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Enhancing skill in constructing scientific explanations using a structured argumentation scaffold in scientific inquiry

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ABSTRACT

Constructing scientific explanations is necessary for students to engage in scientific inquiry. The purpose of this study is to investigate the influence of using a structured argumentation scaffold to enhance skill in constructing scientific explanations in the process of scientific inquiry. The proposed approach is designed to scaffold the following aspects of argumentation: the argumentation process, the explanation structuring, explanation construction, and explanation evaluation. A quasi-experiment was conducted to examine the effectiveness of the structured argumentation scaffold in developing skill in constructing scientific explanations and engaging in electronic dialogues. A web-based collaborative synchronous inquiry system, ASIS (Argumentative Scientific Inquiry System), was utilized to support students as they worked in groups to carry out inquiry tasks. Two intact sixth grade classes ($n = 50$) participated in the study. The data show that the ASIS with the structured argumentation scaffold helped students significantly improve their skills in constructing scientific explanations, make more dialogue moves for explanation and query, and use more of all four argument components. In addition, the use of warrants, one of the components of an argument, was found to be a critical variable in predicting students' competence with regard to constructing scientific explanations. The results provide references for further research and system development with regard to facilitating students' construction of scientific argumentation and explanations.

1. Introduction

Explanation is not only a central artifact of science (McNeill & Krajcik, 2011) but a central issue in science education (Pallrand, 1996; Yang & Wang, 2014). Moreover, construction of scientific explanations may help students obtain a deeper comprehension of content knowledge (McNeill & Krajcik, 2008; Zohar & Nemet, 2002). Furthermore, many studies indicate that constructing scientific explanations is necessary for students to engage in scientific inquiry (Kuhn & Reiser, 2005; Sandoval, 2003). An explanation can be seen as a statement of causation about how or why something occurred, and science education researchers have further defined the term by specifying that a causal statement must be linked to evidence (Berland & Reiser, 2009; Kuhn & Reiser, 2005; Sandoval & Reiser, 2004). Because scientific inquiry is seen as central to science education as a whole (American Association for the Advancement of Science, 1993; C. B. Hall & Sampson, 2009; Kuhn & Reiser, 2005; National Research Council,

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1996), students' abilities to construct explanations based on evidence, which are essential to engaging in scientific inquiry, is now considered critical (Huang et al., 2011; Kuhn & Reiser, 2005; Lemke, 1990; National Research Council, 1996; Schauble, Glaser, Duschl, Schulze, & John, 1995). This issue is made more urgent by the fact that many studies indicate that constructing scientific explanations is difficult for students (Kuhn & Reiser, 2005; McNeill & Krajcik, 2011; Sandoval & Millwood, 2005). Therefore, greater effort must be made to help learners both understand and construct explanations.

Many researchers have attempted to identify the difficulties that students encounter when constructing and communicating explanations and have sought to design supports to address these difficulties (Kuhn & Reiser, 2005), using Toulmin's Argument Pattern (Toulmin, 1958), which is often used as a scaffold in this context (P. Bell, 2000; Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Kuhn & Reiser, 2005; McNeill & Krajcik, 2008; McNeill, Lizotte, Krajcik, & Marx, 2006). The construction and evaluation of explanations are closely related to the core scientific practice of argumentation (McNeill & Krajcik, 2011) because, in developing an argument, students must explain their reasoning and link evidence to it (Kollar, Fischer, & Slotta, 2007). Similarly, Berland and Reiser (2009) observed that explanations can be developed through argumentation in scientific communities. The present study thus seeks to develop a structured argumentation scaffold that not only applies Toulmin's Argument Pattern but also integrates several other strategies that promote argumentation and explanation to help students understand and construct scientific explanations as part of the process of scientific inquiry. With regard to the use of educational technology to extend the scope of classroom discourse beyond school walls (Scardamalia & Bereiter, 1994) and the convenience and effectiveness of technology in facilitating learning (Hsu, Van Dyke, Chen, & Smith, 2015; Tsai, 2015; Wang, 2014), several promising learning technologies, with particular interface designs, have been developed to support collaborative inquiry-based learning (Chang, Sung, & Lee, 2003; Gomez, Gordin, & Carlson, 1995; Guzdial, Turns, Rappin, & Carlson, 1995; Lund, Molinari, Séjourné, & Baker, 2007; Scardamalia & Bereiter, 1991; Suthers, Weiner, Connelly, & Paolucci, 1995) and argumentation (P. Bell, 2000; Golanics & Nussbaum, 2008; Hong, Brudvik, & Chee, 2006; Hsu et al., 2015; McAlister, Ravenscroft, & Scanlon, 2004; Tsai, 2015; Wang, 2014). Similarly, this study seeks to use this structured argumentation scaffold in a computer-supported scientific inquiry environment.

