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Developing pre-service teachers' evidence-based argumentation skills on socio-scientific issues

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ABSTRACT

We report on a study of the effect of meta-level awareness on the use of evidence in discourse. The participants were 66 pre-service teachers who were engaged in a dialogic activity. Meta-level awareness regarding the use of evidence in discourse was heightened by having same-side peers collaborating in arguing on the computer against successive pairs of peers on the opposing side of an issue on the topic of Climate Change and by engaging in explicit reflective activities on the use of evidence. Participants showed significant advances both in their skill of producing evidence-based arguments and counterarguments and regarding the accuracy of the evidence used. Advances were also observed at the meta-level, reflecting at least implicit understanding that using evidence is an important goal of argumentation. Another group of pre-service teachers, who studied about the role of evidence in science in the context of regular curriculum and served as a control condition, did not exhibit comparable advances in the use of evidence in argumentation. Educational implications are discussed.

1. Introduction

Argument skills have a central role in science education (Kuhn, 2010; Lehrer, Schauble, & Petrosino, 2001). Advanced argument skills are associated with appreciation of science as an enterprise that advances through coordination of evidence with theories, rather than as the accumulation of facts (Sandoval, 2005). The goal of advanced argument skills, according to Walton (1989), is to weaken the opponent's claims. Key means to achieving this goal are the employment of argumentive strategies that critique the opposing claim and the effective use of evidence (Kuhn, Zillmer, Crowell, & Zavala, 2013). Yet, studies of students' argument skills in science contexts report these skills to be under-developed at best, even at the college level (Kelly & Takao, 2002; Kelly, Druker, & Chen, 1998; Kolstø, Bungum, Arnesen, et al., 2006; Maloney, 2007; Maloney & Simon, 2006; Sadler, 2004). Despite this fact, the available empirical research in science education studying how the development of argument skills can be supported, has been limited. Until recently, most research on scientific reasoning has been devoted to control of variables, and much less attention has been paid to argument skills (Kuhn, Iordanou, Pease, & Wirkala, 2008). Key questions such as the degree to which educational interventions can promote the development of students' argument skills, and especially their ability to use evidence in argumentation, remain unresolved.

Evidence lies at the heart of science. It constitutes the foundation of science and the mechanism through which it advances. A theory's power and its potential influence in the field of physics are determined by reasoned evaluation of the available data (Franklin, 1994). Evidence evaluation lies not only at the heart of science, but also it has a prominent position in scientific reasoning in the personal arena. Students' approach towards evidence is identified as a central element of epistemological understanding, that is an understanding of the constructive nature of knowledge (Kuhn, Iordanou, et al., 2008), which relates to self-regulated learning (Muis, 2007). The kind of evidence that students value as good evidence in a particular context, what Chinn, Buckland and Samarapungavan (2011) refer to as the evidential standards students pursue, influence the learning processes that students engage in and the conclusions they draw. Yet, studies repeatedly show that students do not use evidence consistently to support their claims (Erduran, Simon, & Osborne, 2004; Jiménez-Aleixandre, Rodriguez, & Duschl, 2000), even when they are

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explicitly instructed to do so (Sandoval & Millwood, 2008). Whether this phenomenon could be due to lack of skill, lack of appreciation of the need to do so or both, remains an open issue.

Instead of coordinating theory with evidence, including changing prior theory where necessary in the light of new evidence, students tend to rely excessively on their initial theories in their justifications. Even in cases where their prior beliefs are inconsistent with the available data, students still tend to make judgements that are consistent with their prior beliefs (Amsel & Brock, 1996). This over-reliance on prior beliefs is well documented in multiple studies across the fields of social psychology (Petty & Wegener, 1999), rational thinking – known as the myside bias – (Stanovich, West, & Toplak, 2013) and science education (Schauble, 1990). In particular, in a study reported by Schauble (1990), elementary school students interpreted identical patterns of evidence differently, depending on whether a particular piece of evidence was consistent or inconsistent with their prior beliefs. In the latter case, students tend to misread, misinterpret or distort evidence in order to conclude that a particular piece of evidence supported their initial theories. In a more specific analysis of how people – both science students and scientists – respond to data that are inconsistent with one's own theory, Chinn and Brewer (1993) identified seven possible reactions. These are ignoring, rejecting, excluding anomalous data from the current theory, holding anomalous data in abeyance, reinterpreting them, making peripheral theory change, and finally changing one's theory. Note that only one, out of the seven responses listed, involves theory change to accommodate new data.

