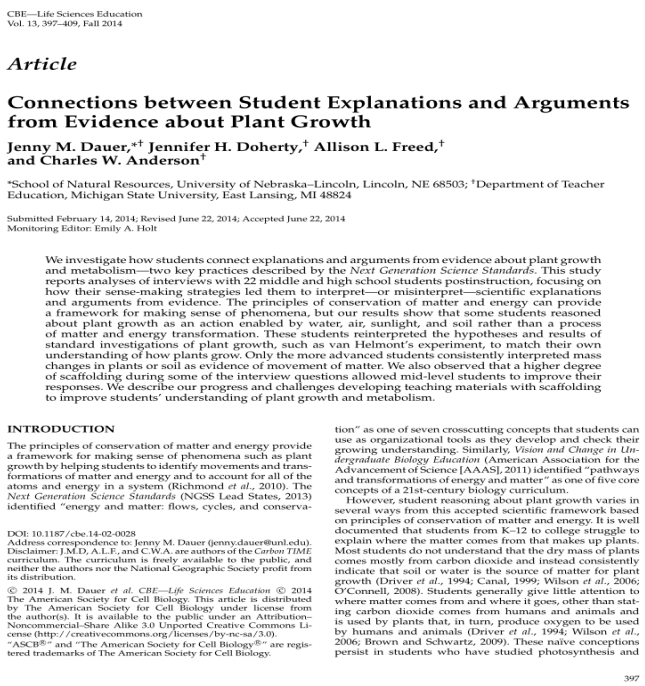
Holt Biology Nebraska: Holt Biology Test Preparation Workbook



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Article

Connections between Student Explanations and Arguments from Evidence about Plant Growth

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We investigate how students connect explanations and arguments from evidence about plant growth and metabolism—two key practices described by the *Next Generation Science Standards*. This study reports analyses of interviews with 22 middle and high school students postinstruction, focusing on how their sense-making strategies led them to interpret—or misinterpret—scientific explanations and arguments from evidence. The principles of conservation of matter and energy can provide a framework for making sense of phenomena, but our results show that some students reasoned about plant growth as an action enabled by water, air, sunlight, and soil rather than a process of matter and energy transformation. These students reinterpreted the hypotheses and results of standard investigations of plant growth, such as van Helmont's experiment, to match their own understanding of how plants grow. Only the more advanced students consistently interpreted mass changes in plants or soil as evidence of movement of matter. We also observed that a higher degree of scaffolding during some of the interview questions allowed mid-level students to improve their responses. We describe our progress and challenges in developing teaching materials with scaffolding to improve students' understanding of plant growth and metabolism.

INTRODUCTION

The principles of conservation of matter and energy provide a framework for making sense of phenomena such as plant growth by helping students to identify movements and transformations of matter and energy and to account for all of the atoms and energy in a system (Richmond *et al.*, 2010). The *Next Generation Science Standards* (NGSS Lead States, 2013) identified "energy and matter: flows, cycles, and conservation" as one of seven crosscutting concepts that students can use as organizational tools as they develop and check their growing understanding. Similarly, *Vision and Change in Undergraduate Biology Education* (American Association for the Advancement of Science [AAAS], 2011) identified "pathways and transformations of energy and matter" as one of five core concepts of a 21st-century biology curriculum.

However, student reasoning about plant growth varies in several ways from this accepted scientific framework based on principles of conservation of matter and energy. It is well documented that students from K–12 to college struggle to explain where the matter comes from that makes up plants. Most students do not understand that the dry mass of plants comes mostly from carbon dioxide and instead consistently indicate that soil or water is the source of matter for plant growth (Driver *et al.*, 1994; Canal, 1999; Wilson *et al.*, 2006; O'Connell, 2008). Students generally give little attention to where matter comes from and where it goes, other than stating carbon dioxide comes from humans and animals and is used by plants that, in turn, produce oxygen to be used by humans and animals (Driver *et al.*, 1994; Wilson *et al.*, 2006; Brown and Schwartz, 2009). These naïve conceptions persist in students who have studied photosynthesis and

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