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Elementary Science Teacher Candidates' Noticing and Interpretation of Student Sensemaking in the Context of Classroom-Level Phenomenon-Based Assessments

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ABSTRACT

This study examined elementary science teacher candidates' (TCs') ability to notice and interpret students' sensemaking and science ideas by analyzing written responses to classroom-based assessments implemented at the end of mini-units during their field placements. TCs were enrolled in a 16-week science methods course at a Midwestern university committed to preparing teachers for three-dimensional instruction, as outlined in the Framework for K–12 Science Education (National Research Council, 2012). As part of this broader focus on three-dimensional instruction, TCs also engaged in learning opportunities to design and implement classroom-based assessments grounded in real-world phenomena. These assessments varied in how strongly they were anchored in phenomena, providing a range of contexts for evaluating student thinking. After enacting their assessments, TCs collected and analyzed students' written responses to identify and interpret instances of sensemaking—defined as the process through which students figure out how or why something happens by articulating ideas, using evidence, and reasoning through science concepts (Odden & Russ, 2019). Using Kang and Anderson's (2015) framework of teacher noticing and responding, we examined how TCs made sense of student thinking. Findings indicate a clear connection between assessment design and noticing when assessments more effectively leveraged phenomena to elicit reasoning, TCs were more attuned to identifying and interpreting student sensemaking. This study underscores the importance of integrating assessment design with the teaching of three-dimensional instruction in teacher preparation programs.

Keywords: Sensemaking, Elementary Science, Teacher Education, Assessment.

Introduction

Background

Sensemaking is central to science classrooms, especially within the three-dimensional instructional framework promoted by the Next Generation Science Standards (NGSS) (Campbell, 2018; Johnson & Cotterman, 2015; Luna & Sherin, 2017; National Research Council [NRC], 2012; Sherin & van Es, 2005). This approach frames sensemaking as an active process where students construct or revise explanations to understand natural and designed phenomena (Odden & Russ, 2019; Penuel & Bell, 2016; Reiser, 2013;). Here, a science phenomenon is defined as an observable event that invites student investigation and explanation, focusing on uncovering the "how" and "why" behind it. The NGSS three-dimensional approach emphasizes sensemaking by involving students in science and engineering practices, as well as cross-cutting concepts, allowing them to explore phenomena in depth and develop a nuanced understanding of scientific ideas.

Research supports the role of phenomena in fostering three-dimensional instruction and aiding student sensemaking (Brown & Bybee, 2023; Lee & Grapin, 2022; Pellegrino et al., 2014; Schwarz et al., 2017; Zembal-Saul & Hershberger, 2019). Teacher practices of noticing and responding play a crucial role in this process, as teachers recognize, interpret, and build upon students' ideas to guide them in investigating and explaining phenomena more deeply (Berland & Reiser, 2009; Davis et al., 2017; Furtak & Ruiz-Primo, 2008; Gotwals & Birmingham, 2016; Hanuscin & Zangori, 2016; Kang & Anderson, 2015). Studies suggest that effective teacher noticing and responding help students meaningfully engage with the natural world, encouraging scientific reasoning and causal explanations (Hammer & Van Zee, 2006; Hutchison & Hammer, 2010; Luna, 2018; Russ et al., 2009).

Emerging research also explores teacher noticing within assessments, showing that high-quality assessments, which include open-ended questions inviting reasoning and evidence, engage teachers in productive noticing of students' ideas, thus supporting student sensemaking (Campbell, 2018; Furtak et al., 2016, 2020; Kang et al., 2014). Such assessments, when tied to phenomena, provide insights into students' understanding of events' underlying mechanisms, offering a richer context for applying concepts (Windschitl et al., 2012). In this study, we examine the role of phenomena as a core element in classroom-based assessments and its impact on elementary science teachers' noticing and responses to students' disciplinary thinking.

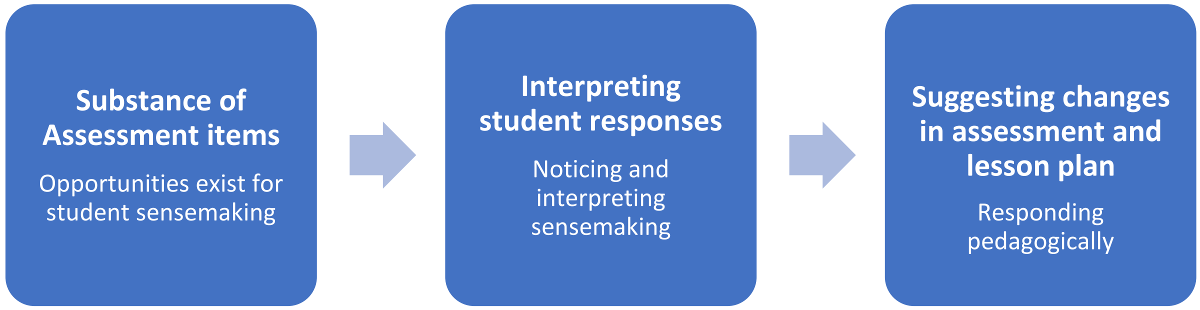
- What do elementary science teacher candidates (TCs) notice in students' written responses to phenomenon-based assessments, and how do they interpret these noticings as evidence of students' sensemaking and respond to them?
- How do TCs noticing and interpretation relate to the role of phenomena in assessments?
- What kinds of adaptations or improvements did TCs suggest for their assessment items based on their noticing and interpretation of students' responses?

Conceptual Framework for Analyzing TCs' Assessment Items and their Noticing and Interpretation of Students' Ideas

Classroom-based assessments were analyzed from 23 TCs and their analysis of students' written responses to these assessments when implemented in their classrooms. Building on the framework developed by Kang and Anderson (2015), a process was structured to investigate TCs' abilities to notice and interpret students' ideas through an analysis of student responses to assessments See Figure 1 for this information.

Figure 1

Responsiveness Toward Student Sensemaking Through Phenomenon-Based Assessments



This process followed three key steps:

1. Examining Opportunities for Sensemaking: We assessed whether and how the assessments provided by TCs allowed for student sensemaking. This involved identifying if the assessment tasks were centered around specific phenomena and gauging the extent to which they encouraged students to engage meaningfully with the content.
2. Connecting Candidates' Noticing and Interpretation: We analyzed the connections between what TCs noticed in students' responses and how they interpreted those responses in terms of students' understanding. This step aimed to reveal patterns in TCs' ability to recognize and interpret evidence of student sensemaking in response to assessment tasks.
3. Modifications to Enhance Assessments: We reviewed any modifications that TCs proposed to improve the assessments, particularly focusing on whether these adjustments aimed to enhance student sensemaking. Additionally, we explored how these adjustments were aligned with the goal of fostering deeper student understanding of the content.

Our analysis began by determining whether the assessment item chosen by each candidate was designed around a specific phenomenon, examining how it enabled students to make connections and construct meaning. TCs provided a written analysis detailing their observations, documenting instances of student sensemaking, and offering interpretations of those instances (see Annexure1). This systematic approach allowed us to identify recurring patterns in the ways TCs noticed, interpreted, and responded to student sensemaking within the context of phenomenon-based assessment items.

