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Examination of Science Learning Equity through Argumentation and Traditional Instruction noting differences in socio-economic status

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ABSTRACT: This study compared student scientific reasoning and conceptual knowledge in argumentation-based and traditional instruction, taught in school regions with low and high socio-economic status (SES) respectively. Furthermore, concrete and formal reasoning students' scientific reasoning and conceptual knowledge were compared during both instructions for the examination of science learning equity between student groups. The study sample constituted 26 8th grade students from two schools in a low SES region and 31 8th grade students from a school in a high SES region. The duration of instruction was four months. Students' scientific reasoning and conceptual knowledge were assessed before and after each instruction. According to the results, students who received argumentation-based instruction developed their scientific reasoning following instruction, but students who received traditional instruction did not. In addition, the conceptual knowledge and scientific reasoning gaps between formal and concrete reasoning students, who received argumentation-based instruction, closed, whereas pre-instructional gaps among formal and concrete reasoning students still existed at the end of traditional instruction. Implications from the findings were discussed.

KEY WORDS: argumentation, equity, socio-economic status, scientific reasoning, achievement gap, conceptual knowledge

INTRODUCTION

The argumentation approach to teaching science has gained momentum in recent years (Jimenez-Aleixandre & Erduran, 2007). It can be thought of as a constructivist teaching method, because student discussion and reasoning are at the core of this form of instruction. From a broader perspective, argumentation can be viewed as evidence-based scientific reasoning. More specifically, it can be taken to be a process of reasoning between alternative viewpoints based on data. On the other hand, argument refers to a template by which an individual can support a theoretical position logically. Although students can be expected to explain phenomena using data and

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reasoning between different alternatives in inquiry learning environments, studies have shown that students have problems with constructing evidence-based arguments (Kelly, Druker, & Chen, 1998; Watson, Swain, & McRobbie, 2004) and reasoning between alternatives (Kuhn, Schauble, & Garcia-Mila, 1992) in inquiry settings.

Several strategies have been used to foster students' argument and argumentation in science education. For example, computer (Sandoval & Milwood, 2005; Zembal-Saul, Munford, Crawford, Friedrichsen, & Land, 2002) and written scaffolds (McNeill, Lizotte, & Krajcik, 2006) have been provided to improve the construction of the students' arguments. Furthermore, components of an argument have been taught and explicated to students (Osborne, Erduran, & Simon, 2004a).

On the other hand, students have been provided with instructional contexts to enhance their argumentation, where they were required to argue between alternative theories, based on data (Acar, 2008; Bell & Linn, 2000; Osborne et al., 2004a). Additionally, small group discussion and writing for thinking have been utilized (Akkus, Gunel, & Hand, 2007; Günel, Memiş, & Büyükkasap, 2010). Overall results of these studies have implied that student argument and argumentation could be enhanced in argumentation-based instructional contexts (Acar, 2008; Akkus et al., 2007; McNeill et al., 2006; Sandoval & Milwood, 2005).

Although achieving equity in science classrooms has become a concern among policy makers and organizations (Milli Eğitim Bakanlığı [MEB], 2013; The Organisation for Economic Co-operation and Development [OECD], 2013), a paucity of study exists within the argumentation literature which focus on this issue. Mostly studies examine the effect of inquiry-based learning environments by comparing High Achieving Students (HAS) and Low Achieving Students (LAS) across a variety of learning goals (Akkus et al., 2007; Dogru-Atay & Tekkaya, 2008; Geier et al., 2008; Huppert, Lomask, & Lazarowitz, 2002; Lewis & Lewis, 2008; Wilson, Taylor, Kowalski, & Carlson, 2010). Results of these studies consistently show that students in inquiry learning environments outperform their peers in traditional learning environments. In addition, several studies show that pre-instructional learning gaps regarding race and gender tend to close in inquiry learning environments (Geier et al., 2008; Wilson et al., 2010). However, other studies point out that learning gaps between LAS and HAS do not close, even after inquiry instruction (Huppert et al., 2002; Lewis & Lewis, 2008; Liao & She, 2009). Only a study by Zohar and Dori (2003) compares reasoning of LAS and HAS in an argumentation-based inquiry instruction. The authors categorize students' achievement levels based on their previous science academic achievement and show that both LAS and HAS improve their reasoning through the instruction. However no consistent results indicate narrowing of the reasoning gap between these groups.

