Seamless Assessment

Using the 5E learning model, the authors describe their strategies for embedding assessment throughout a unit teaching preservice teachers about the phases of the Moon.

By Mark J. Volkmann and Sandra K. Abell

We all want to know whether our students have learned, but if we wait until the end of a unit to assess understanding, then we lose valuable instructional impact. In this article, we demonstrate how assessment can function throughout an instructional sequence to provide important information about student learning. Using Bybee's (1997; 2002) *5E* model—*Engage*, *Explore*, *Explain*, *Elaborate*, and *Evaluate*—we describe a variety of purposes and strategies for assessing student learning.

This article describes how we link these strategies to each stage of the 5E sequence when teaching preservice teachers a unit about phases of the Moon. While we taught this unit to preservice teachers, the unit is identical to many units for upper elementary students, so our experiences are applicable to inservice teachers as well.

Embedding Assessment

The 5E model defines a sequence of inquiry-based science instruction that helps students focus on evidence and explanation, both essential features of inquiry (National Research Council 2000). Each stage implies a unique purpose for assessment: diagnosing students' incoming ideas, collecting information about students' formative understanding, determining if students can apply their understanding to a new problem, and providing data for summative evaluation. Figure 1 (page 42) describes the 5E stages and assessment purposes associated with each stage.

Our experience teaching preservice teachers illustrates how assessment can occur throughout a unit of instruction. In our classes, we typically use the Moon investigation to help future teachers think about themselves as science learners and develop their ideas about science teaching. By studying the Moon in depth, preservice teachers gain confidence in their ability to inquire into and understand concepts they will teach to their students. One of the main goals of the unit is for them to understand phases of the Moon in terms of the relative positions of the Earth, the Moon, and the Sun.

Using the 5E instructional approach,

- We engage students in studying the Moon;
- Students explore by observing the Moon and recording their observations over four weeks;
- We help students explain their observations by developing models of the Moon; and
- Students elaborate and evaluate their understanding by solving new problems related to the phases of the Moon.

We use assessment throughout the unit to find out what ideas students bring into the investigation, to see how their ideas are developing, and to determine their understand-

When we periodically collect students' Moon journals, we learn how students are developing their ideas and where they are having difficulties.

ing at the end of the unit. Figure 2 describes the assessment strategies we use throughout the Moon unit. Below, we describe each of these strategies in turn.

Incoming Ideas

The phases of the Moon is a difficult concept to understand and misconceptions abound. To determine our students' incoming ideas, we developed a questionnaire based on the most common alternative conceptions about the Moon's phases (see Driver et al. 1994)—that phases of the Moon are caused:

- When planets cast a shadow on the Moon;
- When clouds cover part of the Moon;
- When the shadow of the Earth falls on the Moon; or
- When the shadow of the Sun falls on the Moon.

Figure 1.

A comparison of the 5E model of science instruction (Bybee 2002; National Academy of Sciences 1998) and assessment purposes.

Model Phase/Description	Assessment Purpose
Engage • Initiates the learning task • Introduces the major ideas of science in problem situations • Makes connections between past and present learning experiences • Focuses student thinking on the learning outcomes of the upcoming activities • Mentally engages students in the concept to be explored	• To identify students' existing science ideas
Explore • Provides opportunities for students to test their ideas against new experiences and compare with the ideas of their peers and teacher • Provides a common base of experiences in which students actively explore their environment or manipulate materials	• To determine how students are building conceptual understandings
Explain • Provides opportunities for students to develop explanations • Introduces formal language, scientific terms, and content information to make students' previous experiences easier to describe and explain	• For students to demonstrate their current understanding
Elaborate • Applies or extends students' developing concepts in new contexts • Students develop deeper and broader understanding	• For students to demonstrate their ability to apply/transfer their understanding to new contexts
Evaluate • Encourages students to assess their understanding as they apply it to solve problems	• To determine what students learned from the lessons • For students to be metacognitive about their learning

We present these alternatives, as well as the scientifically accurate answer—that the relative positions of the Earth, the Moon, and the Sun create the phases—and ask students to select the explanations that seem most reasonable to them. We also ask them to explain why they think the Moon's appearance changes over time.

We have found that our students enter the Moon investigation with the same set of common misconceptions as found in the research. Few have a solid understanding of the Moon's phases. With knowledge of their incoming ideas in hand, we're ready to move on to the next phase of instruction—guiding students as they form new ideas.

