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Scientific reasoning, conceptual knowledge, & achievement differences between prospective science teachers having a consistent misconception and those having a scientific conception in an argumentation-based guided inquiry course

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ABSTRACT

This study examined scientific reasoning, conceptual knowledge, and achievement differences between prospective science teachers who had a consistent misconception and those who had a scientific conception in an argumentation-based guided inquiry physics course. Results showed that there were scientific reasoning, situational knowledge and achievement differences between the two groups at the beginning of instruction. However instruction helped these groups reduce the situational knowledge and achievement gaps. On the other hand, scientific reasoning gap still existed after the instruction. Both groups developed their scientific reasoning, declarative knowledge, and situational knowledge during the course. In light of these results, the author recommends that research can use a categorization, which is having a consistent misconception or scientific conception, to examine the effect of instruction by comparing learning gains of these two groups. In addition the author recommends that argumentation-based guided inquiry approaches should be incorporated into science curriculum in early education years.

1. Introduction

Inquiry-based learning environments have been favored to traditional learning environments in that students are supposed to be their own learning agents in these contexts. Ideally, students in inquiry-based learning environments should be fostered to reason between alternatives, explain the phenomena, and consequently construct their learning (Kuhn, 1993; Lawson, 2003). However studies show that student argumentation, which is a process of evidence-based reasoning between alternative theories, is not sufficient in inquiry learning environments (Kelly, Druker, & Chen, 1998; Watson, Swain, & McRobbie, 2004). To improve student poor argumentation, previous studies on argumentation provided argumentation-based instructional contexts. Encouraging results were obtained with regard to enhancement of argumentation and conceptual understanding (Osborne, Erduran, & Simon, 2004; Zohar & Nemet, 2002).

As the most important hypothesis that can be drawn from inquiry approach is students learn better because they can construct their own learning, studies tested this assumption by mostly comparing low and high achievers' performance in control and experimental groups that received traditional and inquiry teaching respectively (Akkus, Gunel, & Hand, 2007; Geier et al., 2008; Huppert, Lomask, & Lazarowitz, 2002; Lewis & Lewis, 2008; Liao & She, 2009; Wilson, Taylor, Kowalski, & Carlson, 2010). Results of these studies showed that learning gains of students go higher levels in inquiry classes compared to traditional classes (Akkus et al., 2007; Geier et al., 2008; Huppert et al., 2002; Lewis & Lewis, 2008; Liao & She, 2009). In addition they found race (Wilson et al., 2010), gender (Geier et al., 2008) and conceptual knowledge gap (Akkus et al., 2007) can be closed in inquiry learning contexts. However the results are elusive in obtaining the equity among low and high Scholastic Aptitude Test (SAT) scorers (Lewis & Lewis, 2008) and different scientific reasoners (Liao & She, 2009).

In the case of argumentation-based inquiry contexts, several studies tested the effect of argumentation instruction by comparing learning gains of students in traditional instruction and argumentation-based inquiry instruction (Osborne et al., 2004; Zohar & Nemet, 2002). These studies found encouraging results regarding student argumentation and conceptual knowledge in favor of argumentation instruction. On the other hand, only a study by Zohar and Dori (2003) compared learning gains of low and high achievers receiving argumentation-based inquiry instruction. Although results of this study indicated both high and low achievers had significant reasoning gains after the instruction, no consistent result was found for the closure of the reasoning gap between these groups.

Reviewed literature shows comparison of learning gains of students with different achievement levels is new to argumentation research. In addition, although efforts were undertaken to incorporate argumentation

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to inquiry courses in college level (e.g., Zembal-Saul, Munford, Crawford, Friedrichsen, & Land, 2002), paucity of study exists in this context which explored the effect of argumentation intervention on student learning gains (e.g., Kaya, 2013; Nussbaum & Sinatra, 2003). Exploring the effect of argumentation on students' learning gains is more important especially in prospective science teacher education programs because research draws attention to equipping teachers with argumentation in their early education careers (Osborne, Simon, Christodoulou, Howell-Richardson, & Richardson, 2013; Simon, Erduran, & Osborne, 2006; Zohar & Schwartzer, 2005). The present study aimed to examine learning gains of low and high achieving prospective science teachers in an argumentation-based guided inquiry course.

2. Literature review

2.1. Achievement gap in inquiry and argumentation instruction

Studies which focused on the comparison of student learning in middle school science inquiry-based and common place teaching pointed out a success of students, who were taught in inquiry-based contexts, across a range of learning gains (Geier et al., 2008; Wilson et al., 2010). In addition studies demonstrated that achievement gap between races (Johnson, 2009; Wilson et al., 2010) and genders (Geier et al., 2008) lessened after receiving inquiry instruction. However for college level, only one study found in the literature which aimed to examine the effectiveness of inquiry-based teaching over traditional instruction. Undergraduate students enrolled to a chemistry class were either taught using a traditional or a peer led guided inquiry instruction in this study (Lewis & Lewis, 2008). SAT scores were used to identify students with different achievement levels. Results indicated that students in inquiry outperformed students in traditional learning on a final exam. In addition, analyses showed final exam scores of students in inquiry were still significantly dependent on student SAT scores indicating inequity between low and high achievers after the instruction.