Study Context, Participants, and Learning Opportunities for TCs in Understanding Phenomenon-Based Assessments

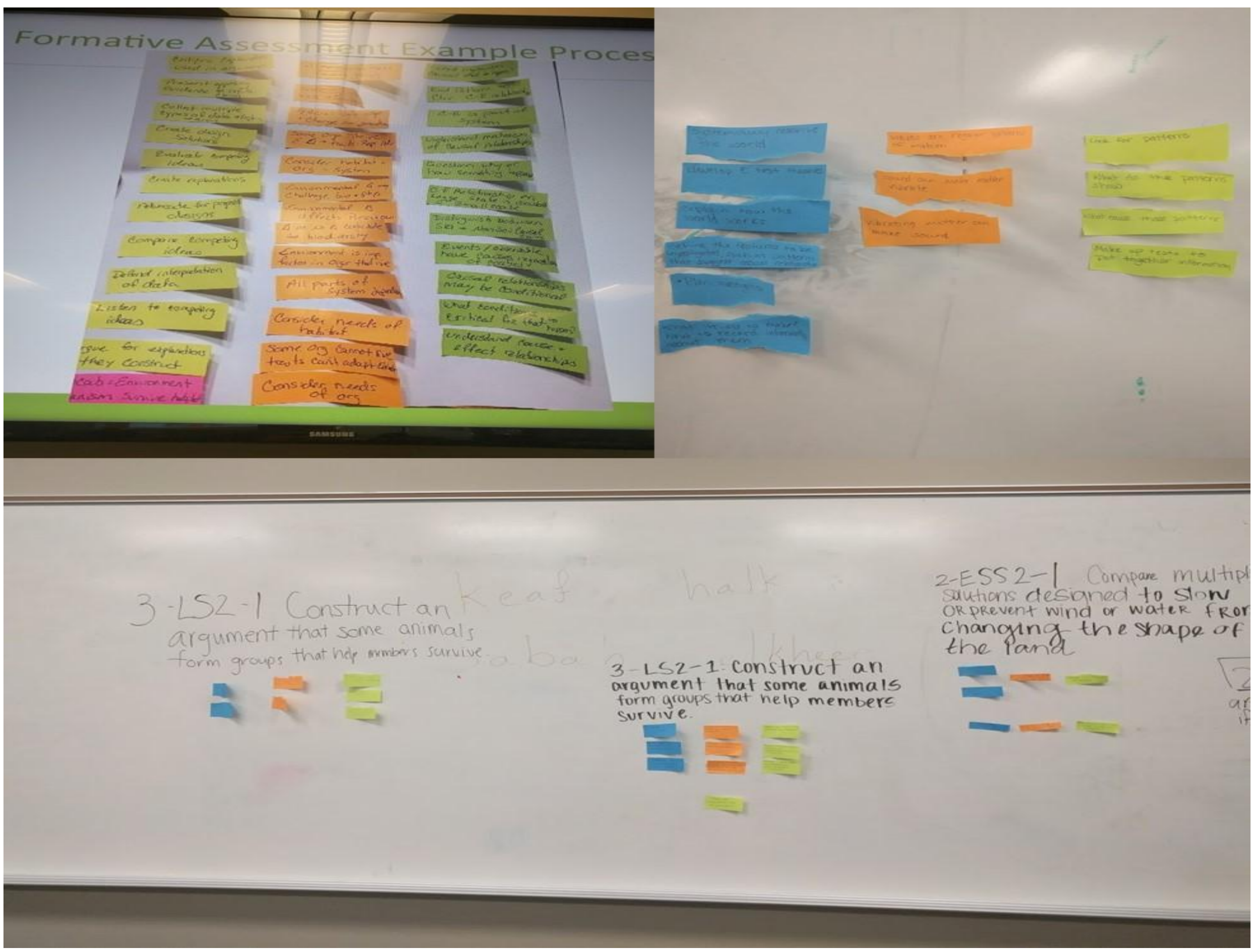
All 23 TCs in this study were enrolled in an NGSS-aligned elementary science methods course, which serves as the first pedagogy-based course in their teacher preparation program at a Midwestern university. This course is taken in the fall semester and is followed by a second methods course in the spring. Toward the end of the fall semester, TCs designed and taught two-day science lessons in their assigned elementary school field placement classrooms. As part of these lessons, they also developed and implemented classroom-level assessment items grounded in scientific phenomena.

As part of their coursework, TCs were provided learning opportunities to learn and develop their understanding of three-dimensional learning instruction (NRC, 2012) and examined the significance of grounding science instruction in real-life phenomena relevant to K–5 learners' everyday experiences. TCs had opportunities to read about and view examples of using phenomena as a way to elicit a wide range of student ideas. As the course progressed, to help candidates view an alignment between instruction and assessment, opportunities were introduced to help them learn about three dimensional assessments. One goal was to support candidates in designing assessments grounded in phenomena for their two-days science units—helping them shift from traditional, closed-ended assessments, to more open-ended tasks that could elicit students' reasoning and evidence-based thinking about the phenomenon .TCs also engaged in discussions about student sensemaking—what it looks like in practice—reinforcing the importance of affording students' use of evidence, reasoning, and explanations as they try to make sense of a phenomenon and respond to the assessment task they implemented.

All TCs participated in a three-hour workshop focused on unpacking the NGSS performance expectations into their three dimensions: disciplinary core ideas (DCIs), scientific practices (SPs), and crosscutting concepts (CCCs). This information is available in Figure 2.

Figure 2

Opportunities to Deepen Understanding of Phenomenon-Based Assessment While Unpacking the Three Dimensions of the NGSS



This workshop provided a foundation for designing phenomenon based, NGSS-aligned, three-dimensional assessment items. During the assessment workshop, candidates collaborated in small groups with peers, using performance expectations and examining them through the lens of all three NGSS dimensions. Throughout this process, TCs received ongoing input and guidance from course instructors and workshop leaders.

To design their assessment item(s) to be implemented at the ends of their two-day mini unit in their field placement classrooms, TCs identified relevant grade level appropriate NGSS performance expectations. Although the science methods course encouraged and guided TCs to create phenomenon-based assessments, mentors and curricula in their school placements may not have consistently supported this goal, resulting in variability in the guidance and modeling they received.

Data Sources and Analysis

Two primary sources of data were analyzed:

a) The first source of data was the design of 23 assessment items created and implemented by TCs at the end of their two-day instructional units.

b) The second source of data comprised TCs' analyses of their students' responses to the designed assessment items. Each teacher candidate selected six written work samples from their students, representing a range of responses. These submissions included both the student responses and the teacher candidate's written analysis. The analysis focused on identifying evidence of student sensemaking, with TCs offering their noticing and interpretations based on the analytic prompts provided in the course assignment (see Annexure 2).

Coding of Assessment Items

To conduct a comprehensive examination aligned with the responsiveness framework developed by Kang and Anderson (2015), we first analyzed the assessment items designed and implemented by each of the 23 TCs. The assessment task submitted by TCs as part of their course assignments offered valuable initial insight into their potential to support student sensemaking when implemented. Our coding of the assessment tasks was guided by the notion of how the assessment allowed for, or limited, opportunities for students to make sense of phenomena through their response.

In addition to designing, TCs also implemented their assessment items and collected student work samples for analysis. TCs examined whether and how student responses showed evidence of sensemaking of the science ideas underlying the phenomenon. Each teacher candidate selected six student work samples that reflected a range of responses to their assessment tasks. TCs analyzed these responses using course-provided prompts (see Annexure), considering what the students' ideas revealed, how the assessment supported or constrained sensemaking, and how students' thinking was made visible through their responses.

TCs' written reflections served as a valuable source of data for understanding how phenomenon-based assessments mediated what and how TCs noticed in students' ideas and interpreted them as evidence of sensemaking. The reflections also highlighted how the design features of the assessment tasks influenced their ability to notice and interpret student thinking. This dual analysis—of the phenomenon-based assessment tasks and TCs' reflections on student work—offered a comprehensive perspective on how assessments can be used to support responsive instruction in science classrooms.

We conducted coding of the assessment items, guided by the following questions, to explore the substance of the assessments designed by TCs. We used the following guiding questions: a) Was the phenomenon clearly defined to guide the assessment? In other words, did the assessment center around a natural process, or event, that students were expected to make sense of and explain?, b) If so, in what ways did the assessment give students a chance to build explanations about why and how the phenomenon happens? Did students have opportunities to notice important factors and patterns that affect the phenomenon, and use these ideas to explain what they observed? How were students encouraged to share their thinking and reasoning, as much as possible, in ways that make sense for their K-5 grade level?

