Chapter 9
Formative Assessment in Hands-On STEM Education

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ABSTRACT

This chapter serves as an introduction to transdisciplinary learning, Integrative STEM Education, and current methods for infusing formative assessment into hands-on instruction at the elementary level. Subscribing to the approach that formative assessment is a process that takes place in the classroom to enable learning, the chapter discusses the use of engineering notebooks, competency-based assessment, and qualitative assessment (rubrics and portfolios) in the context of formative assessment while facilitating hands-on learning opportunities. In addition to introducing each of these topics from a research and literature perspective, examples are provided and discussed from a practical perspective. No one formative assessment is better than another, however, one type may be more practical due to the teacher's willingness to try new things, development of students, standards teacher is measuring, type of lesson/unit, time, available resources, and associated costs.

INTRODUCTION

As a society, we are solidly in the 21st century. However, our learning priorities are just starting to catch up with the ideas and processes needed to prepare students for the society and systems they will inherit in the future. As educators work to provide environments and curricula in which students can thrive and effectively prepare for students' futures, topics such as college and career readiness, 21st century skills, STEM (science, technology, engineering, math), formative assessments, hands-on learning, and others are being explored by practitioners and researchers alike. This chapter will explore the unique role

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of formative assessments in STEM education through the numerous opportunities for observation that hands-on learning provides to directly assess students' learning processes. These opportunities to assess student knowledge, skills, and abilities when engaging in hands-on STEM activities are pivotal moments that have broader impacts regarding students' levels of activation, efficacy in STEM content areas, and career interests, especially in terms of formative assessment where the feedback is low-stakes. STEM education will be explained in terms of transdisciplinary learning and the development of Integrative STEM Education as model of hands-on-education in a STEM classroom and how formative assessment plays a role in the learning process. Finally, this chapter reviews several options of formative assessment that can be used in conjunction with Integrative STEM Education at the elementary level, including engineering notebooks, competency-based assessment, portfolios, and rubrics.

Formative assessment is an important part of the learning process; it allows for growth to occur more readily in a hands-on context, like that found in Integrative STEM education, because it allows for instant or near-instant correction and discussion. The cause and effect of decisions and processes are identifiable and reteaching can occur in a more timely manner, and also in a manner that has more meaning for the student. Like pebbles being thrown in a lake, teachers' decisions make create ripples in their students' lives. Researchers are currently investigating these ripples and their effects through the lenses of STEM literacy and career interest in STEM fields. Early and often seems to be a recurring theme found in the literature, as such, the inclusion of STEM education at the elementary level is an important step for American Education.

The Next Generation Science Standards (NGSS) provide an engineering education focus that was not previously included in most public science education (Next Generation Science Standards Lead States, 2013) and also requires varying forms of ongoing formative assessment. The inclusion of engineering in all grade levels science curriculum supports early exposure to STEM education and a belief that young children are capable of this level of thinking (Moomaw & Davis, 2010). Furthermore, STEM education shows promise in teaching for future science, technology, engineering, and mathematics as one cohesive learning experience. However, the rebranding of science or engineering content as STEM does not fulfill the true educational movement. STEM education is a style of education that uses pedagogical skills from all of the disciplines to teach in a way that resembles how education will be used in real-life. The challenges that future generations will solve will require scientific and mathematical knowledge, and STEM education is perfectly placed to teach kids content and skills, such as critical thinking, problem-solving, and creativity (Ernst, 2009; Bybee, 2013; Peterson, 2017). One way teachers can better prepare their students is by providing them opportunities to solve engineering design challenges using everyday recyclables and inexpensive materials. It is important for students to build connections between the challenge and their other schoolwork, so building the challenges into the curriculum (as opposed to stand alone) is recommended. Design challenges like this help students learn adaptability, complex communication, non-routine problem solving, self-management, social skills, and systems knowledge (Dym, Agogino, Eris, Frey, & Leifer, 2006; Peterson, 2017). The use of engineering design challenges aligns with best practice and policy priorities set by President's Council of Advisors on Science and Technology (Holdren, Lander, & Varmus, 2010).

Recently, policymakers have renewed interest in promoting STEM in K-12 education with the Every Child Succeeds Act (ESSA), the National Science Foundation funding focus, and the US Department of Education's list of educational priorities. At the elementary level, STEM education focuses on hands-on STEM introductory classes and occupations to interest students into wanting to pursue STEM careers, not require them to gain a certain number of credits in secondary education. In particular, the hands-on,

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