to be addressed by task designers to develop meaningful and interpretable assessment tasks.
Scoring Rubrics and Student Exemplars	Scoring rubrics and student exemplars are designed to help educators accurately and consistently interpret evidence of student learning from the assessment.
Differentiation Strategies and Resources for Diverse Learners	Each unit provides differentiation strategies and resources for diverse learners for each Universal Design for Learning principle – *Multiple Means of Engagement, Multiple Means of Representation, and Multiple Means of Action & Expression* – to support the design and delivery of accessible instruction and learning opportunities to the widest range of students (CAST, 2000).
Source: sipsassessessments.org	

Table 2 – Common NGSS Terminology

Term	Definition
Performance Expectations	Performance expectations set the learning goals for students, but do not describe how students get there.
Disciplinary Core Ideas	Disciplinary core ideas are necessary for understanding a given science discipline. The core ideas all have broad importance within or across science or engineering disciplines, provide a key tool for understanding or investigating complex ideas and solving problems, relate to societal or personal concerns, and can be taught over multiple grade levels at progressive levels of depth and complexity.
Science and Engineering Practices	Scientific and Engineering practices are what students do to make sense of phenomena. They are both a set of skills and a set of knowledge to be internalized. The practices enable students to think like scientists and engineers which enables them to investigate the world and design and build systems.
Cross Cutting Concepts	Crosscutting concepts hold true across the natural and engineered world. Students can use them to make connections across seemingly disparate disciplines or situations, connect new learning to prior experiences, and more deeply engage with material across the other dimensions. The NGSS requires that students explicitly use their understanding of the crosscutting concepts to make sense of phenomena or solve problems.

Design Philosophy and Framework

Curriculum and assessment development initiatives are all too often carried out independently from each other. As a result, educators lack science curricula and assessments that work together to support teaching and learning. This often leads to a lack of alignment between the curriculum goals, assessment, and instruction. Additionally, it does not ensure students receive meaningful and adequate learning opportunities that they can apply to real-life situations. We provide a solution to this problem by building a coherent system that aligns curriculum, assessment, and instruction.

Our design philosophy is centered on the Assessment Triangle (Pellegrino, Chudowsky & Glaser, 2001) and the necessary coherence among its three elements: cognition, observation, and interpretation (Nichols et al., 2016). This philosophy enabled us to (a) carefully define the expectations for learning in relation to standards as well as research on how students gain competency toward those standards and (b) design observations (assessment tasks) that can elicit information about students' learning status and progress so that (c) this information can be interpreted and used to support and to evaluate student learning.

Principled Assessment Design (PAD) was also applied to articulate expectations and design decisions to guide claims about the meanings of student scores (Mislevy & Haertel, 2006). PAD approaches have been successfully used in the past to design assessment tasks and learning activities (Next Generation Science Assessment, n.d; Gane et al., 2024). This approach begins with a deep analysis of the target domain for assessment. PAD approaches have three characteristics in common. The first is that they are construct-centered, which makes all design decisions centered on the original definition of the constructs to be assessed. Secondly, PAD approaches are geared towards solving design challenges by collecting evidence to support the intended interpretation and uses of the assessments. Finally, the need for collecting evidence necessitates making all design decisions and rationales explicit and transparent, which is best facilitated by the collection of documentation to support them (Ferrara et al., 2016). Out of all PAD approaches, Evidence Centered Design (ECD; Mislevy & Haertel, 2006) has gained the most widespread use and implementation. Its key features (domain modeling, domain analysis, conceptual assessment framework, assessment implementation, and assessment delivery) were used as a guide to develop our tasks and resources.

The resulting tasks and instructional resources were also embedded within Understanding by Design (UbD; Wiggins & McTighe, 1998) instructional frameworks that used a backward approach by first designing the goals to be assessed as a means of informing the instructional process. As such, the learning goals are contextually grounded in ways that support students' optimal demonstration of their knowledge, skills, and competencies (Fischer et al., 1993; Yan & Fischer, 2002).

Both ECD and UbD approaches have similarities in the ways that they both look for evidence present in the learning outcomes of students, driven by the curriculum and assessment goals. In the section that follows, we demonstrate the procedure involved in mapping both approaches through the use of alignment and transfer of learning goals.