Although studies focusing on an achievement gap between LAS and HAS carry out research on learning in control and experimental groups, they do not pay much attention to the characteristics of the school environment at the sampling process. This issue becomes more important in terms of students' Socio-Economic Status (SES), because it is documented that students' SES explains a considerable variance in student science success in most developing countries (OECD, 2013).

The present study aims to compare learning of two groups of students: one which receives argumentation-based inquiry instruction in school regions having low SES and the other which receives traditional instruction in school regions having high SES. The following research questions are examined in this study:

Research Question 1: How do students' scientific reasoning and conceptual knowledge compare during argumentation-based instruction, taught in a school located in a region with low SES, with traditional instruction taught in a school located in a region with high SES?

Research Question 2: How do concrete and formal reasoning students' scientific reasoning and conceptual knowledge compare during argumentation-based instruction, taught in schools, located in a region with low SES and traditional instruction taught in a school located in a region with high SES?

LITERATURE REVIEW

Argument and Argumentation

Argumentation theory emerged from a need to define arguments in everyday life situations, where conclusions could not be drawn analytically from premises as opposed to logical arguments (van Eemeren et al., 1996). A leading figure of this philosophy, Toulmin (1958), proposed an argument framework that could be used in science as well as in other disciplines (Toulmin, Rieke, & Janik, 1984). According to his framework, mostly known as Toulmin's argumentation pattern (or TAP in an abbreviated format), a simple argument consists of data, grounds and claims. Specifically, data are the observations or evidence that can be used to support a conclusion in an argument. Grounds are the reasoning statements that connect the data to conclusions. Finally, a claim is a conclusion in an argument to support a position. Also, according to Toulmin (1958), in more complex arguments, rebuttals and qualifiers can be used. A rebuttal specifies the conditions where a claim cannot be true and a qualifier specifies the conditions where a claim is true.

Although argument and argumentation have been used reciprocally, having similar meaning in the literature, each term referred to different constructs. Thus, argument was a product of a position statement about an issue. On the other hand, argumentation was a process of reasoning between different alternative positions (Kuhn &Udell, 2003). Studies stated that students had problems when referring to insufficient data and rarely using warrants in their arguments (Kelly et al., 1998; Watson et al., 2004). Furthermore, studies also pointed out that students used pseudo-evidence, ignored data, made wrong inclusion and excluded data when they reasoned between different alternative theories or positions (Fleming, 1986; Kuhn, 1993; Kuhn et al., 1992; Zeidler, 1997).

Teaching Strategies to Foster Argumentation

Several teaching strategies were employed to foster student argumentation in the literature. Science Writing Heuristics (SWE) was one such strategy, suitable for guided laboratory experiments. Students were encouraged to write reflectively in this strategy. Thus, students were provided with a writing template which provided scaffolding to construct a hypothesis, observe data, reach a conclusion, support their conclusion and compare their conclusion with their peers. The effectiveness of this strategy on student conceptual knowledge and achievement has been documented in the literature (Günel et al., 2010; Kıngır, 2011). A Competing Theories Strategy (CTS), utilizing several alternative positions about a scientific phenomenon and relevant data, were provided to students to stimulate discussion (Bell & Linn, 2000; Osborne et al., 2004a). Results of the studies implied that CTS was an effective method to foster student argumentation (e.g., Acar, 2008; Osborne et al., 2004a). Similar to CTS, several alternative positions about a scientific phenomenon were provided to students by means of concept cartoons (Balım, İnel, & Evrekli, 2008; Keogh & Naylor, 1999; Osborne, Erduran, & Simon, 2004b). It was found that concept cartoons were effective in improving student inquiry learning skills perceptions (Balım et al., 2008) and their motivation and engagement (Keogh & Naylor, 1999) in science classes.

In another strategy, named Predict-Observe-Explain (POE), students went through several stages to implement an investigation about a scientific issue. In the first stage, students discussed and stated their prediction about what would happen. In the second stage, students undertook an experiment related to the issue and recorded their findings. In the final stage, students discussed the interplay between what they observed and what they predicted and wrote an explanation for this. For the most part, POE was not used solely to foster student argumentation but used with other argumentation teaching strategies (Osborne et al., 2004b; Peker, Apaydın, & Taş, 2012).

Achievement Gap and Scientific Reasoning

The science achievement gap among various student groups has been a concern in science education (OECD, 2013). As constructivist approaches in education have emphasized student active engagement and inquiry, researchers and policy makers had hoped that LAS would also benefit from class environments which have been designed according to these approaches. Consequently the achievement gap between LAS and HAS would be reduced or closed.

