Chapter 3
Scientific Practices and Skills Supported by a Problem-Based Learning Approach

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ABSTRACT

In the era of education reform, most educators face the pressures of standardized tests and state accountability measures. Because of these demands and other factors, students often experience classroom lessons that minimally disturb the surface of knowledge acquisition. The adoption of rigorous three-dimensional science standards poses additional challenges to practitioners; one of these challenges is the pedagogical shift from rote memorization of science facts toward participation in scientific practices through cross-curricular investigations. In this chapter, the author discusses several research-based practices and skills that he uses in his classroom to better prepare students for 21st century careers: analogies, models, creativity, cultural identity, and discourse.

INTRODUCTION

Due to teacher accountability measures and standardized testing, science education has traditionally assumed the positivist approach to learning, in which teachers lead students to the "right" answers from predetermined experiments and lectures (Driver, Newton, & Osborne, 2000). Through the use of project-based learning activities, education could evolve into a pedagogical framework that supports students in constructing their own scientific reasoning, developing literacy skills, and improving computational thinking. However, in order for this to occur, an educational reform must take place. It should withdraw from students memorizing concepts and progress toward students participating in scientific practices and skills through an integration of content areas (e.g., science, English Language Arts, mathematics, history, and visual arts). These practices and skills include analogic reasoning, building models, using creativity, developing a culturally-relevant scientific identity, and participating in discourse.

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ANALOGIES

An analogy is a relationship between two entities–one familiar and one unfamiliar. Valuable in communication, conceptual learning, and scientific progress, analogies can have a powerful influence over students' scientific discovery, when they are used correctly. Venville and Treagust (1996) found that analogies serve multiple purposes in science learning. They facilitate conceptual change in the learner's mind, allow students to make sense of new content, and assist students in recalling concepts that are difficult to remember.

In the interest of delivering instruction centered on critical thinking within a contemporary context, educational researchers have focused on understanding cognitive development–how people learn and think. Daugherty and Mentzer (2008) studied the effects of analogical reasoning on design problem-solving with technology education students. Analogical reasoning, which is essential for design problem solving, is part of the associative reasoning system, whereby cognitive solutions form by connecting prior knowledge with other known information (Daugherty & Mentzer, 2008). Its uses include understanding new phenomena, creating inferences using current knowledge to solve problems, and assisting in identifying learning misconceptions. Analogies strengthen a student's symbolic ability, or the ability to identify patterns in new situations and then apply the newly identified patterns to create solutions to problems.

In his search for the strategy that increases the likelihood of making scientific discoveries, Dunbar (1997) revealed that contemporary scientists actually use a variety of cognitive strategies, such as analogy and distributed reasoning, to promote creative cognition. He explained analogies as containing two parts: The target (i.e., the explained concept) and the base (i.e., knowledge used to understand the target). Scientists within a specific branch, such as biology, infrequently use distant analogies or those outside the current branch of study; moreover, they primarily use analogies as a scaffold in theory creation (Dunbar, 1997). Additionally, distributed reasoning was effective in the development of new scientific concepts from scientists with common backgrounds and similar research goals (Dunbar, 1997). Comparing conceptual change to evolution, Dunbar (1997) concluded that "creative ideas and novel concepts arise through a series of small changes produced by a variety of different cognitive functions" (p. 488). These cognitive processes, combined with their ability to take risks, help direct scientists to create conceptual change.

Analogical reasoning and scientific creativity are interwoven within the nature of science (NOS). In science education, analogies deepen the understanding of scientific concepts by allowing students to make the abstract more concrete. Teachers should facilitate students as they develop problem-solving abilities through the creation, analysis, and evaluation of analogies in individual and group settings. As analogies are a powerful creative cognitive tool, science educators must ensure they are incorporating them into their instruction effectively to avoid the development of misconceptions.

Analogies can play a fundamental part in conceptual change; yet, some educators have found that sociocultural barriers can hinder content understanding. For example, during a lesson where students use analogical reasoning to solve community-based problems, English Language Learners might struggle to participate due to their lack of prior knowledge and the lesson's context. In order to combat this pedagogical oversight, teachers could encourage English Language Learners to use a community-based problem from their native country as a contextual alternative. If students are to develop and use analogical reasoning when solving problems, it is critical for science educators to use explicit instruction. Professional development focused on analogical reasoning, its cognitive benefits, and its pedagogical integration are fundamental. In addition, teachers need to understand the strengths and limitations of using analogies in