Figure 2.
Assessment strategies for the Moon investigation.

5E Phase	Assessment Strategies
Engage	• Moon Explanations Questionnaire
Explore	• Moon Observation Journal • Moon Puzzlers
Explain	• Moon Models
Elaborate	• Thought Experiments • Evaluating Children's Books • Individual Moon Investigation Plans
Evaluate	• Moon Explanations Essay • Moon Investigation Poster Presentation

Forming New Ideas

Throughout the Moon study, students keep a journal in which they record their observations (Brandou 1997). We also ask them to describe the patterns they have noticed, make predictions, ask questions, and posit tentative explanations for their observations. When we periodically collect these journals, we learn how students are developing their ideas and where they are having difficulties. The journals suggest next steps in our instruction that will challenge students to think in new ways.

In response to students' formative ideas, we have developed a series of "Moon Puzzlers" (Abell, George, and Martin 2002). Moon Puzzlers make explicit what students are struggling to understand by posing thought-provoking questions. We insert the puzzlers into instruction when we judge our students are ready for them.

For example, early in the Moon investigation, students often fail to see the Moon and get frustrated. Moon Puzzler #1 helps them use this experience to think more about their observations: "*OK, this is crazy. I go out every night and look for the Moon, but I don't see it. I see the stars, but I don't see the Moon. What suggestions could you give me so that I would be successful in seeing the Moon?*"

Typically, students generate such suggestions as

- Look at a different place in the sky;
- Look at a different time of day; and
- Look from a different location.

We help the class plan new observations around these suggestions. Later in the Moon investigation, as students have collected and shared more observations, they are ready for a more difficult puzzler.

Discrepancies often arise as students share their data. Moon Puzzler #2 helps students sort out data that is reasonable and data that is unreasonable: "*1. Someone in my class saw the Moon last night at midnight in the southwest sky. I saw it at 6 P.M., and I swear it was in the southeast. Who is right? 2. Someone in my class saw the Moon on Sunday and said it was Full. I saw the Moon on Monday and it was half Full. Could that be? What do you think?*"

When students analyze their own data and class data, they typically recognize that Part 1 of the puzzler is possible, but Part 2 could never happen. These puzzlers not only provide information about student thinking, they also help students form new ideas. As student facility with puzzlers increases, they demonstrate they are ready for the next phase.

Demonstrating Understanding

After students have been observing the Moon for several weeks, we ask them to explain the patterns they have seen using a model-building activity (for example, Foster 1996). Students make models of the Earth–Moon–Sun system, act out various phases of the Moon, and discuss their explanations in small groups. Our assessment at this phase of the instructional sequence is structured to find out to what degree students understand the scientific explanation for the Moon's phases.

After they have made and discussed the models, we ask individuals to replicate several Moon phases (for example, Full, New, First Quarter, Waning Gibbous) by drawing two-dimensional representations. For each phase, students draw the relative positions of the Earth,

Two summative assessment strategies we have used in the Moon investigation are the Moon Explanations Essay and the individual Moon Investigation Poster Presentation.

the Moon, and the Sun as if they're viewing it looking down on Earth's north pole. In addition, they indicate the direction of the Moon's motion and provide a written description of their drawing.

These drawings and writings provide assessment information about the quality of students' current understanding. These activities also help students clarify their thinking about the Earth–Moon–Sun system. However, at this stage, students are still constructing complete explanations and our instruction and assessment continue.

Applying Knowledge

In the Elaborate phase of the instructional sequence, we change our assessment objective from finding out what students know to seeing how they apply their current understanding to new problems. One way we do this is through thought experiments reminiscent of great scientists such as Galileo and Einstein. Thought experiments—essentially thought-provoking questions for students to explore using the models—enable preservice teachers to think more deeply about the models and test out their applicability in various situations. Students respond to our thought experiments individually or in small groups.

For example, typically, we ask students to use their Earth–Moon–Sun model to explain why lunar and solar eclipses do not appear during each lunar cycle.

(Lunar eclipses occur when the Earth blocks sunlight from reaching the Moon—when the Moon is Full, and solar eclipses occur when the Moon blocks sunlight from reaching the Earth—when the Moon is New. Because the Moon's orbit is slightly inclined with respect to the plane of the Earth's orbit, we experience Full Moons and New Moons regularly, but lunar and solar eclipses rarely.)

