WHITE PAPER

Formative Assessment Practices in Middle School Science Education

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Assessment practices in K-12 educational settings have undergone many transformations over the years. Classroom assessment practices have been more recently influenced by local, state, and federal accountability mandates. Hence, summative assessments have been the dominant means by which teachers obtain information regarding what students know. In recent years, there has been a move towards providing continuous instructional feedback to students with the goal of increasing students' academic performance. Formative assessment is a means by which classroom teachers can provide continuous instructional feedback to students with the aim of bridging learning gaps in what students currently know and what students should know.

There have been three trends in education that have highlighted the need for teachers to do formative assessment. These trends include (a) continuous summative assessment, (b) multiple purposes for assessment and teaching (e.g., summative, formative, accountability), and (c) assessment for conceptual development (Bell & Cowie, 2001). In a comprehensive review of the literature on classroom formative assessment, Black and Wiliam (1998) found that incorporating formative assessment within classrooms improved students' academic achievement. In 2008, the president of the National Science Teachers Association (NSTA) emphasized the importance of transforming formative assessment practices in science classrooms and suggested ways that the NSTA could assist teachers in transforming their professional learning in formative assessment (Keeley, 2008a, 2008b, 2008c). This paper describes formative assessment, formative assessment practices in science education, benefits and challenges to formative assessment practices, and provides some strategies for implementing formative assessment during daily instruction.

iSCIENCE For examples, see *Page Keeley Science Probes*, Key Concept Checks, Reading Checks, and Visual Checks found in Integrated Owl, Vol. 2, p. T19.

Formative Assessment

Many definitions of formative assessment exist in the literature. For example, Sadler (1989) states that formative assessment "is concerned with how judgments about the quality of student responses (performance, pieces, or works) can be used to shape and improve the student's competence by short-circuiting the randomness and inefficiency of trial-and-error learning" (p. 120). Gareis (2007) describes formative assessment as "any means by which a teacher figures out what students are getting and what they are not getting-in the classroom, for the purpose of teaching and learning, but not for purposes of grading" (p. 18). Central to both definitions and other definitions of formative assessment available in the literature is the interactive feedback system between teachers and students for purposes of using the information gathered to improve students' learning through instructional modifications, as necessary. Using information gathered during the interactive instructional feedback process between teachers and students is considered vital to providing a validity argument for formative assessment (Nichols, Meyers, Burling, 2009).

Nichols et al. (2009) presented a formative system framework "within which to consider evidence-based claims that information from performance on a particular assessment can be used within specified contexts to improve student achievement" (p. 15). This framework consists of three phases: assessment, instructional, and summative. Each phase includes structures (i.e., organized information) and actions (i.e., interpretations made using structures). Implications inferred from applying the framework included (a) assessment information can be used effectively to improve student achievement when used as a component of a system that coordinates assessment and instruction, (b) formative assessment results are contextual, and (c) test developers using the frame to prescribe instructional activities that link assessment and instruction during the design phase.

On a continuum, formative assessment practices can be formal or informal (Ruiz-Primo & Furtak, 2007). Formal formative assessment practices are structured and provide teachers with more control. Examples of formal formative assessment practices include group-administered quizzes, tests, and writing assignments. Informal formative assessment practices, on the other hand, provide less structure and can be embedded within regular classroom activities. Examples of informal formative assessment practices include questioning and observations in which there is direct teacher-student interaction.

Formative Assessment Practices in Science Education

Several researchers have proposed models and frameworks for formative assessment practices in science classrooms. Cowie and Bell (1999) described one of the earliest models of formative assessment in science education. The model includes (a) planned and interactive formative assessments; (b) complex, skilled tasks; (c) central role of purpose in planned and interactive assessment; (d) action taken as part of planned and interactive formative assessment; and (e) details of the formative assessment process raise awareness. Planned

formative assessment involves teachers eliciting, interpreting, and acting on assessment information. In contrast, interactive formative assessment involves teachers noticing, recognizing, and responding to student thinking during student-teacher interactions. Planned and interactive formative assessments are linked through the purpose of the formative assessment, and teachers can move between the two forms of formative assessment based on the purpose.