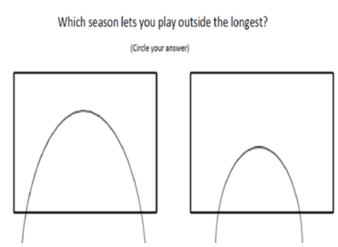
For clarity, TCs had limited time to implement an assessment at the end of their two-day lesson. Therefore, we did not explicitly delve into the extent to which an assessment item incorporated scientific practices or crosscutting concepts. Adapting from Kang and Anderson's (2015) definitions, we categorized the assessment tasks into the following groups.

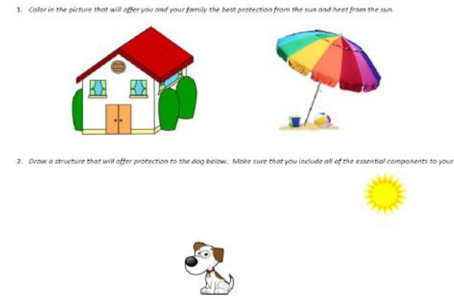
1) Unproductive assessments characterized items that lacked a phenomenon, simply requiring students to present canonical information, check off boxes, or circle correct answers, without providing opportunities for student sensemaking or expressing their understanding of science.
2) Unproductive assessments with a phenomenon characterized items that included a phenomenon but did not engage students in sensemaking of the phenomenon, as they remained limited to closed-ended questions.
3) Phenomenon-based productive assessments, which effectively prompted students to engage in reasoning, data collection, interpretation, and the construction of scientific explanations.

See Table 1 for more information about the assessment types, characteristics, and examples.

Table 1

Descriptions and Examples of Assessment Types

Assessment Type	**Characteristics**	**Examples**
Unproductive assessment	No phenomenon is present in the assessment. The task focuses primarily on the reproduction and recall of fact-based information, emphasizing classification and description rather than engaging students in deeper sensemaking or application of concepts	How can you describe two new solids based on the knowledge of the properties used to describe solids in previous lessons?
	Although the phenomenon is present, it is not effectively utilized to promote student sensemaking or provide opportunities for students to demonstrate their understanding. Instead, the focus is primarily on the reproduction and recall of factual information, with an emphasis on classification and description, rather than encouraging deeper engagement with the phenomenon through analysis or explanation	

Assessment Type	Characteristics	Examples
		 Color in the picture that will offer you and your family the best protection from the sun and heat from the sun. Draw a structure that will offer protection to the dog below. Make sure that you include all of the essential components to your structure. **PHENOMENON**: *Sunlight and its effects*
Productive assessment	The assessment was designed around a real-world phenomenon, providing students with varying level of opportunities for meaningful sensemaking. It included questions that encouraged deeper reasoning and required students to explain their thinking, promoting a more comprehensive understanding of the concept.	Students will draw what they observed on the playground outside in the morning and in the afternoon and color their drawing based on how they think the object felt related to the temperature of the object: Blue=cold, Green=cool, Orange=warm, Red=hot. Also, the students will indicate where they found the object by either coloring the ground gray if they found the object in the shade, drawing a sun if they found the object in the sun, or explaining where they found the object in words, when asked individually. Thus, I will assess the students formatively by observing students as they conduct investigations to determine how sunlight affects the temperature of the objects that they touch.

Coding TCs' Written Analysis of Student Assessment Responses

The analysis of TCs written evaluations of student assessment responses focused on their responsiveness to student sensemaking within phenomenon-based assessments. Each teacher candidate analyzed six samples of student work, resulting in a total of 138 samples examined across 23 candidates. We systematically coded the written analyses to explore how TCs noticed and interpreted student sensemaking and the evidence they used to support their conclusions. The codes and sub-codes that emerged from this analysis are presented in Table 2.

Table 2

Overall Codes for Analyzing TCs' Assessment Items and Written Analyses of Student Work

Categories	Codes	Sub-codes	Descriptions of codes
Opportunities: eliciting & probing student ideas/initial explanations	Substance of the assessment	Phenomenon	Presence/absence of phenomenon in assessment item If & how assessment was grounded in phenomenon
		Open-ended	Asking for explanations & mechanisms underlying phenomenon
		Closed	Assessment centered on factual/canonical knowledge
Noticing & interpretation: analysis of student responses, noticing of when & how students sensemaking occurred	TCs written analysis of student work	Procedural skill	Engaging students in label/draw/circle responses
		Sensemaking	sensemaking as ability to reason, hypothesize, or construct causal explanations as evidenced by analysis of responses. Students' leveraging from learning experiences cited as source of sensemaking
		TCs Describing observations	Sensemaking interpreted as ability to make & describe observations
		TCs Interpreting prior experiences	Experience as source for sensemaking, rather than evidence from analysis
		TCs making Inferences	Inferring & extrapolating student ideas based on students' work & responses
		TCs noticing the extent to which a student responded to the assessment-partially/completely	Sensemaking as ability to respond to assessment partially or completely
		Correct/Incorrect	Response to assessment
Responding: TC suggesting changes in assessment & instructions	TCs written analysis of student work	Task-based changes	Suggesting linguistic, social, & logistical changes in assessment
		Conceptual changes	Suggesting changes in support of sensemaking
		Task-based changes	Addressing linguistic, social, & logistic changes
		Conceptual need-based changes	Addressing conceptual idea for enhanced student sensemaking through lesson adjustment

The first category, Opportunities, emphasizes how TCs engaged with student ideas and initial explanations, specifically regarding the grounding of assessments in scientific phenomena. The second category, Noticing & Interpretation, captures TCs' analyses of student responses, focusing on their observations of when and how student sensemaking occurred. Finally, the Responding category highlights TCs' suggestions for changes in assessments and instruction based on their evaluations of student work. This structured approach provided valuable insights into TCs' understanding of student sensemaking and their capacity to adapt assessments to better support student learning.

Findings

We present our findings, reflecting on what we learned from analyzing the assessment tasks designed by TCs, and the ways in which they noticed, interpreted, and responded to students' sensemaking based on these assessments.

Approximately one-third (seven out of 23) of the TCs implemented an assessment design centered around a scientific phenomenon. This open-ended approach allowed for a wide range of student responses. In contrast, the remaining TCs either did not incorporate a phenomenon into their assessment design or, if they did, failed to utilize it effectively as a guiding element. Consequently, their assessments lacked the necessary framework of a guiding phenomenon, resulting in a dearth of opportunities to collect student ideas related to the phenomenon. TCs predominantly posed questions aimed at recalling canonical information or employed closed-ended inquiries that served only to confirm information, lacking any open-ended engagement. Table 3 provides a visual representation of these categories along with relevant examples for reference.

Table 3

Categories of TCs Based on Phenomenon and Substance of Assessment

Substance of Assessment	Phenomenon	Phenomenon aligned to assessment	Substance of the assessment (open-ended/ closed)
No phenomenon (Weak)	x	x	unproductive
	x	x	unproductive
	x	x	unproductive
	x	x	unproductive
	x	x	unproductive
	x	x	unproductive
	x	x	unproductive
	x	x	unproductive
	x	x	unproductive
Phenomenon is present, it is not utilized to facilitate student sensemaking (Moderate)	√	x	unproductive
	√	x	unproductive
	√	x	unproductive
	√	√	unproductive
	√	√	unproductive
	√	√	unproductive
	√	√	unproductive
Phenomenon present assessment aligned, Open-ended (Strong)	√	√	Productive
	√	√	Productive
	√	√	Productive
	√	√	Productive
	√	√	Productive
	√	√	Productive
	√	√	Productive

TCs Noticing and Interpretation of Student Responses

Recall that each of the 23 TCs analyzed the work of six students in response to the assessment item they implemented in their classrooms. TCs noticing and interpretation of student sensemaking were closely linked to the extent to which candidates used the phenomenon to guide the assessment. The largest group of TCs (nine out of 23) designed assessments that primarily engaged students in recalling and reproducing information, as well as defining vocabulary related to the science content concepts (Table 3). The design of these assessments was coded unproductive, meaning, it did not allow meaningful opportunities for students to show reasoning and construct mechanistic science explanations. The assessments mainly asked students for actions such as label, draw arrows, or follow a procedure. TCs who did not have a phenomenon guiding the assessment, and an unproductive assessment, mainly noticed student sensemaking as a matter of their behavior and attitude. These TCs mainly viewed student talking, alertness, and ability to answer correctly to various parts of the assessment as a proxy for sensemaking. These TCs repeatedly interpreted the students' ability to engage in this form of sensemaking as a manner to leverage their prior knowledge, whether from schooling or personal background. TCs engaged in limited interpretation because they could not gather many student ideas in the first place.