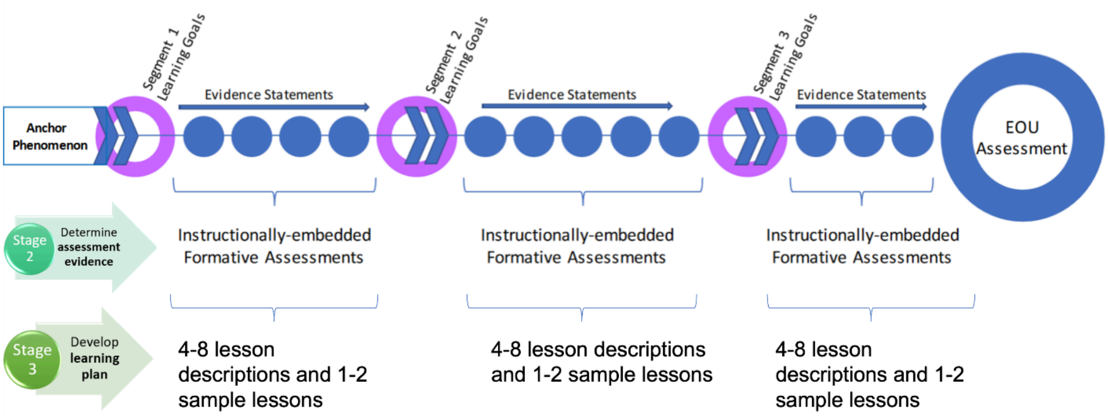
Design and Procedure

The design and development of the instructional frameworks and assessments was an iterative process that revolved around overcoming the design challenges of combining the domain-specific nature of ECD (Mislevy & Haertel, 2006) with the more comprehensive approach of UbD. We began the process by seeking answers to the following questions:

1. What knowledge, skills, and abilities can be assessed for a selected three-dimensional science performance expectation?
2. What student products (what students produce in a task) can provide evidence of learning the selected knowledge, skills, and abilities?
3. What tasks or situations should elicit products that can be teacher-scored across a range of student abilities?

To answer the above questions, we needed to develop instructional framework templates and common assessment templates for each of the grade-level units. This was done with input from state representatives and expert panelists representing six partner states distributed across the US. Educators from each of these six states participated in workshops and professional learning programs designed to enable them to develop the UbD instructional frameworks and sample lessons for each of the four units at grades 5 and 8. For each unit, a group of five educators participated in professional development activities to develop the components of the instructional frameworks. These components were iterated and revised by 19 project staff and state partner representatives and informed the development of the unit's End of Unit (EOU) science assessment. The outline of each unit's instructional framework is shown in Figure 1.

Figure 1 – Outline of an Instructional Framework



Each instructional framework was divided into three sections as follows: Stage 1, the desired results, provides the expected learning outcomes of the unit. These include a) the performance and learning expectations covered in the unit; (b) major concepts and questions that students would explore (i.e., the enduring understanding and essential questions); and (c) the breakdown of specific content knowledge and skills that students would need to master the learning expectations. Stage 1 outlines what students need to know and be able to do by the end of the unit. Using the components of the topic bundles, a student profile was generated for each unit. The profile documents the overall measurement target that integrates the core ideas, practices, and crosscutting concepts into a single statement representing what is to be taught and assessed in each unit. These profiles outline the prior learning and future learning opportunities for each unit guided by the NGSS and the National Research Centre (NRC) Framework. They also outline how the content of the performance expectations could be developed into a structure for the development of core ideas, practices, and crosscutting concepts throughout the unit.

Stage 2, the assessment evidence, describes the means of assessing the concepts, knowledge, and skills from Stage 1. This includes:

a. graphic organizers, exit tickets, and discussion prompts defined as “in the moment” assessment opportunities that identify student challenges and lack of knowledge or alternate conceptions;
b. formal assessments (e.g. performance tasks, projects) that measure how well students perform when engaging in more complex tasks that require integration of the three dimensions (core ideas, practices, crosscutting concepts) in the service of sensemaking. They are administered at specific, intentional points in time along an instructional plan before or after a lesson or a series of lessons; and
c. the end-of-unit assessment, comprised of three tasks that support educators in evidence-driven planning for subsequent instruction after each unit in combination with evidence from the informal and formal instructionally-embedded assessments.

Stage 2 explains how teachers would evaluate the level of student understanding based on the information taught. This section of the instructional frameworks makes a direct connection between the learning expectations and content to be delivered in a unit and how students and teachers would evaluate learning and mastery of those expectations. The instructional framework offers embedded links to sample instructionally-embedded assessments that provide data to inform instructional planning.