To examine the achievement gap in inquiry learning environments, researchers used several criteria to categorize students into different achievement groups. For instance, Zohar and Peled (2008) grouped students based on their previous science academic achievement. Akkus et al. (2007) categorized students under their scores on a baseline science test, while Lewis and Lewis (2008) grouped students based on their scores on a Scholastic Aptitude Test (SAT). In other studies, the achievement gap between different races and genders was investigated (Dogru-Atay & Tekkaya, 2008; Geier et al., 2008; Johnson, 2009; Wilson et al., 2010) and, moreover, scientific reasoning ability was used to categorize students (Ates & Cataloglu, 2007; Liao & She, 2009). After implementation of inquiry teaching, Akkus et al. (2007) found that the learning gap between LAS and HAS narrowed. In addition, studies found that race and gender achievement gaps narrowed during inquiry teaching (Geier et al., 2008; Huppert et al., 2002; Johnson, 2009; Wilson et al., 2010). However study outcomes related to the narrowing of achievement gaps between students with different SAT scores and scientific reasoning were discouraging (Lewis & Lewis, 2008; Liao & She, 2009).

A paucity of studies examined learning gains of students with different achievement levels in an argumentation-based instruction. Only a study by Zohar and Dori (2003) investigated learning gains of both LAS and HAS. Students were grouped under LAS and HAS, according to their previous science academic achievement and the study was part of an overall report of four studies conducted previously. In two of these studies, a one group pre-and post-test design was employed while in the other two studies, a quasi-experimental design was utilized to compare experimental and control groups, which received argumentation and traditional instruction respectively. Results of these studies indicated that students in argumentation-based science classrooms outperformed their peers in traditional science classes. However, no consistent result was observed for the narrowing of achievement gaps between LAS and HAS in argumentation-based instruction.

Although argumentation and scientific reasoning have been examined separately in the literature, both constructs have similar processes. For instance, students reasoned between alternatives during argumentation. This higher order reasoning, named as hypothetico-deductive, was one of the most important components of scientific reasoning, in a study by Kwon and Lawson (2000). Despite this explicit connection between argumentation and scientific reasoning, no research examined the relation of argumentation-based instruction with students' scientific reasoning. In fact, scientific reasoning has been viewed as an important variable for prediction of students' overall achievement in science, because studies documented its significant relation with conceptual knowledge (Coletta & Phillips, 2005; Lawson & Weser, 1990; Lawson & Worsnop, 1992) and science academic achievement (Ates & Cataloglu, 2007; Johnson & Lawson, 1998). In addition, although Schen (2007) found a significant relation between student argumentation skills and their scientific reasoning, no research took the initiative to compare learning gains of students having different scientific reasoning levels in an argumentation-based instructional context. The present study aimed to address these gaps.

METHOD

Research Context and Sample

This study took place in the spring semester, i.e., four months, in an industrial city located in Turkey. For examination of equity between different school environments, the SES for the region in which the school was situated was considered. To gain acceptance to a middle school in Turkey, students are required to meet one of two criteria: either a student's residence should be in that school region, or one of the student's parents should work within the region.

Two schools in a suburban area were selected as representative of schools in low SES regions. Families in this area were mostly emigrants from other cities and had low SES. Another school in an urban area was selected as representative of a school in high SES regions. Families in this area had, for the most part, high SES. The performance of students in these schools on a nation-wide exam, which was used to place students in high schools, supported the accuracy of the sampling process with regard to SES. These performances were: 8th grade students' mean score in the school located in high SES region was 328.59. On the other hand, the 8th grade students' mean scores in the schools located in low SES region on the same exam were 318.26 and 284.19 respectively.

26 eighth grade students from schools located in low SES region and 31 eighth grade students from the school located in high SES region participated in this study. Each former and latter student groups were derived from two science classes. Two science teachers taught former student group and a science teacher taught the latter. Teachers of students from schools located in low SES region were informed about how to teach

argumentation-based lessons before the students undertook each argumentation activity.

Rather than categorizing students based on their science achievement, students were categorized on their scientific reasoning levels in the present study. The reason for this suggestion derives from the findings in the science education literature. Studies demonstrate that scientific reasoning is an important variable in science education which predicts student conceptual knowledge (Coletta & Phillips, 2005; Lawson & Weser, 1990; Lawson & Worsnop, 1992), achievement (Johnson & Lawson, 1998; Lawson, Banks, & Logvin, 2007), and problem solving skills (Ates & Cataloglu, 2007).