Some TCs (seven) successfully used phenomenon to guide assessment, however, the assessment was still limited in ways to elicit students' ideas regarding the phenomenon. Very characteristic of these candidates was their tendency to make extrapolated claims about students' understanding of the phenomenon based on their responses. TCs frequently noticed the students' ability to follow procedures as a process of sensemaking. Again, there were limited student ideas to notice and interpret. The assessments mainly used phenomenon as a hook or an interesting scenario while still probing to follow procedures like drawings, circling pictures, using arrows, etc.

The remaining seven TCs in this study were able to use science phenomena to guide their assessments, designing items that were productive to varying extents in probing students' construction of explanations, collecting data and observations, and responding to the relevant parts of the assessment based on those observations. TCs in this group noticed student ideas in relation to the phenomenon, which were mainly of cause-and-effect nature. These TCs engaged in richer analyses of student responses and provided evidence of student sensemaking from their work. The interpretation involved discussing learning opportunities from the two-day lesson as well as within the context of the assessment that led to supporting student sensemaking.

Suggesting Changes to Assessment

TCs reflected on the design and structure of the assessments after analyzing six sample responses of their students to the assessment item, considering how their noticing/ interpretations could inform future teaching practices. Out of the candidates, only three suggested changes to the assessments that were truly productive, meaning these adjustments had the potential to create more opportunities for student sensemaking in future lessons. In most cases, however, TCs struggled to propose meaningful adaptations. Their suggestions tended to be generic and focused on superficial changes, such as adding more content, incorporating additional vocabulary, or altering the sequence of activities and the structure of worksheets. While these adjustments might have eased transitions or improved comprehension, TCs primarily addressed structural issues rather than fostering deeper student engagement or understanding.

This tendency to focus on structural modifications suggests a gap in the TCs' ability to connect their assessments to the specific learning needs of their students. Instead of facilitating opportunities for richer sensemaking experiences, their recommendations often fell short of promoting critical thinking or deeper conceptual understanding. By failing to leverage insights gained from students' assessment responses, many candidates missed the chance to create more dynamic and responsive instructional strategies that could enhance student learning.

We had limited data on this aspect. Only one prompt asked TCs to reflect on any adaptations they made to the assessment based on what they noticed and interpreted from students' work. TCs reflections were generally shorter compared to their more elaborate analyses of the six student samples, which provided more opportunities for noticing and interpreting student thinking.

Examining Patterns Through Illustrative Examples

In this section, we illustrate model examples to provide a comprehensive picture of how phenomenon-based assessments influenced TCs' noticing and interpretation of student sensemaking. Examples also highlight the significant role phenomena play in TCs' noticing and interpretation of students' responses.

Example 1: TCs with No Phenomena and Close-Ended Assessments

In this case, the teacher candidate designed an assessment for first-grade students, targeting the NGSS performance expectation 2-PS1-1: Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties. This expectation encourages students to observe materials based on properties like color, texture, hardness, and flexibility, and identify patterns among materials with similar properties.
The assessment item, shown in Figure 3, asked students to observe two solids and record their physical characteristics on a worksheet.

Figure 3

Example of a Recall-Based Assessment Not Grounded in a Phenomenon

Name:_______________

Two New Solids

	Block	Paper Clip
color		
shape		
hardness		
rolls		
stacks		
magnetic		
float or sink		

Figure 4 shows students' responses to a recall-based assessment. While this task required students to engage in basic observational skills, it offered limited opportunities for deeper sensemaking. The closed-ended and somewhat vague nature of the task constrained students' ability to reason through their observations or construct meaningful explanations. As a result, the task emphasized procedural compliance over conceptual understanding. This was reflected in the TCs' noticing, which centered primarily on students' ability to follow directions, make surface-level observations, and categorize materials—without delving into the underlying reasoning processes or encouraging richer student dialogue (. The following reflections from the teacher candidate further illustrate these observations and offer insight into how they interpreted the assessment's impact on student learning.

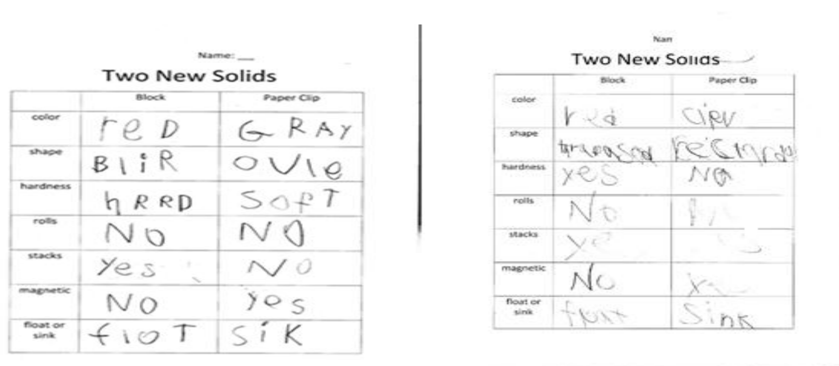
> This student seemed to show understanding in each area of assessment I was looking at. All of the spaces in the chart will be filled with reasonable and correct answers. On the back the student answered question one, offering the block because it stacks better. And for number two she came up with a pencil and wood are other solids that are similar to the block. Based on these items Focal Student 1 is meeting my assessment objectives. He filled out the entire

> observation sheet with thoughtful and reasonable answers. For one box in the observation sheet, he said the paper clip was soft. I do not think this is an ideal answer, however comparatively to the block he may have concluded it was not as hard, so I still accept that answer as reasonable for showing understanding.

However, TCs interpretation of the student's sensemaking was mainly focused on the student's ability to match correct answers, rather than on how the student reasoned through the scientific concepts involved. For instance, when the student described the paperclip as "soft," the candidate accepted this as reasonable, interpreting the response as relative to the block, which the student might have perceived as harder. Although this acceptance allowed some flexibility in evaluating understanding, the candidate still concentrated on the correctness of the response rather than delving into how the student arrived at this conclusion or the quality of their reasoning. As a result, the interpretation was somewhat superficial, focusing on whether the students could describe objects and complete the chart correctly, rather than engaging with the complexity of how students reasoned through their observations and made sense of the materials.

Figure 4

Examples of Student Work Samples in Response to Recall-Based Assessment Not Grounded in a Phenomenon



The candidate suggested generic adaptations/changes to the assessment. For instance, the candidate suggested:

> After reviewing all of the responses I got on my assessment there are a few things I may change to get a better picture of the students' progress towards mastering the learning goals. One thing would be to provide a picture or visual next to each of the properties on the observation chart as a scaffolding.

For example, the teacher candidate proposed adding pictures or visuals next to the properties on the observation chart as a form of scaffolding. While this might improve accessibility and comprehension for students, it is a structural change that does not directly enhance the opportunities for deeper sensemaking or reasoning. The suggestion focuses more on supporting students in completing the task accurately, rather than fostering their ability to engage in more meaningful scientific thinking or explanation-building.