Stage 3, the learning plan for each unit, aligns with Stage 1 and Stage 2 of the instructional framework. It provides a roadmap that teachers can use to design a plan of instruction that helps students attain the unit’s learning goals (Stage 1) and respond effectively to the assessment and evidence targets designated in Stage 2 for the unit.

The above perspective enabled us to achieve coherence at the unit level by guiding coordination and alignment across the three major components of curriculum, instruction, and assessment. By referring to the Stage 1 learning goals and engaging teachers and other educators in the development processes, the tasks, and ultimately the assessments composed of them, yield evidence regarding critical aspects of what happens in the classroom. The next section outlines and discusses the design decisions made to build coherence within and across instructional frameworks

Design Decisions in Developing a Coherently Aligned System of Curriculum, Instruction, and Assessment

Connecting ECD and UbD approaches enabled us to incorporate transfer into the learning process and also align curriculum, instruction, and assessment within and across units. We were able to incorporate the benefits of each approach into the following phases of the design process: 1) Unpacking of the core ideas, practices, and crosscutting concepts; 2) Developing big ideas; 3) Identifying enduring understandings and essential questions; 4)

Developing acquisition goals to support transfer and alignment of learning; and 5) Aligning the instructional sequence with stage 1 and 2.

Each phase was guided by design decisions geared towards achieving coherence between the learning goals, assessment tasks, and instruction as described below:

Unpacking of the core ideas, practices, and crosscutting concepts

To create an instructional framework, it was necessary to unpack a related set of NGSS core ideas, practices, and crosscutting concepts, and combine them in ways that would best support knowledge transfer as evidence for learning. Guided by various resources, including topic area and sequence recommendations from the NGSS, the decision was made to use all the Grade 5 performance expectations and a selection of MS performance expectations outlined in the NRC Framework (NRC, 2012). The performance expectations in each bundle were selected based on related disciplinary content as well as their capacity to build on one another. Figure 2 shows information about the performance expectations that were combined to form the topic bundles for Grade 5 Unit 1. In addition to specifying how the content, practices, and crosscutting concepts would be present within a given unit, we also documented the overall flow of these dimensions across the different units. This allowed us to show how learning opportunities occur across the entire year, and to support the identification of important prior knowledge and skills that may be needed within a given unit.

Figure 2 – Grade 5 Unit 1 Performance Expectations used in the topic bundle: Matter and Its Interactions. Source:NGSS (2013)

5-PS1 Matter and Its Interactions

5-PS1 Matter and Its Interactions

Students who demonstrate understanding can:

5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen. [Clarification Statement: Examples of evidence could include adding air to expand a basketball, compressing air in a syringe, dissolving sugar in water, and evaporating salt water.] [Assessment Boundary: Assessment does not include the atomic-scale mechanism of evaporation and condensation or defining the unseen particles.]

5-PS1-2. Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved. [Clarification Statement: Examples of reactions or changes could include phase changes, dissolving, and mixing that forms new substances.] [Assessment Boundary: Assessment does not include distinguishing mass and weight.]

5-PS1-3. Make observations and measurements to identify materials based on their properties. [Clarification Statement: Examples of materials to be identified could include baking soda and other powders, metals, minerals, and liquids. Examples of properties could include color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility; density is not intended as an identifiable property.] [Assessment Boundary: Assessment does not include density or distinguishing mass and weight.]

5-PS1-4. Conduct an investigation to determine whether the mixing of two or more substances results in new substances.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions. ▪ Develop a model to describe phenomena. (5-PS1-1) **Planning and Carrying Out Investigations** Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions. ▪ 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. (5-PS1-4) ▪ Make observations and measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. (5-PS1-3) **Using Mathematics and Computational Thinking** Mathematical and computational thinking in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions. ▪ Measure and graph quantities such as weight to address scientific and engineering questions and	**PS1.A: Structure and Properties of Matter** ▪ Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon; the effects of air on larger particles or objects. (5-PS1- ▪ The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. (5-PS1-2) ▪ Measurements of a variety of properties can be used to identify materials. (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.) (5-PS1-3) **PS1.B: Chemical Reactions** ▪ When two or more different substances are mixed, a new substance with different properties may be formed. (5-PS1-4) ▪ No matter what reaction or change in properties occurs, the total weight of the substances does not change. (Boundary: Mass and weight are not distinguished at this grade level.) (5-PS1-2)	**Cause and Effect** ▪ Cause and effect relationships are routinely identified, tested, and used to explain change. (5-PS1-4) **Scale, Proportion, and Quantity** ▪ Natural objects exist from the very small to the immensely large. (5-PS1-1) ▪ Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume. (5-PS1-2),(5-PS1-3) --- ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** ▪ Science assumes consistent patterns in natural systems. (5-PS1-2)