Ruiz-Primo and Furtak (2006, 2007) proposed a framework for informal formative assessment that consists of the teacher eliciting a question, the student responding, the teacher recognizing the student's response, and then the teacher using the information collected to support student learning (ESRU). In studying informal assessment practices (i.e., assessment conversations) of middle school science teachers during the implementation of science investigations, the authors found that most teachers used incomplete ESRU cycles in their everyday instruction. However, teachers whose assessment conversations were more consistent with the ESRU cycle had students with higher performance. Higher performance was also associated with teachers who held the most discussions, asked the most concept-eliciting questions, and used the most diverse strategies for obtaining information gained about student learning. The epistemic science inquiry domain (e.g., interpretation of data, identification of patterns, or use and apply procedures), as opposed to the conceptual science inquiry domain (e.g., provide definitions or compare concepts), was the primary focus in discussions.

In addition to proposing models and frameworks for formative assessment practices in science education, researchers have conducted studies that explore various aspects of using formative assessments in science classrooms. Buck and Trauth-Nare (2009), for example, described the experiences and challenges of a middle school teacher who implemented formative assessment in her classroom while engaging in cooperative inquiry with postsecondary researchers. Several findings emerged from the study. First, the cooperative research process positively affected the teacher's understanding of the formative assessment process in that the teacher began to acknowledge limitations of selected-response assignments on revealing students' understanding and began to use other modes of formative assessment. Secondly, overtime, students became less reluctant and more involved in the formative assessment process. Finally, the teacher dialoguing with students through continuous cycles of feedback and revision, explicitly educating students about the formative assessment process, establishing a trusting environment where students could explore their conceptual development without fear of penalty, and realizing that some students may not achieve complete conceptual understanding until they encounter unifying ideas across topics emerged as results of integrating formative assessment into the teacher's daily instructional practices.

iSCIENCE See Page Keeley's assessment probes on p. 529 of Integrated iScience (Owl), Vol. 2, for an example of formal assessment in science.

Characteristics of Formative Assessment in Science Education

Based on the findings of a two-year research project in New Zealand, Bell and Cowie (2001) described nine characteristics of formative assessment in science education, as discussed by teachers in their study. The characteristics are:

- responsiveness (e.g., ongoing and progressive, informal, and interactive);
- the sources of information and evidence (e.g., nonverbal as well as verbal information, and teachers' observations);
- a tacit process (i.e., teachers were not always aware of doing formative assessment);
- using professional knowledge and experiences (e.g., teachers' knowledge and experiences of the topic and of the students as learners);
- an integral part of teaching and learning (i.e., action taken by the teacher and the student as a result of the information gathered);
- teachers and students were doing the assessing;
- purposes for formative assessment (e.g., inform student learning and inform teaching);
- the contextualized nature of formative assessment;
- dilemmas faced by teachers during formative assessment (e.g., tensions between formatively assessing the class or an individual and tensions between formatively assessing the science or the personal and social development); and
- student disclosure (i.e., students disclosed their ideas but did not disclose their thinking).

Look for the Performance Assessment suggestions found in Blueprints for Success Section G, pp. 283-420.

Benefits of Formative Assessment Practices

Several benefits exist for using formative assessment practices in instructional settings. From a pedagogical perspective, Marsh (2007) described five benefits of formative assessment. Benefits include:

- Formative assessment helps with planning because it involves giving clear learning intentions to students.
- Formative of learning intentions.
- Formative assessment empowers the student to realize his/her own learning needs and to have control over future targets.

- Formative assessment tracks progress diagnostically and informs a student of his/her successes and weaknesses.
- Formative assessment ensures student motivation and involvement in progress—it raises achievement, it keeps teachers informed of individual needs. (p. 26)

iSCIENCE For examples, see Formative Assessment suggestions in Integrated iScience (Owl), Vol. 1, p. T19.

Challenges to Formative Assessment Practices

Although there are a number of benefits to using formative assessment practices in daily instruction, a challenge exists for teachers in how to use the information to adapt instruction. For example, Heritage, Kim, Vendlinski, and Herman (2009) found in a generalizability study of measures of teacher knowledge for teaching mathematics that teachers were more adept in identifying key mathematics principles and evaluating student understanding and less adept in planning the next instructional steps based on the evaluation of student understanding. Yin et al. (2008), using a randomized experiment, explored whether formative assessments embedded within a middle school inquiry science unit on sinking and floating would improve student motivation and achievement and lead to conceptual changes. Overall, the preliminary analysis and the multilevel analysis provided evidence that the embedded formative assessments did not significantly influence students' motivation, achievement, and conceptual change. The authors asserted that the study provided confirmation of the difficulty in implementing formative assessment when teachers do not follow the formative assessment as designed. Moreover, formative assessment is infrequently used because of teachers' personal experiences with summative assessments, principals' pressure on teachers to obtain high academic results, national and state focus on high-stakes tests, a reward system based on summative assessments, and inadequate preparation of preservice teachers in formative assessment practices in teacher education programs (Marsh, 2007).