Overall, the candidate's noticing and interpretation of student responses reflected a focus on correct answers and procedural completion, rather than on probing the quality of students' sensemaking. The suggested adaptations similarly centered on improving task accessibility, rather than creating opportunities for richer exploration and understanding of scientific concepts.

Example 2: Phenomenon-Guided Assessment with Some Level of Open-Ended Questions

This example is typical of the TCs whose assessment item was guided by a phenomenon and included some opportunities for open-ended responses. While the assessment still had structured components, it allowed students some flexibility in reasoning and constructing explanations based on their observations of the phenomenon.

In this example, the phenomenon of flooding aligned well with the NGSS performance expectation 5-ESS2-1: Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. This standard emphasizes understanding how Earth's systems (geosphere, biosphere, hydrosphere, and atmosphere) interact, and flooding could be used to illustrate how the hydrosphere (water) impacts the geosphere (land), biosphere (living organisms), and atmosphere (weather and climate). This provides students with the opportunity to think about complex systems and real-world connections between these spheres.

However, despite the selection of a well-chosen phenomenon, the assessment designed by the teacher candidate—shown in Figure 5—did not fully capitalize on the richness of the phenomenon and instead resembled a reading comprehension exercise.

Figure 5

Example of a Closed-Ended Assessment Item Grounded in a Phenomenon

Extreme weather conditions

Floods

Floods happen after or during heavy rainfall. This excess of water can damage peoples' property, damage roads and even wash cars away.

Flooding can be very dangerous to people. If flooding happens quickly without warning people can sometimes become stranded and have no way of escape. They have to be rescued from their rooftops or even from car roofs.

A severe weather warning helps prepare people for heavy rain and flooding. People try to protect their properties using sandbags stacked up against their doors to prevent water coming into their homes.

Rivers can sometimes burst their banks so people living in low lying areas or near rivers are more at risk from flooding. Often if heavy rain is forecast these areas are evacuated before the floods arrive.

Some scientists say that because of global warming, Britain will suffer more heavy rainfall and floods.

Questions

1 What can heavy rainfall cause? ________
2 Do floods usually occur in lowlands or highlands? ________
3 Describe how floods can be dangerous to people: ________
4 What can happen to rivers during a flood? ________
5 What do some scientists say is causing more floods in Britain? ________
6 What are sandbags used for? ________
7 What can help people prepare for heavy rain? ________

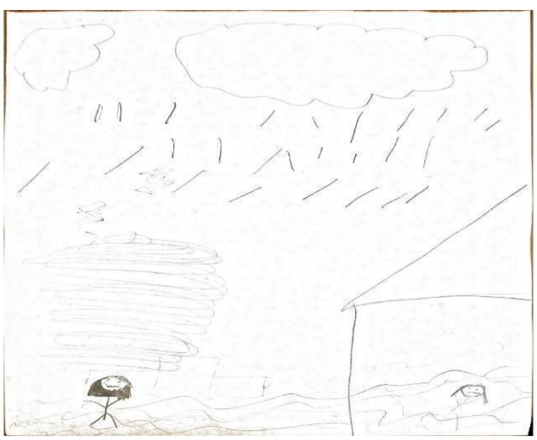
The assessment primarily consisted of closed-ended prompts, many of which were structured like reading comprehension questions. Instead of encouraging students to deeply engage with the phenomenon and reason through the interactions of Earth systems, the assessment relied heavily on "what" questions that asked students to recall facts or provide straightforward answers.

For example, instead of open-ended questions that might encourage students to explain how flooding impacts both living and non-living parts of the environment or to construct models illustrating these interactions, the questions asked students to recall specific details. This limited the students' opportunities to demonstrate deeper sensemaking, reasoning, or explanation-building around the phenomenon. While the phenomenon of flooding offered rich potential for exploring complex interactions and student-driven inquiry, the closed-ended nature of the assessment constrained students' engagement with the content, reducing the opportunity for more open-ended reasoning and explanation.

However, candidate also asked students to draw a flooding scenario. Artifacts showing a flooding scenario produced by students are shown in Figure 6.

Figure 6

Examples of Student Work Samples in Response to Closed-Ended Assessment Item Grounded in a Phenomenon



This teacher candidate attempted to infer students' understanding based on their drawings. Student drawings were not accompanied by any reasoning prompts, still TCs' were able to interpret students' sensemaking, for example, this teacher candidate inferred the following from one student's drawing:

> Flood water seemingly flowing into a house and carrying away people, which shows knowledge of how strong the water flow can be and recognition of the damage that can occur.

Drawings can be helpful in capturing students' initial thinking, but they need to be accompanied by prompts that encourage students to explain their representations or link them to scientific ideas. For instance, the teacher candidate inferred that a drawing showing "flood water flowing into a house and carrying away people" demonstrated the student's knowledge of the force of water and its potential to cause damage. However, without additional explanations or reasoning, it was difficult to determine whether the student truly understood the scientific concepts of water force and its effects on landforms.

In this case, this teacher candidate, like others with similar assessment items, equated student attentiveness and the ability to ask questions with sensemaking:

> The student was asking clarifying questions to other students at the table and was attentive in watching the demonstrations.

TCs interpreted students' ability to draw from personal experiences and connect learning opportunities from the lesson they taught before the assessment to the phenomenon as sensemaking. However, they did not explicitly identify the specific evidence students used from these personal and lesson-based experiences to engage in sensemaking:

> This student seemed to be engaged in sense making through the worksheet and what he had read. When producing the drawing it was clear that he had utilized the worksheet and a fact that he had gained from it. The nature of his ideas seemed to stem from the video as well as how we had discussed living by a riverbank.

For example, this teacher candidate observed that the student was making sense of the flooding phenomenon through various lesson components, such as the worksheet, video, and discussion. The student's drawing was viewed as a final artifact that connected information from these learning opportunities, leading the teacher candidate to perceive the student as a successful sense-maker. However, the teacher candidate's interpretation lacked specific details about which ideas the student connected and how those ideas related to the lesson content.

The present example underscores the need for assessment designs that not only include a phenomenon but also explicitly prompt students to articulate their reasoning and reflect on their understanding. This approach would provide stronger evidence of student sensemaking. In this case, if the assessment had included prompts asking students to explain how their personal experiences, the video, and class discussions informed their drawings, the teacher candidate would likely have gained a more comprehensive view of the student's sensemaking process.

Example 3: Phenomenon-Based Assessment with Open-Ended Questions to Encourage Reasoning

The following example illustrates the case of a teacher candidate who was successful in articulating a phenomenon and planning an assessment which provided a richer context for student sensemaking of the science phenomenon. The case of the teacher candidate presented here used the following NGSS performance expectation for the lesson: 1-PS4-1: Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate. The assessment primarily focused on: Students making predictions of what the waves they see will look like and then recording what they saw. Figure 7 describes student responses to the assessment.

The lesson and assessment were centered on the scientific phenomenon of how sound affects matter. The teacher candidate provided students with various opportunities to observe sound waves traveling through different mediums. Students were prompted to predict outcomes and then record actual observations, encouraging them to share their thinking on how sound interacts with matter. Throughout the assessment, the teacher candidate consistently referred to students' ideas about the phenomenon, using these reflections as concrete evidence of student sensemaking. This teacher candidate also analyzed these ideas to draw conclusions about students' understanding of the phenomenon.