Development of Big Ideas

Table 3 – Grade 5 Unit 1 Big Ideas

NGSS Disciplinary Core Idea	Big Idea
PS1.A Structure & Properties of Matter	1. Matter can change states (solid, liquid, gas) when heated, cooled, and/or mixed. [prior understanding: PE 2-PS1-1] 2. Matter is made up of particles that are too small to be seen. (5-PS1-1) 3. Certain properties of substances can be used to identify them. (5-PS1-3)
PS1.B Chemical Reactions	4. Mixing two or more substances can lead to the formation of new substances. (5-PS1-4) PS1.A & PS1.B
PS1.A & PS1.B	5. The total weight of matter does not change, even when it changes form or when new substances are formed. (5-PS1-2)

Big ideas were developed to describe what students would work on during the delivery of a coherent sequence of lessons and opportunities to learn. The process involved describing the disciplinary knowledge best aligned to the unit's Performance Expectation bundle that students would acquire in the context of a phenomenon or design problem. The development of the big ideas also considered how students would transfer their knowledge to different situations as they integrate the dimensions to answer specific questions about the natural and designed world. Table 3 shows the big ideas developed for Unit 1 as aligned to the core ideas of the Performance Expectation bundle.

Identification of Enduring Understandings and Essential Questions

Following the UbD model of developing Stage 1 goals, we identified enduring understandings and essential questions that were aligned to the dimensions present in the topic bundle. An enduring understanding is an overarching statement that reflects a deeper internalization of a topic and may connect to a real-life issue or a larger understanding of the world for both students and teachers. It reflects an important idea that has lasting value beyond the classroom and should be transferable beyond the scope of a particular unit. On the other hand, an essential question is an open-ended question that provokes sustained inquiry and meaningful reflection that leads the student to enduring understandings (Wiggins & McTighe, 1998). Overarching essential questions point beyond the particulars of a unit to the larger skills and understandings. Topical essential questions address the specific core ideas in focus for the unit. Both enduring understandings and essential questions guided assessment and instruction design decisions incorporated a principled design approach, ensuring evidence to support the intended purpose and use of the entire curriculum. This approach guided the scoring and interpretation of students' scores. Table 4 shows the essential questions and enduring understandings used to develop the first unit for Grade 5.

Table 4 – Grade 5 Unit 1 Enduring Understandings and Essential Questions

Enduring Understandings	Essential Questions
Students will understand that . . . 1. We can use different types of models to represent particles too small to be seen. 2. Patterns of properties can be used to: identify, describe, and compare substances. Patterns of certain properties can be used to describe and explain whether new substances are formed when substances are mixed. 1. Matter can change form through physical and chemical changes, but through any of these changes, the total weight of matter is conserved. 2. Scientific explanations are based on: evidence and reasoning. Data collected from an investigation can be analyzed and compared to provide the most relevant evidence for an explanation.	1. How can I use models to represent and explain something I cannot see? 2. How can I identify, describe, and categorize substances? 3. How can matter change? 4. How do I use evidence and reasoning effectively to evaluate an explanation? How much evidence is needed to support an argument?

Use of Acquisition Goals to Support Alignment and Transfer of Learning

Stage 1 of each unit includes a set of learning goals. These encompass acquisition goals reflecting different combinations of the core ideas, practices, and crosscutting concepts that comprise the topic bundle. The acquisition goals aim to enable students to flexibly use their knowledge with a range of practices and crosscutting concepts not only within the unit but also in other contexts/situations. Thus, providing students opportunities to learn the acquisition goals can prepare them to demonstrate the associated transfer goal at some point in time.

The acquisition goals did not reference specific phenomena and design problems. Therefore, the instructionally-embedded assessments that were developed in Stage 2 of the UbD process can be flexibly used with other instructional frameworks (e.g., Open Educational Resources state-developed resources) besides the Stage 3 learning plan.

Using Ruiz-Primo et al.'s (2000) levels of knowledge transfer, two claims were made about how knowledge acquisition, in the context of a phenomenon or phenomenon-rooted design problem based on the topic bundle, may occur:

1. transfer as demonstrating sense-making through the flexible application of knowledge through integrating the original combinations of dimensions within the performance expectations from the unit bundle, i.e., close transfer.
2. transfer as the flexible application of knowledge through integrating new/different combinations of the dimensions represented by the performance expectations in the bundle/unit, i.e., proximal transfer.

