Using Formative Assessment to Uncover How Students Think About Science

By Joyce Tugel

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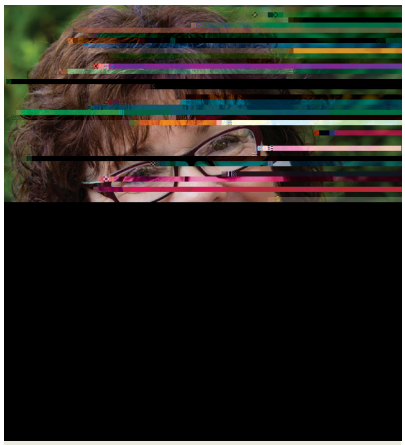

Joyce Tugel is a K–12 STEM Education Specialist at the Maine Mathematics and Science Alliance. She primarily focuses on teacher leadership, professional development in the areas of science curriculum, instruction and formative assessment, STEM integration, and implementation of the Next Generation Science Standards.

Joyce has served on the National Science Teachers Association and the National Science Education Leadership Association Board of Directors. She is a Fellow of the National Academy for Science and Mathematics Education Leadership.

Introduction

Firm evidence shows that formative assessment is an essential component of classroom work and that its development can raise standards of achievement. We know of no other way of raising standards for which such a strong prima facie case can be made.

3. Providing feedback that moves learning forward
   Teachers work with students and provide them with the information they need to better understand problems and solutions.
4. Activating learners as instructional resources for one another
   Getting students involved with each other in discussions and working groups can help improve student learning.
5. Activating learners as owners of their own learning
   Self-regulation of learning leads to improved performance.

Page Keeley is well known in the field of science education as a leader and expert in science formative assessment. She began developing formative assessment probes in the early 1990's, and she continues to develop and publish assessment probes (uncoveringstudentideas.org) and formative assessment classroom techniques (Keeley 2015, 2016) for science and mathematics educators.

Keeley's ability to translate theory into concrete practice has been enthusiastically received by classroom teachers, curriculum coordinators, and administrators as a means to transform classrooms across the K–12 continuum. Keeley points out that formative assessment classroom techniques (FACTs) can be used for multiple purposes (Keeley 2016):

- Elicit and Identify Preconceptions
- Engage and Motivate Students
- Activate Thinking and Promote Metacognition
- Provide Stimuli for Discussion
- Initiate Inquiry and Idea Exploration
- Formal Concept Development and Transfer
- Improve Questioning and Quality of Student Responses
- Provide Teacher-to-Student Feedback
- Peer and Self-Assessment
- Reflection

Embedding multiple purposes within the same assessment strategy results in a rich teaching and learning environment.

Formative Assessment and the "New Standards"

The release of the *Framework for K–12 Science Education* (NRC, 2012) and *Next Generation Science Standards* (NGSS Lead States, 2013) has provided an additional layer of complexity and opportunity for science education. The NGSS were developed with the goal of improving science education for ***all*** students. Every NGSS standard has three dimensions, consisting of: disciplinary core ideas, science and engineering practices, and crosscutting concepts.

The integration of content and application reflects how science and engineering are practiced in the real world, and many states have adopted the NGSS as their state standards. For states and districts who have not, the vast majority choose to adapt components of the three dimensions, particularly the core ideas and science & engineering practices.

The implications of working towards the vision of the NGSS are profound. The emphasis is now on making sense of science through exploring and explaining phenomena, and teachers are being asked to shift from some commonly-used teaching approaches to a more learner-centered approach (NRC 2015, p. 11):

IMPLICATIONS OF THE VISION OF THE NGSS

THE TRADITIONAL APPROACH TO TEACHING SCIENCE	THE NGSS APPROACH TO TEACHING SCIENCE
Science education will involve less	Science education will involve more
Rote memorization of facts and terminology	Facts and terminology learned as needed while developing explanations and designing solutions supported by evidence-based arguments and reasoning
The learning of ideas is disconnected from questions about phenomena	Systems thinking and modeling are used to explain phenomena and give context to ideas being presented
Teachers provide information to the whole class	Students conduct investigations, solve problems, and engage in discussions with the guidance of their teacher
Teachers pose questions with only one right answer	Students discuss open-ended questions that focus on the strength of the evidence used to generate claims
Students read textbooks and answer questions at the end of the chapter	Students read multiple sources, including science-related magazines, journal articles, and web-based resources, and they develop summaries of information
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These transformative shifts lend themselves to the integration of formative assessment strategies that support the science and engineering practices of:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Developing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Formative Assessment in Science: Examples and Suggestions

As we shift towards learner-centered classrooms that place high priority on learning science through asking questions, developing explanations, and engaging in argument from evidence, educators need formative assessment techniques that can support this transformation and help students persevere in a manner that is enjoyable and rewarding.

The following strategies have shown to engage and motivate students, encourage student discussion, and provide the feedback needed to promote thinking and inform instruction.

P-E-O (Predict-Explain-Observe)

P-E-O is a strategy that lays the foundation for the science practices of developing explanations, as well as planning and carrying out investigations. It can be used to provide stimuli for scientific discussion and initiate scientific inquiry, idea exploration, and reflection.

P-E-O begins with the teacher presenting a phenomenon. For example, students are shown an apple floating in water. Students are asked to make a (P) prediction or select a prediction from a set of responses that best matches their ideas about the question: “What will happen if a hole is drilled all the way through the apple?”

Students are asked to (E) explain their predictions by sharing what they think they will see and why they think this.

The teacher and/or students will then carry out the experiment and (O) observe what happens. At this point, students should analyze and discuss the results to see if they match their original predictions. The teacher uses the information to inform instruction, and after investigating, students are provided an opportunity to revise their earlier explanations based on the results and class discussion.

Sticky Bars

The sticky bars strategy provides an opportunity for teachers to publicly share student responses while allowing students to remain anonymous. Creating a safe environment encourages the sharing of a range of ideas and promotes metacognition (students thinking about their own thinking).

Card Sorts

Card sorts are a formative assessment strategy that can be used to access prior knowledge and activate thinking. Students work in pairs or small groups and are provided a set of cards related to a category associated with a specific concept or idea. For example, they may receive 15 cards with words and/or pictures such as squirrel, bird, fish, seed, fire, and river. Students are then asked, "Is it living?". As students discuss each card one at a time, they sort them into two categories: "It is living" or "It is not living."

During the sorting process, students must justify their thinking and develop rules or reasons for their decisions. The card sort strategy becomes formative as the teacher observes where the group is placing their cards and listens to the small- and subsequent whole-group discussions to inform the next steps in instruction. This strategy promotes learning as students discuss their ideas, listen to the ideas of their peers, and modify their thinking accordingly.

For further descriptions and over 100 additional strategies, see *Science Formative Assessment,* Vol. 1 and 2 (Keeley, 2015, 2016).

Conclusion

Formative assessment is used to inform instruction and promote student thinking, not to grade students. Students should be reminded that there are no right or wrong answers during a