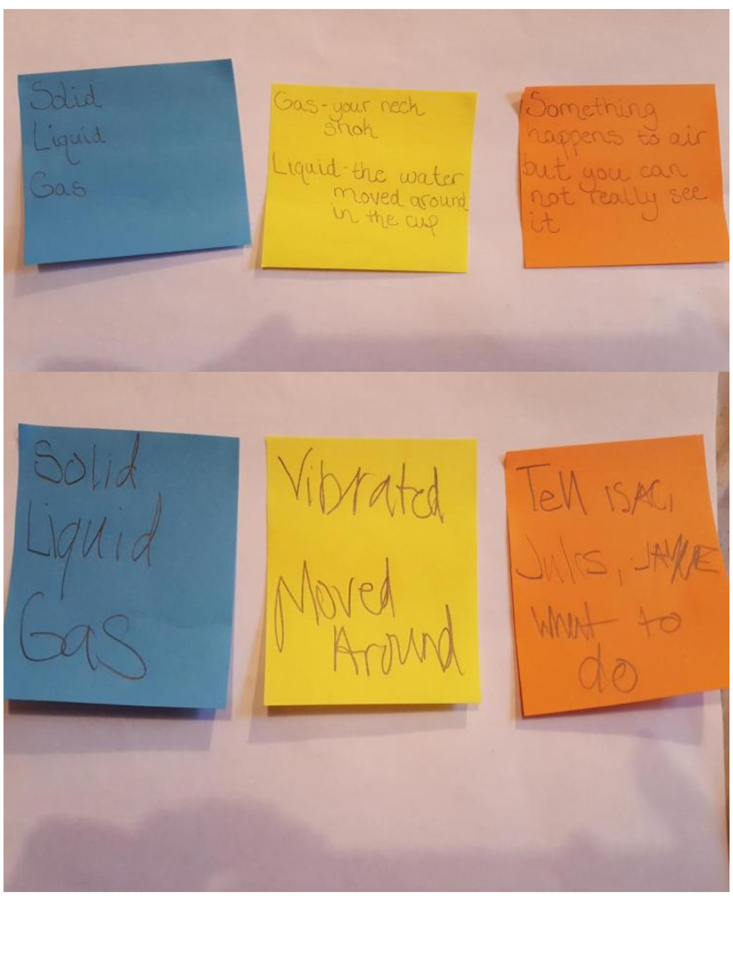
> This student was engaged in the sensemaking activity because she was using the water bottles to show us what she had learned within the experiment and what she had did. She showed us

> how the water moved and how you could see and feel that the water bottle was moving when sound was applied.
>
> This student was engaging during the sensemaking because she took what she had learned from the lesson and applied it to what she would learn in the future. She made the question to say is there an easier way to see that things move in the air? So this makes me think that she is thinking outside of the box and that she is thinking about how to extend her knowledge.
>
> I know that this student understands what happens when sound is applied to a state of matter because he said that that state of matter moves.

The quotes from this teacher candidate's reflection on individual students' responses reveal a strong focus on students' ideas. The teacher candidate noted how students used their classroom investigations to make sense of the phenomenon, and how some students generated questions based on their learning experiences as evidence of deeper sensemaking. This reflection highlights the TCs' attention to students as sense makers, and how they applied their experiences to understand the phenomenon of how sound affects matter.

Figure 7

Examples of Student Work Samples in Response to Assessment Item with Open-Ended Questions to Encourage Reasoning



Although the teacher candidate provided opportunities and noticed student ideas around the scientific phenomenon, the assessment did not effectively probe or offer scaffolds for students to express their mechanistic thinking. The focus on mechanistic thinking—reasoning about how and why things happen—was not emphasized in the assessment item. Like other TCs in the data set, the candidate in this example also struggled to respond productively based on their observations:

> I would change my assessment by having students fill out a worksheet with the same questions before the lesson to see what they know, and then fill it out again after to see if anything changes. I would do this to determine whether students are truly learning from the lesson or just filling out answers at the end to be done.

However, this adaptation was rather generic, as the teacher candidate suggests using a pre- and post-lesson worksheet to compare students' knowledge and see if they genuinely learned from the lesson or simply filled in answers to finish. However, this approach focuses on checking for changes in factual knowledge rather than probing students' deeper understanding or sensemaking.

Range in TCs' Noticing and Interpretation Across Assessment Examples

The design of assessments—whether they included a phenomenon or not, emphasized reasoning, or featured vague or open-ended questions—influenced TCs' ability to notice and interpret students' scientific ideas and disciplinary thinking. Although we did not directly study this as a research question, our analysis suggests a possible connection between the quality and structure of the assessments and the depth of TCs' noticing and interpretation. For example, TCs who designed assessments without a phenomenon (e.g., Example 1) tended to ask questions that provided little to no opportunity to interpret students' thinking. In these cases, their noticing and interpretation often overlapped, with interpretation leaning heavily on whether a student's response was correct. These candidates tended to equate sensemaking with correctness and missed opportunities to identify moments where students were actively trying to construct understanding.

In contrast, assessments that included a phenomenon but had vague or limited questioning (e.g., Example 2) emphasized the importance of preparing TCs to ask meaningful, student-accessible questions. Without strong questioning strategies, even a phenomenon-rich task may not yield deep insight into student thinking or provide opportunities for sensemaking. Finally, in assessments that combined a well-grounded phenomenon with purposeful questioning (e.g., Example 3), TCs were more successful in noticing students' ideas and offering interpretations that recognized authentic moments of sensemaking. These candidates not only attended to individual student reasoning but also considered how students interacted with peers as they worked to make sense of the phenomenon together. This range of assessment examples underscores the importance of supporting TCs in designing assessments that are both anchored in meaningful phenomena and structured to elicit and interpret students' thinking in responsive ways.

Discussion

The study revealed that many TCs struggled to ground their assessments in phenomena (Reiser, 2013). Even those who managed to identify a relevant phenomenon often found it difficult to design open-ended assessments that would elicit students' sensemaking and deeper thinking (Furtak & Ruiz-Primo, 2008; Gotwals & Birmingham, 2016). TCs who developed somewhat open-ended assessments still faced challenges incorporating probing questions that encouraged students to articulate their reasoning, both orally and in writing. These findings highlight that TCs need support and course learning opportunities to help them develop well-aligned, phenomenon-based assessments that foster students' sensemaking (Pellegrino et al., 2014). This alignment is essential for creating opportunities to gather and interpret a broad range of student ideas and thinking.

One possible reason for these challenges could be the influence of traditional notions of assessment, where assessments are often viewed primarily as tools to determine whether students have the "correct" information, rather than as opportunities to elicit and analyze diverse forms of student thinking (Otero, 2006). Additionally, TCs need learning opportunities that emphasize the importance of student reasoning, particularly in helping students engage with mechanistic thinking. A persistent misconception among teachers is that young learners, especially in elementary grades, are not capable of engaging in scientific explanations. However, research shows that even young learners can reason mechanistically when provided the opportunity (Metz, 2004, 2011; NRC, 2007). Overcoming these traditional beliefs is critical for TCs as they learn to design assessments that allow students to make sense of phenomena at a deeper level (Russ et al., 2009).

Course learning opportunities in our program were intentionally designed to address these areas by emphasizing the value of reasoning, student ideas, and three-dimensional learning in science instruction. However, these shifts remain challenging for TCs, as they continue to encounter traditional approaches to science teaching during their observations and student teaching in K–5 classrooms. While a methods course, like the one which made for the context of this study, can establish a good foundation for understanding phenomenon based three-dimensional learning, induction and sustained professional development is needed to rehearse and continue building on this understanding.

This study adds to the literature by focusing on preservice elementary science teachers and how phenomenon-based assessment structures can serve as a lever for deepening their noticing and response to students' ideas, reasoning, and use of scientific practices. Specifically, we position our work within ongoing efforts to better understand how TCs develop the ability to notice and interpret students' sensemaking—TCs must come to view assessment not only as a means to evaluate learning, but as a way to gather, interpret, and build from students' thinking (Pellegrino et al., 2014). When TCs used phenomenon-based assessments accompanied with open ended reasoning-based questions to access students' ideas they move beyond simply checking for correctness; instead, they noticed and interpreted students' thinking. The design of assessments played a critical role in this process. Therefore, preparing TCs to design and use assessments that prioritize sense-making, explanation, and conceptual reasoning is key to responsive teaching.