Studies focused on argumentation, on the other hand, compared learning gains of students in argumentation-based instruction and students in common place instruction. Findings of these studies stated student argumentation and conceptual knowledge better developed in argumentation-based instructional contexts (Osborne et al., 2004; Zohar & Nemet, 2002). Only a study by Zohar and Dori (2003) found in the literature which analyzed learning gains of students from diverse achievement levels in an argumentation-based inquiry instruction. This study reported the results of data obtained from four different studies. Results of these studies indicated that students who received argumentation instruction outperformed their peers who received traditional instruction with regard to reasoning skills. Furthermore both low and high achievers gained from argumentation instruction regarding reasoning skills.

It is clear that paucity of study exists in argumentation which focused on comparison of student learning gains from different achievement levels. Furthermore, although argumentation-based instructional contexts were provided to prospective science teachers, neither experimental design nor examination of students with different achievement levels was utilized in these studies (e.g., Acar, 2008; Zembal-Saul et al., 2002). Thus we have no clue about the effectiveness of argumentation-based instruction with this population group. Examination of this research population is necessary because equipment of teachers with argumentation skills in their education years is essential for their pedagogic performance in actual practice (Osborne et al., 2013; Simon et al., 2006; Zohar & Schwartzer, 2005).

2.2. Scientific reasoning, conceptual knowledge, achievement and misconceptions

Since inquiry learning has been viewed as student exploration and discovery of scientific concepts using scientific methodology, it has been assumed that student scientific reasoning should develop in these settings (Daempfle, 2006). Two research lines that differed on their view of what constitutes of scientific reasoning examined if scientific reasoning can be enhanced through inquiry instruction.

The first research line viewed scientific reasoning as a process involved in the construction of evidence based arguments. Within this research tradition, by arguing between different alternative positions namely argumentation, development of conceptual knowledge and reasoning skills is possible (Kuhn, 1993; Kuhn, Schauble, & Garcia-Mila, 1992). Curriculum materials and instruction have been designed in a way to promote student argumentation in this research. Results showed that student argumentation and conceptual knowledge may be enhanced in argumentation-based inquiry science classrooms (Acar, 2008; Martin & Hand, 2009; Osborne et al., 2004; Zohar & Nemet, 2002).

The second line of research viewed scientific reasoning as constituting of reasoning skills that are content independent but dependent on developmental stages. That is to say, according to this approach to scientific reasoning, one's performance of scientific reasoning skills in a domain, e.g., control of variables, proportional reasoning, combinatorial reasoning, hypothetical reasoning, does not depend on domain specific content knowledge but depends on his developmental stage. Results of these studies showed that students' misconception level (Lawson & Weser, 1990; Lawson & Worsnop, 1992), their conceptual knowledge (Ates & Cataloglu, 2007; Coletta & Philips, 2005) and achievement (Johnson & Lawson, 1998) in a science course can be predicted by their scientific reasoning ability. That is to say, these studies found high scientific reasoners had fewer misconceptions and gained higher conceptual knowledge, and achievement. Finally, they found student scientific reasoning skills can be enhanced through inquiry-based instruction (Johnson & Lawson, 1998; Liao & She, 2009).

Although these two research lines show reasoning skills are an important factor in explaining student learning, no special attention was given to compare gains of students with different pre-instructional reasoning abilities in inquiry-based instructions. In the literature, different criteria were used to group students to low and high achievers. Specifically, Akkus et al. (2007) used student scores on a baseline science test, Lewis and Lewis (2008) used SAT scores and Zohar and Peled (2008) used student past academic achievement. In addition, Geier et al. (2008) and Johnson (2009) examined the gender and race achievement gap respectively.

If reasoning ability is a good predictor of a student's achievement in an inquiry science course (Johnson & Lawson, 1998), then an inquiry instruction that aims to enhance reasoning skills should take into account students' pre-instructional reasoning abilities. A study by Zohar and Dori (2003) investigated gains of low and high achievers in response to an inquiry instruction in which critical thinking and argumentation were incorporated. However authors categorized students based on their general academic achievement rather than their reasoning skills before instruction.

Based upon the findings of the literature (i.e., Lawson & Weser, 1990; Lawson & Worsnop, 1992), it is hypothesized in this research that students with a consistent misconception would have low level of scientific reasoning and vice versa. Furthermore it is hypothesized that students with high scientific reasoning would also have high achievement (e.g., Johnson & Lawson, 1998). If these hypotheses are demonstrated then if an argumentation-based inquiry course would help to close the gap between students who have a consistent misconception and students who have a scientific conception can be investigated. To examine these hypotheses, following research questions were sought:

1. What are the scientific reasoning, conceptual knowledge and achievement characteristics and differences between prospective science teachers having a misconception and prospective science teachers having a scientific conception before an argumentation-based guided inquiry course?