To categorize students based on their pretest scientific reasoning scores, cut levels of scientific reasoning scores, based on a study by Gerber, Cavallo, and Marek (2001), were used. More specifically, Gerber et al. (2001) examined scientific reasoning of 7th, 8th, 9th and 10th graders and found scientific reasoning mean scores for these student groups were between 3.38 and 5.55, with the standard deviation around 2.5. According to these statistics, it was decided (recognizing a reasonable balance in numbers) that students who scored between 0 and 1 could be grouped into a concrete reasoning group and students who scored between 2 and 6 could be grouped as formal reasoning. This suggested that a student should score above 6 to be put into a post-formal reasoning group, but no student attained this. Based on these criteria, there were 13 formal and 13 concrete students in argumentation-based learning environment and 11 concrete and 20 formal students in traditional learning environment.

Instruction

Students in argumentation-based learning environment received six argumentation lessons on the topics of sound, electricity, heat, and seasons. The Competing Theories Strategy was used to develop three argumentation tasks about how sound travels in a medium, how seasons are formed, and the relation between heat and temperature. Relevant data on two alternative theories about each issue were provided to students. Students were required to construct their arguments, counter-arguments and rebuttals. Thus, for instance, two hypothetical students were provided supporting alternative explanations for the formation of seasons. One explanation claimed that different seasons occur as the distance between the Earth and the Sun changes, because of the Earth’s rotation around the Sun. The other claimed that the slope of the Earth’s orbit causes seasons. A third hypothetical student was included as providing evidence about this discussion (e.g., movement of the Earth in an elliptical orbit around the Sun; higher temperature of the regions at the equator throughout the year than other regions). Following the scenario, prompting questions were indicated on a student worksheet, which also asked students to construct their argument, counter-arguments, and rebuttals about the controversy.

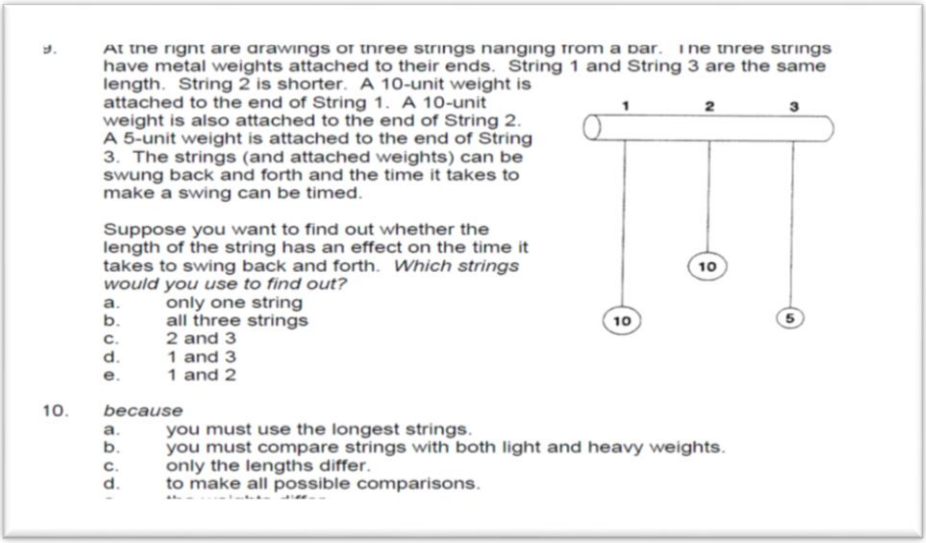
A blend of SWH and POE strategies was used to develop three argumentation tasks on factors affecting the attraction strength of an electro-magnet and the relation between electricity and heat energy. For instance, students made a class discussion about which factors affect the temperature of water in which a wire was placed that is connected to a power supply. Then students were divided into small groups to test each variable that they predicted would make an effect. Students were given a worksheet containing prompting questions. More clearly, questions encouraged students to state the dependent, independent and controlling variables, water temperature at the beginning and fifteen minutes later for two different values of the independent variable, and the relation of water temperature to the electrical energy supplied. Students answered these questions individually after they finished the activity.

Students in the traditional learning environment were taught the same topics without any intervention. Although the Ministry of Education in Turkey emphasized the importance of using student centered instructional approaches (MEB, 2006), most teachers still maintained teacher centered approaches, because of the pressure of raising their classroom average score on the nation-wide exam that was used to place students in high schools. Since these students' families mostly had high SES, they had higher expectations about their children success on this exam. Consequently, the pressure to increase student achievement on this nation-wide exam was felt more by teachers and administrators of this school. Thus the teacher of these students mostly instructed and rarely gave opportunities for students to undertake student centered activities.