Overall, TCs in science methods courses need scaffolding throughout various stages of the assessment design process. First, they need learning opportunities to develop phenomena-based assessments with relevant open-ended driving questions (Harris et al., 2012). Additionally, they need to understand the purpose of such assessments to gather diverse student ideas and provide students with opportunities to show and apply their thinking, use evidence to explain their ideas, and demonstrate their understanding (Windschitl et al., 2012). Engaging TCs in analyzing student work samples from open-ended assessments can help them practice noticing and interpreting a range of student thinking patterns (Benedict-Chambers & Aram, 2017). TCs must learn to notice and interpret this range of student thinking and use that information to guide their instruction. Expanding TCs' understanding of the purpose of assessments and how assessment design impacts student learning is critical to achieving the goals of fostering student sensemaking in science education.

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Annexure 1

Assessment and Data Collection Plan Lesson Design & Analysis

In the previous assignments you a) identified a topic, as well as appropriate NGSS Performance Expectations b) began framing your lesson in alignment with the NGSS and the Experiences, Patterns and Explanations model of teaching; and c) identified your students' prior ideas and experiences (sensemaking #2) in relation to the science content you will be teaching. In this assignment, you will lay out specific plans for ASSESSING your students' ability to meet the identified learning goals (NGSS) after teaching your lesson.

Assignment Template and Explanation:
Name(s):
Grade Level:
Targeted Learning Goals:
Copy this section from your Framing assignment. (Lesson Identification and Learning Goal)

Post Assessment Task
Design ONE brief assessment task that will provide rich information about your students' thinking and understanding for your unit learning goals. ***Include a copy of your assessment task in this assignment.*** *Rich tasks should involve the students in creating a somewhat elaborate response, not just giving a one-word answer. It should involve the students carrying out the practices defined in your learning goal, not just recalling information. It should provide an opportunity to apply a main idea, not just recall or recognize it. Examples of rich tasks include performance assessments such as providing students with a variety of objects, asking them to use those objects to construct or do something and asking them to explain how the science ideas are important in their decisions to meet that goal. You can engage students in figuring things out, finding patterns, using their explanations to justify their decisions in written response items. You can use a variety of other assessments such as observing students as they work in groups, analyzing their drawings, labels and explanations in their science notebooks, or even a task that is already in your instructional materials.*

Here are some hints for designing a "rich" assessment task:

- *Your assessment task should be closely aligned with your NGSS Performance expectation.*
- *Your assessment task should engage students in meaningful and thoughtful work. They should be applying a big idea from your lesson and carrying out practices/cross-cutting concepts defined in your NGSS Unpacking and related knowledge & skills, not just recalling or listing information and ideas.*
- *Students should provide an elaborate response, not a one-word answer.*
- *Analysis of your students' responses should provide you with information about their strengths and weaknesses with respect to your assessment objective. This should go beyond whether students "got" your assessment objective and whether they participated in your lesson and/or the task.*
- *All students should be able to respond to your task, perhaps with varying degrees of quality. (If some students cannot respond at all, you miss the opportunity to find out what they* <u>*do*</u> *understand.)*

Post Assessment Task Rationale
Write a brief statement explaining what this assessment task will allow you to learn about how much and how deeply your students understand your lesson NGSS Performance Expectation. What specific skills, ideas and practices are you trying to assess in this task? (Include how you are addressing your SEP/DCI/CCC in your assessment.)

Scoring Guide for Analyzing Students' Responses to the Post Assessment Task

Next, you will need to determine how you will analyze and interpret the students' responses to your task. Analyzing students' responses can be done by identifying features in their responses that you can look for and document. You will create a scoring guide that thoroughly describes all of the desired features of students' responses that would indicate the extent to which they have met your assessment objective. Your scoring guide should include the ***specific details*** *you would look for in a student's response that will let you know what aspects they know well, what aspects they struggled with, and how they were reasoning about your task.*

These features can be used to evaluate how much your students have learned the lesson content and how deeply they have understood it. The essential features represent the criteria you will use to analyze your students' responses on the post assessment after your lead teaching. These features will provide the starting point for your analysis after the post assessment – but you may find that you'll make some changes to these as a result of seeing the kinds of responses your students provide on the post assessment task.

Note: If there are important aspects related to the learning goal (i.e., main ideas students should know, practices students should be able to do) that you cannot evaluate based on your task, you may need to add to or change your task so that it will provide sufficient evidence to help you decide how well your students are meeting the learning goal.

Grading Criteria:

	Desired Features	**Points**
Post Assessment Task and Rationale	• The assessment objective matches the NGSS Performance Expectations. • The assessment task engages students in opportunities to use knowledge gained from SEP/DCI/CCC for elaborated responses. • The assessment objective describes a behavior that demonstrates a deep understanding of the learning goal. (not rote memorization, multiple choice, fill in the blank, etc.) • The assessment task is likely to elicit rich information that will allow evaluation with respect to the assessment objective. • The assessment task is accessible to students with a range of mastery (above and below expected levels of performance) of the assessment objective. • The rationale clearly explains how the assessment task assesses the students' understanding of the NGSS Performance Expectation. • The rationale clearly explains what the assessment task is intended to show regarding students' understanding of the NGSS Performance Expectation – including opportunities for illuminating possible misconceptions or advanced ideas.	/5

Post Assessment Rubric/Scoring Guide	• There is a clear plan for analyzing students' responses to the assessment task, including the way in which results can be used to reflect upon students' strengths and weaknesses (and not just whether they are "right" or "wrong".) • The scoring guide includes the **specific details** teachers should look for in a student's response. • The scoring guide provides students with an opportunity to give their explanations and reasoning related to the task.	/5

Annexure 2

Analysis of Classroom Interactions, Student Learning, & Reflection Final Segment of Lesson Design & Analysis

This assignment is designed to support you in analyzing evidence from teaching your lesson in your field placement and in reflecting on your teaching.

Preparing for the Assignment

In order to successfully complete this assignment, you will need to collect a video or audio recording of your lesson and take detailed notes after teaching to have as much information about the nature of your lesson as possible. You will also need assessment responses or samples of student work from six students including the focal students in your placement classroom during the time that you teach your lesson. Your reflections should be detailed and specific, and should focus on the evidence from the recordings/notes and from student work.

Assignment Directions

There are several parts to this assignment. You will be providing a detailed response for each part that is well supported with specific examples from the recording of your lesson, your students' work and your teaching notes.

Analysis of Whole Class Interactions and Classroom Culture

Carefully review your video/audio recording of your lesson and the detailed notes. Analyze and evaluate classroom community and interactions in the lesson using evidence from your recordings. Below, you will write a detailed, multi-paragraph analytical response for each of the following questions: *What opportunities did students have to participate and engage in the lesson? How did they participate? How were students' resources (e.g., funds of knowledge, ways of knowing) elicited and leveraged? How did students interact with each other and you as the teacher?*

Analysis of Individual Learning from Student Work

Work with your instructor to decide how to choose sample student work. Carefully review evidence from identified focal and other students about student learning including their actions and talk as well as their work in the assessment. You will analyze student work using the assignment template (below), and write a detailed, multi-sentence analytical response for each of the following questions: *In what ways did students engage in sensemaking? In what ways did their work indicate they are not meeting, partially meeting, or meeting the learning goal?*

Reflections on Analysis and Teaching

Review the analysis and findings from above regarding whole class interactions and student learning in addition to your notes from teaching. Then, you will write a detailed response to reflection questions about *your overall impression of strengths and weaknesses of the lesson, how the lesson plan addressed diverse student learners, the strengths and limitations of the assessment, and how this experience impacted your teaching identity.*

Implications for Future Teaching

Review the analysis and findings from above regarding whole class interactions and student learning in addition to your notes from teaching. Then, you will write a detailed response to the questions: *Given the analysis of interactions and student learning, describe your written and oral feedback you would provide your focal and other students to advance their science learning. How would you teach this same lesson again to improve the lesson and why?*

Assignment Template
The next part of this assignment is the assignment template to help guide you in your analysis and reflections

Name(s):

Lesson Topic and Grade Level:

- **PERFORMANCE EXPECTATION:**
    - **NARROWED LESSON FOCUS:**
    - **SCIENCE AND ENGINEERING PRACTICE**:
    - **CROSSCUTTING CONCEPT**:

Phenomenon and Driving Question for Lesson:
Identify a phenomenon and write a driving question designed to support students' developing understanding of your learning goals. Your driving question should be directly aligned with the NGSS Performance Expectation, have a real-world context, and demonstrate a deep understanding of the learning goal when answered. See course slides for examples of how to identify a phenomenon and write a driving question.