Or, we ask students to imagine what the First- and Third-Quarter Moons would look like in Australia. *(The Moon's apparent shape during each phase—except Full—appears the opposite to Australians because an observer in the Southern Hemisphere is facing north during viewing the Moon while an observer in the Northern Hemisphere is facing south.)*

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More Applications

Another application assessment we have used involves evaluating representations of the Moon in children's picture books, which we have often found to be inaccurate. For example, in Crockett Johnson's *Harold and the Purple Crayon* (1981), a young boy named Harold gets lost and searches for his way home. Then he remembers something. "He remembered where his bedroom window was, when there was a moon. It was always right around the Moon."

Preservice teachers who have been studying the Moon for almost a month realize that this cannot be true. They feel confident enough in their own Moon understanding to question that of the author. This in turn helps them feel more prepared to teach the phases of the Moon to their own students someday.

Another way we assess students' application of their current understanding is through asking them to plan individual investigations. Each student chooses to investigate a question that emerges from observations and discussions. These questions have a special appeal, because they arise out of the student's own curiosity. Examples of questions that students have pursued in the past include:

- Does the Full Moon decrease in size as it rises from the horizon?
- Does the Moon always set at the same position on the horizon?
- How much time passes from one Moonrise to the next?

Our assessment involves examining the quality of their investigation questions (i.e., Do the questions require further observation and not merely library study?) and the quality of their investigation plan (i.e., Will their plan help them answer their question?).

Determining Learning

Toward the end of the instructional sequence, we need to assess student understanding in a summative manner. This assessment helps both instructors and students see how far their understanding has progressed. Two summative assessment strategies we have used in the Moon investigation are the Moon Explanations Essay and the individual Moon Investigation Poster Presentation.

Students complete these assignments individually and we evaluate their products using a scoring rubric. The rubric for the explanations essay defines levels of understanding about phases of the Moon. The rubric for the poster includes categories for the quality of the question, the methods, the findings, and the presentation.

The Moon Explanations Essay requires students to write a synthesis of what they have learned. Using a

Connecting to the Standards

This article relates to the following *National Science Education Standards* (NRC 1996):

Assessment Standards

Standard A: Assessments must be consistent with the decisions they are designed to inform.

- Assessments are deliberately designed.
- Assessments have explicitly stated purposes.

Standard C: The technical quality of the data collected is well matched to the decisions and actions taken on the basis of their interpretation.

- Assessment tasks are authentic.
- Students have adequate opportunity to demonstrate their achievements.

Content Standards

Grades K–4

Standard D: Earth and Space Science

- Objects in the sky
- Changes in Earth and sky

Grades 5–8

Standard D: Earth and Space Science

- Earth in the solar system

series of prompts, we ask students to draw their current understanding of the Earth–Moon–Sun system and explain at least three phases of the Moon using that model. We encourage them to include diagrams and data from class observations to clarify their explanations. In the essay, we also ask students to compare their incoming explanations on the Moon Explanations Questionnaire to their final explanations. This demonstrates to them (and to us) just how far they have come in their thinking.

We use the poster presentation as a summative assessment of the individual investigations that students undertook during the Elaborate phase. The students design posters to display the question they investigated, data gathered, and an explanation based on the evidence. With the posters exhibited in the classroom, we invite other faculty and students to view them and speak to the investigators. Students receive feedback about their work and recognize that they have become experts about one facet of the Moon.

Deeper Understanding

Assessment should take place at every phase of an instructional unit, serving various purposes across the unit. The mark of a good assessment is that it not only provides information about what students know, but challenges students to develop deeper understanding.

Each of the assessment tools we used to monitor preservice teachers' understanding about the phases of the Moon meets these criteria. We believe that, with a few adjustments, these assessment strategies could be applied to any science content area at any grade level.

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Resources

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NSTA Connection

For more about assessment, check out a new book from NSTA Press: *Everyday Assessment in the Science Classroom*, edited by Mike Atkins and Janet E. Coffey. This collection of 10 essays introduces the theories behind the latest assessment techniques and provides in-depth "how to" suggestions on conducting assessments as a matter of routine. A preview of the book is available online at *http://www.nsta.org/store/product_detail.aspx?id=10.2505/9780873552172*