The way students handle data does not seem to change with age. Even though young children show some competence in producing arguments in support of a claim (Anderson, Chinn, Chang, Waggoner, & Yi, 1997; Stein & Miller, 1993), serious weaknesses have been observed in the arguments of adolescents, adults, and even college students who major in Physics. Studying high school students' usage of justification for their claims as they were engaged in an electricity-based performance assessment, Kelly et al. (1998) found that although students produced some warrants when involved in experimentation, when they formalised their reasons in a written form they didn't do so. In this study, Toulmin's (1958) term of "warrant" was employed, which is defined as a "statement that acts to show that the move from data to claim is valid" (p.856).

In addition, little improvement is observed in individual's ability to use evidence in argumentation with standard curriculum. Observations of high school students' discussions in science classrooms showed a predominance of claims and rare usage of evidence to back up claims (Jiménez-Aleixandre et al., 2000). Studies that have undertaken explicit teaching of argument skills in a scientific context have shown, that the ability of considering alternative positions and integrating evidence with claims, which are key components of argumentation, showed little improvement (Mercer & Littleton, 2007; Osborne, Erduran, & Simon, 2004; Zohar & Nemet, 2002). Of particular concern are findings revealing weaknesses in science teachers' understanding and performance in incorporating evidence in argumentation (Zohar, 2004). Zembal-Saul, Munford, Crawford, Friedrichsen, and Land (2002) reported science teachers' inability to determine what counts as evidence in the context of an investigation. These findings, along with the fact that our understanding of how science teachers' argument skills can be developed is very limited (Zohar, 2008), point to the urgent need for examining ways to support science teachers' argument skills. How can we expect teachers to support the development of students' argument skills if they haven't themselves developed adequately these skills? Or, why are we expecting teachers to promote evidence-based argumentation, if they do not see the point of it? In the present study, we examined the development of evidence-based argumentation skills in a sample of pre-service teachers. Although use of evidence is a key component of skilled argumentation (Kuhn et al., 2013), we use the term evidence-based argumentation to stress the focus of the present study in developing the skill of using evidence in argumentation. Evidence-based argumentation involves both the ability to use evidence in argument production, that is when one uses evidence to support his/her own position and the evaluation of evidence in argument reception, that is when one weighs evidence offered by the opponent. In particular, this study examined the effect of enhancing meta-level awareness of the use of evidence, along with engagement in peer discourse, on the use of evidence in argumentation. We first present empirical evidence regarding the development of argument skills, particularly the skill of using powerful argumentive strategies. Then, we present a theoretical model which proposes a relationship between meta-level knowledge and argument skills, followed by empirical evidence regarding the relationship between meta-level knowledge and the development of effective argumentive strategies. We end our literature review with a description of the present study and our hypothesis.

1.1. Development of argument skills

According to Walton (1989), skilled argumentation has two goals. One is to secure commitments from the opponent that can be used to support one's own argument. The other is to undermine the opponent's position by identifying and challenging weaknesses in his or her argument. Note that both goals require attention to the opponent's claims. Previous cross-sectional research showed that there were developmental differences between adolescents' and adults' dialogic argumentation skills in respect to Walton's goals of skilled argumentation. Adolescents and adults differed in their focus during argumentation and on the argumentation strategies that they employed. Adolescents focused on exposition of their own position and used relatively weak argumentive strategies, whereas adults focused on the other's position, trying to weaken it using powerful argumentive strategies (Felton & Kuhn, 2001).

A series of experimental studies, over the last 15 years, has shown that dense engagement in dialogic argumentive discussions supports the development of argument skills of adolescents towards the direction of adults' argument skills (Iordanou, 2010, 2013; Kuhn, Goh, Iordanou, & Shaenfield, 2008; Crowell & Kuhn, 2014; Felton, 2004; Felton & Kuhn, 2001; Kuhn et al., 2013; Mason, 1998; Reznitskaya, Anderson, & Kuo, 2007). Advancements have been observed both in individuals' written arguments, namely individual argument skills, and the strategies they employed when engaged in a dialogue with individuals holding opposing position, namely dialogic argumentation skills (Kuhn, 2001). In particular, Kuhn, Shaw and Felton (1997) showed the effectiveness of engagement in dyadic discussion on the development of argumentation skills. In their study, young adolescents and adults participated in five weekly dyadic discussions on a social topic with different classmates, while another group of participants received initial and final assessment at the same time interval as experimental condition but did not participate in dyadic discussion. Results showed that participants who engaged in dyadic discussions progressed from 1-sided to 2-sided arguments, showing a shift in their attention from one's own position to the other's position. In contrast, control condition participants did not show any progress in argumentation skills.

Felton and Kuhn (2001) examined whether arguing in the context of an agreeing dyad as opposed to a disagreeing dyad would influence the development of argumentation skills. Young adolescents and young adults were assigned to agreeing or