The design of the tasks determines how close or proximal those assessments are to instruction. A family of tasks could be created in which a task is close to instruction (same phenomenon, context/situation) and other tasks are proximal (somewhat close, but slightly more distal to instruction).

Table 5 presents sample acquisition goals developed to address transfer goals aligned to the 3 dimensions (core ideas, practices, crosscutting ideas) present in the unit.

Table 5 – Grade 5 Unit 1 Sample Acquisition Goals

Students will know and be able to . . .

1. Describe how properties of matter can be used to compare and contrast materials.
2. Use mathematical and computational thinking on the properties of substances to identify a substance.
3. Conduct an investigation to measure and/or qualitatively describe the properties of substances.
4. Develop or use a model that shows that a substance, regardless of the quantity, is made up of particles too small to be seen.

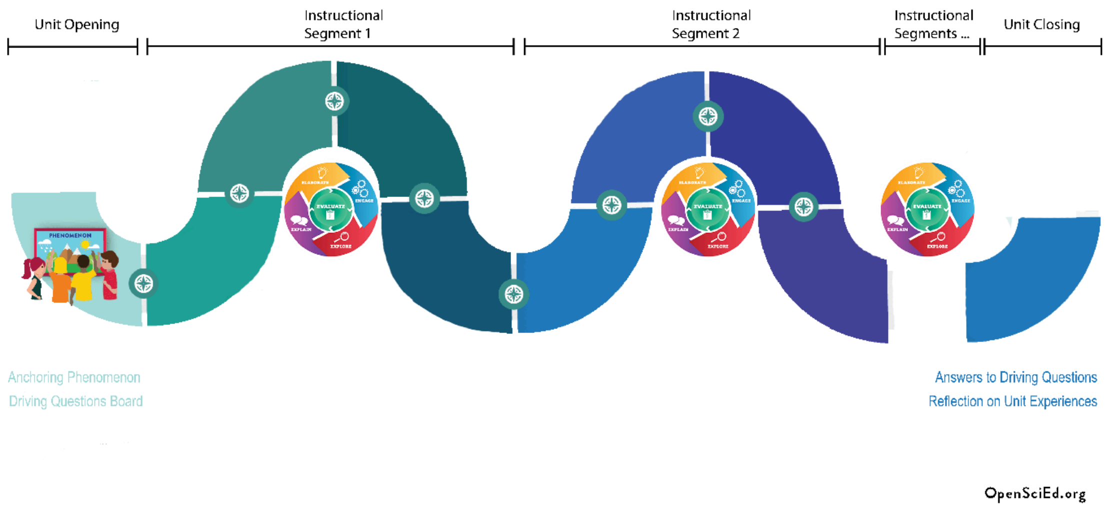
Aligning instructional sequence with stages 1 and 2

The design of the instructional sequence in Stage 3 (Figure 3 - OpenSciEd 2020) was developed to explicitly teach for transfer by varying contexts and creating opportunities for students to generalize concepts defined in Stage 1. In doing so, educators can effectively assess the knowledge, skills, and abilities incorporated in the instructionally-embedded assessments in Stage 2.

Overall, each instructional framework has a multilevel design that includes: (a) The Storyline, (b) Instructional Segments, and (c) Individual Lessons. Each storyline also incorporates the 5E instructional model (Bybee et al., 2006), an inquiry-based approach developed by the Biological

Sciences Curriculum Study (BSCS). Each instructional segment engages students in a sequence that requires them to ask questions that they would investigate and obtain information to enhance and self-assess their understanding. The unit design work was also guided by the Universal Design for Learning framework (CAST, 2000; Rose & Meyer, 2006) to ensure that all learners would have access to equitable and meaningful learning opportunities.

Figure 3 – Instructional Sequence (OpenSciEd 2020)