PHENOMENON:

DRIVING QUESTION:

1. **Analysis of Whole Class Interactions and Classroom Culture**

    Write a detailed, multi-sentence analytical response for each of the following questions:

    a. What opportunities did students have to participate and engage in the lesson? Examples include talk, interactions with materials, etc. **How did students participate?** (e.g., who was doing the talking, what kind of language were they using?)

    b. How did you elicit and leverage students' resources (e.g., funds of knowledge, ways of knowing)**?**

    c. How did students interact with each other and you as the teacher? (e.g., how were their ideas responded to, were they acknowledged, rejected or built on, whose ideas were taken up and whose were not?)

2. **Analysis of Individual Learning from Student Work**

    Assessment Objective:

    Desired Assessment Features/Scoring Guide:
    [list the features you identified in your LDA #1-2 assessment assignment for evaluating student work.

Focal Student 1 **Brief description for why you chose this student's work.** **Description of the student's interactions/engagement including their talk (e.g., what they said) during the lesson.** **Photo of student work sample(s):**	**Focal Student 1** **Evidence of sensemaking:** *Describe how this student was engaged in sensemaking. What resources were they using? What was the nature of their ideas, reasoning, experiences, and how did they use those to address the lesson topic?* **Evidence from work sample of student learning:** *List features you have identified in your student work sample that indicate student understanding of the learning goal. Provide a claim for what this indicates about student understanding and a rationale of why this demonstrates that they are not meeting, partially meeting, or meeting your NGSS assessment objective.*
Focal Student 2 **Brief description for why you chose this student's work.** **Description of the student's interactions/engagement including their talk (e.g., what they said) during the lesson.** **Photo of student work sample(s):**	**Focal Student 2** **Evidence of sensemaking:** *Describe how this student was engaged in sensemaking. What resources were they using? What was the nature of their ideas, reasoning, experiences, and how did they use those to address the lesson topic?* **Evidence from work sample of student learning:** *List features you have identified in your student work sample that indicate student understanding of the learning goal. Provide a claim for what this indicates about student understanding and a rationale of why this demonstrates that they are not meeting, partially meeting, or meeting your NGSS assessment objective.*
Focal Student 3 **Brief description for why you chose this student's work.** **Description of the student's interactions/engagement including their talk (e.g., what they said) during the lesson.** **Photo of student work sample(s):**	**Focal Student 3** **Evidence of sensemaking:** *Describe how this student was engaged in sensemaking. What resources were they using? What was the nature of their ideas, reasoning, experiences, and how did they use those to address the lesson topic?* **Evidence from work sample of student learning:** *List features you have identified in your student work sample that indicate student understanding of the learning goal. Provide a claim for what this indicates about student understanding and a rationale of why this demonstrates that they are not meeting, partially meeting, or meeting your NGSS assessment objective.*
(Focal) Student 4 **Brief description for why you chose this student's work.** **Description of the student's interactions/engagement**	**(Focal) Student 4** **Evidence of sensemaking:** *Describe how this student was engaged in sensemaking. What resources were they using? What was the nature of their ideas, reasoning, experiences, and how did they use those to address the lesson topic?* **Evidence from work sample of student learning:**

including their talk (e.g., what they said) during the lesson. **Photo of student work sample(s):**	*List features you have identified in your student work sample that indicate student understanding of the learning goal. Provide a claim for what this indicates about student understanding and a rationale of why this demonstrates that they are not meeting, partially meeting, or meeting your NGSS assessment objective.*
(Focal) Student 5 **Brief description for why you chose this student's work.** **Description of the student's interactions/engagement including their talk (e.g., what they said) during the lesson.** **Photo of student work sample(s):**	**(Focal) Student 5** **Evidence of sensemaking:** *Describe how this student was engaged in sensemaking. What resources were they using? What was the nature of their ideas, reasoning, experiences, and how did they use those to address the lesson topic?* **Evidence from work sample of student learning:** *List features you have identified in your student work sample that indicate student understanding of the learning goal. Provide a claim for what this indicates about student understanding and a rationale of why this demonstrates that they are not meeting, partially meeting, or meeting your NGSS assessment objective.*
(Focal) Student 6 **Brief description for why you chose this student's work.** **Description of the student's interactions/engagement including their talk (e.g., what they said) during the lesson.** **Photo of student work sample(s):**	**(Focal) Student 6** **Evidence of sensemaking:** *Describe how this student was engaged in sensemaking. What resources were they using? What was the nature of their ideas, reasoning, experiences, and how did they use those to address the lesson topic?* **Evidence from work sample of student learning:** *List features you have identified in your student work sample that indicate student understanding of the learning goal. Provide a claim for what this indicates about student understanding and a rationale of why this demonstrates that they are not meeting, partially meeting, or meeting your NGSS assessment objective.*

3. Reflections

Write a detailed, multi-sentence analytical response for each of the following questions:

Overall reflections (see tips for your reflections below):

1. What were some strengths of your lesson? Support your claims with evidence.
2. What were some weaknesses of your lesson? Support your claims with evidence.
3. How did your lesson support or not support student science learning? Support your claims with evidence.

Reflections on responsiveness to diverse students:

1. How did the lesson meet or not meet the needs of the students?
2. How did you adjust the lesson plan and teaching in response to students' contributions and sensemaking?

Reflections on assessment: In addition to analyzing student responses to your assessment task for clear evidence of student understanding, you will also need to reflect upon the effectiveness of your assessment.

1. What were the strengths of the assessment you chose for providing evidence of student science understanding? Explain why. Include evidence (e.g., one example; overall class responses).
1. What were the limitations of the assessment you chose for providing evidence of student science understanding? Explain why. Include evidence (e.g., one example; overall class responses).
1. Based on your analysis of the responses, what changes would you make for this assessment task in order to get a more complete picture of all students' progress towards mastering your science content NGSS learning goals? Why?

Reflections on classroom culture:

1. How did the lesson conform or deviate from the established classroom culture from the mentor teacher? How might that have impacted student interactions and learning?

Reflections on teacher identity:

1. How did teaching your lesson impact your own identity as a teacher and as a science learner?

4. Implications

Write a detailed, multi-sentence analytical response for each of the following questions:

1. If you were to give feedback to your six students whose work you analyzed, what would you write and say to help them learn and make better sense of the science? Provide specific text examples for each student and a rationale for the feedback.
2. If you were to teach this same lesson again, what changes would you make to your lesson plan to better support your students' science learning? Why?

Tips for your reflections

- As you are working on your reflections, take time to review the themes from the course. Reference and use these ideas in your responses.
- As you are reflecting on your science teaching and student learning, remember that this reflection is not about behavior management or constraints out of your control. Instead, we are asking you to focus on your planning, your teaching, students' engagement, and student learning.
- Be sure to use evidence in your analyses and reflections to support the statements you are making.
- Even if your lesson was highly successful, challenge yourself to consider something on which you could make improvements in the future. This is an important skill to develop as a life-long learner.