1.1. Background

1.1.1. Scientific explanation in scientific inquiry

Recent research on science education has stressed that scientific learning involves more than memorization but rather is a way of knowing and thinking (Hsu et al., 2015; McNeill & Krajcik, 2006). This means that scientific learning should help students learn how to think and act like scientists (McNeill & Krajcik, 2006). More specifically, science curriculums should help students learn more about the processes that scientists engage in when they validate scientific knowledge through the method of scientific inquiry (Sandoval & Reiser, 2004). Like scientists, students should learn to ask questions, generate evidence, propose explanations based on evidence and reasoning, and form conclusions in the process of their inquiries (T. Bell, Urhahne, Schanze, & Ploetzner, 2009; National Research Council, 1996). To propose explanations, students must offer evidence to support their claims and use scientific language and ideas to illustrate their reasoning (Duschl, Schweingruber, & Shouse, 2007). In other words, constructing scientific explanations is indispensable for students in engaging in scientific inquiry (Kuhn & Reiser, 2005; Sandoval, 2003). Moreover, many studies have found that engaging students in scientific inquiry enhances their ability to construct explanations and arguments (McNeill & Krajcik, 2006; McNeill et al., 2006). H. K. Wu and Hsieh (2006) observed that participating in inquiry-based learning activities can significantly improve students' abilities to construct explanations. In brief, the practices of scientific inquiry not only provide opportunities for students to construct scientific explanations but improve their abilities to do so.

Broadly, an explanation is a statement of causation about how or why something occurred (Berland & Reiser, 2009; Kuhn & Reiser, 2005). However, science education researchers have further defined this term by specifying that a causal statement must be linked to evidence (Berland & Reiser, 2009; Kuhn & Reiser, 2005). Similarly, scientific standards emphasize the importance of reasoning according to evidence and logic when developing explanations (Kuhn & Reiser, 2005). Rutherford and Ahlgren (1990) noted that explanations should include or correspond with appropriate scientific principles. The National Research Council (1996) proposed that students should be able to construct explanations that provide “causes for effects and establishing relationships based on evidence and logical argument” (p. 145). McNeill and Krajcik (2006) defined scientific explanation as proposed explanations of phenomena, using relevant evidence and reasoning to support such explanations. This definition is adopted in the current study.

Many studies have reported that students face difficulties in constructing scientific explanations (Kuhn & Reiser, 2005; McNeill & Krajcik, 2011; Sandoval & Millwood, 2005; H. K. Wu & Hsieh, 2006). Kuhn and Reiser (2005) found that constructing scientific explanations is difficult for students because it requires incorporating many different elements, including amassing evidence to appraise and revise claims, reasoning about how to support claims, connecting evidence to scientific principles, and communicating what has been understood. However, students often do not clearly interpret their inferences or clearly articulate relationships between evidence and claims in their explanations. Sandoval and Millwood (2005) found that students often fail to cite sufficient and appropriate evidence for their claims and articulate how a certain piece of evidence relates to a particular claim. H. K. Wu and Hsieh (2006) found that students tend to generate incoherent explanations from personal thoughts and fail to make logical connections between evidence and claims in their explanations. McNeill and Krajcik (2011) observed that students are often unclear about what it means to construct a scientific explanation and about what to include in their explanations. It is thus important to help students understand the importance of constructing a