iSCIENCE In each chapter look for *Page Keeley Science Probes* in the **eTeacher Edition**. See Integrated iScience (Owl), Chapter 13, p. T459.

Strategies for Formative Assessment Practices

Based on the work of Wiliam and Thompson (2007), Black and Wiliam (2009) highlighted five strategies for formative assessment that emerged out of the interaction of three processes of learning and teaching (i.e., knowing where the learner is going, knowing where the learner is currently, and know how to get the learner to a certain level) and the different stakeholders in the learning and teaching process (i.e., teacher, peer, and learner). The strategies include (a) clarifying and sharing learning intentions and criteria for success, (b) engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding, (c) providing feedback that moves learners forward, (d) activating

students as instructional resources for one another, and (e) activating students as the owners of their own learning (p. 8). The authors purport that these strategies, along with other ideas developed in earlier publications, serve to provide a unifying basis for diverse practices that are considered formative.

Within Ruiz-Primo and Furtak's (2006, 2007) model for informal formative assessment, several strategies by ESRU cycle phase were outlined. For example, for eliciting, strategies include the teacher asking students to compare and contrast data, make predictions, and apply concepts. In the recognizing phase, teachers can clarify student responses, provide evaluative responses, and re-voice students' words. In the using phase, teachers can promote student thinking with why and how questions, help relate evidence to explanations, and provide helpful feedback. Strategies most frequently used in informal formative assessment practices were re-voicing or rephrasing students' responses (Ruiz-Primo & Furtak, 2006, 2007) and asking why and how questions to challenge or redirect students' thinking (Ruiz-Primo & Furtak, 2006). Strategies most infrequently used in informal formative assessment practices were providing helpful feedback (Ruiz-Primo & Furtak, 2006, 2007); comparing and contrasting students' responses (Ruiz-Primo & Furtak, 2007); and promoting argumentation (Ruiz-Primo & Furtak, 2007).

Other strategies include using prompts. Furtak and Ruiz-Primo (2008) compared the usefulness of four types of formative assessment prompts (i.e., graph, predict-observe-explain [POE], constructed response [CR], and predict-observe [PO]) in eliciting middle school students' ideas about sinking and floating in writing and discussion. The authors found that the prompts effectively elicited students' concepts in writing, with the POE prompt being more likely to elicit student responses at the expected level and the CR and PO prompts more clearly disclosing students' multiple and inappropriate conceptions. In whole-class discussions, the graph and CR prompts did not elicit discussions that lasted as long as discussions elicited by the POE and PO prompts. Furthermore, discussions elicited by the POE and PO prompts were more conceptually oriented and tended to elicit more students' conceptions at the expected level. Overall, the results indicated that the success of the prompts in eliciting students' conceptions may be depended on the openness and familiarity of the prompts.

iSCIENCE Look at *Blueprints for Success*, pp. 185-202, "Writing in Science".

Conclusion

The use of formative assessment practices in science classrooms has potential for increasing students' achievement. However, many teachers have not received training on how to successful implement formative assessment practices within their daily instruction. If teachers are to assess gaps in students' understanding of science topics through a feedback system that requires teachers to use information collected from students to make instructional adjustments, ongoing professional development training is needed. Keeley (2008a, 2008b, 2008c) offered five ways the NSTA can assist teachers with their professional learning in formative assessment (i.e., know science content, resources and information, professional

learning communities, act on new learning, and student learning). To ensure that teachers are incorporating formative assessment practices in their daily lessons, schools and districts can use a science lesson plan analysis instrument (e.g., Jacobs, Martin, & Otieno, 2008). Furthermore, when schools and districts consider adopting formative assessment systems, there needs to be alignment between a system's characteristics and schools' or districts' intended use (Militello, Schweid, & Sireci, 2010).

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