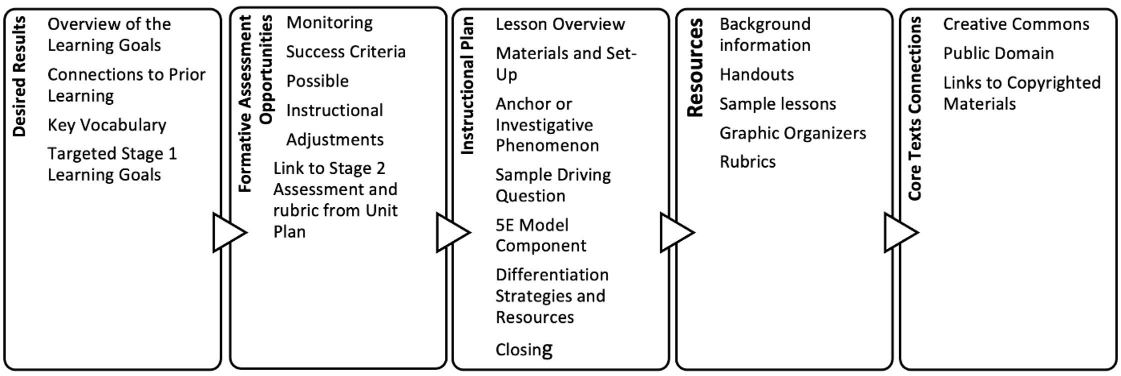


The unit's storyline begins with students exploring an anchor phenomenon. They attempt to make sense of the phenomenon by connecting it to what they already know about it and identifying what they are curious to know. The anchor phenomenon provides a context to raise questions that initiate a sequence of investigations for a unit. Students uncover what needs to be figured out. As noted by Reiser (2021), "it is not the sole thing that a class will try to explain and may not even be the most central one" (p. 815). In a unit storyline model, related phenomena are also identified. Over the course of the unit teachers and students are introduced to a related phenomenon that could help them know more about the anchoring phenomenon. These related phenomena are unique to a particular instructional segment or are used only within a single lesson. As part of the storyline design, students identify questions and ideas for investigations. As the unit progresses, students are given opportunities to answer questions generated when they first explored the anchoring phenomenon and generate more throughout the subsequent instructional segments.

An instructional segment articulates a portion of the unit's learning goals as defined in Stage 1 of the UbD process. These learning goals are used in a corresponding Stage 2 segment to identify and describe the assessments that would be used to collect evidence of students' learning throughout the unit and instruction. The lessons in each instructional segment are designed to ensure students have opportunities to acquire and apply the learning goals from Stage 1. Each instructional segment that was developed has the following characteristics: (a) an outline of four to eight lessons; (b) at least two out of the five phases of the BSCS 5E model per lesson (Bybee, et al., 2006; (c) a description of what students are expected to do during each lesson, and (d) a list of acquisition goals covered in each lesson. The complete set of lessons in an instructional segment covers all the acquisition goals previously identified (in Stage 2) for that segment and all five phases of the 5E model.

Within each unit's instructional segments, sample lessons were developed for use by state and local administrators and teacher leaders (e.g., curriculum directors, instructional facilitators, and professional learning specialists) to: (1) illustrate examples of instructional lessons developed using an ECD approach, and (2) support accompanying process documentation about how to use the instructional frameworks to intentionally design high-quality lessons in an aligned curriculum, instruction, and assessment system. Figure 4 is an outline of the components of a sample lesson, illustrating how learning goals, formative assessment opportunities, resources, and core text connections are integrated into the learning process.

Figure 4 – Components of a Sample Leasson



In summary, we have demonstrated the importance of ensuring that each phase aligns with the learning goals to ensure they measure the original knowledge, skills, and abilities as defined in the topic bundles. In doing so, students can transfer knowledge within and across instructional frameworks, ensuring coherence throughout their learning process.

Conclusion and Recommendations

We have demonstrated the importance of aligning curriculum, instruction, and assessment that will be useful for state and district science specialists and classroom teachers. At a global level, our approach will be helpful to educators struggling to adopt rigorous and challenging science standards. Our design approach is also useful to curriculum developers struggling to design and implement assessments that adequately reflect science standards and meet technical quality and validity requirements. We believe in a coherent research-to-practice model with rigorous evidence to support design and evaluation decisions which in turn supports better classroom instruction.

The design decisions that resulted in developing the instructional frameworks show that it is possible to create a coherent system of curriculum, instruction, and assessment guided by ECD and UbD approaches applied to NGSS. This was made possible by incorporating acquisition goals developed using ECD design principles throughout the three stages of the UbD approach. Acquisition goals proved useful in ensuring alignment of the learning goals throughout the unit. They also support the transfer of learning by combining different dimensions to provide opportunities for close and proximal transfer within the unit.

Feedback from educators shows that SIPS instructional frameworks are best used to supplement other curriculum materials that have been used in the past, which can be adapted to align with the acquisition goals. The effectiveness of the entire curriculum in improving student achievement and understanding of the dimensions is still under investigation. However, there is considerable evidence that shows that this approach to designing coherent systems of curriculum, instruction, and assessment will give students the agency they need to solve real-life problems as they engage in three-dimensional science learning.

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