Instruments

Scientific reasoning test

This test was originally developed by Lawson (1978). In its original form, there were questions about conservation of mass, control of variables, proportional reasoning, correlational reasoning, and probabilistic reasoning. Questions related to hypothetical reasoning were included in a modified version (Lawson, 2000). A total of 12 two tier multiple choice items were included in this version. Each tier had content and a reasoning question. The content question was about a reasoning skill in a specific context and the reasoning question was about the justification of the content question (see a two-tier test example in Figure 1). This version of the test was translated into Turkish by the author, and an expert from the 'Teaching English as a Second Language' department edited any vague statements in this translation. A student response was coded as 1 if he/she answered each tier correct and 0 for any other circumstance. Cronbach alpha estimate of the internal consistency was found to be 0.70 (*n* = 73) for the posttest.



9. At the right are drawings of three strings hanging from a bar. The three strings have metal weights attached to their ends. String 1 and String 3 are the same length. String 2 is shorter. A 10-unit weight is attached to the end of String 1. A 10-unit weight is also attached to the end of String 2. A 5-unit weight is attached to the end of String 3. The strings (and attached weights) can be swung back and forth and the time it takes to make a swing can be timed.

Suppose you want to find out whether the length of the string has an effect on the time it takes to swing back and forth. *Which strings would you use to find out?*

a. only one string
b. all three strings
c. 2 and 3
d. 1 and 3
e. 1 and 2

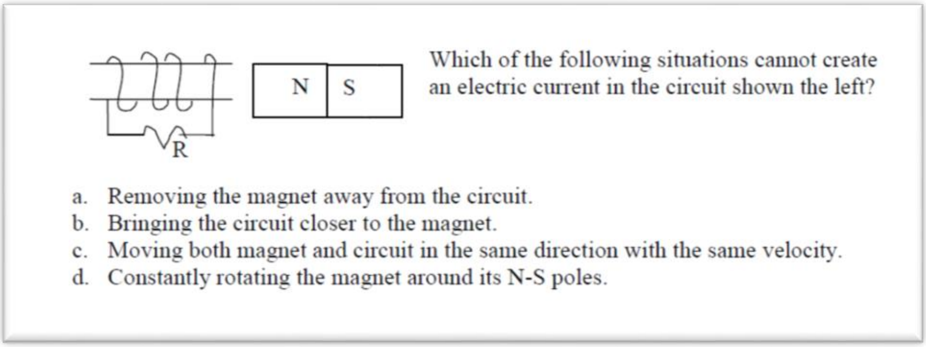
10. *because*

a. you must use the longest strings.
b. you must compare strings with both light and heavy weights.
c. only the lengths differ.
d. to make all possible comparisons.

Figure 1. A sample two-tier item.

Conceptual knowledge test

This 17 multiple choice item test was used to assess 8th graders conceptual knowledge about sound, heat and temperature, states of matter and heat, electricity in our life, and natural processes. Several items were selected from different student study books, while others were constructed by the researcher. An English translation of a sample item can be seen in Figure 2.



Which of the following situations cannot create an electric current in the circuit shown the left?

a. Removing the magnet away from the circuit.
b. Bringing the circuit closer to the magnet.
c. Moving both magnet and circuit in the same direction with the same velocity.
d. Constantly rotating the magnet around its N-S poles.

Figure 2. A sample conceptual knowledge item.

The science teachers participating in this study examined the test for content validity before the study took place. Student responses were coded as 1 if they answered an item correctly; otherwise they were coded as 0. Posttest administration of the test yielded a Cronbach alpha of 0.83 (n = 81).

Since previous research showed that student scientific reasoning predicted their conceptual knowledge, significant correlation was expected between these measures. As shown in Table 1, students' scientific reasoning pretest scores had a significant correlation with their conceptual knowledge pretest scores and scientific reasoning posttest scores had a significant correlation with conceptual knowledge posttest scores.

Table 1 Correlation Table of Conceptual Knowledge and Scientific Reasoning Scores

	1	2	3	4
Conceptual Knowledge Pretest (1)		.41*	.51*	.17
Conceptual Knowledge Posttest (2)			.54*	.65*
Scientific Reasoning Pretest (3)				.46*
Scientific Reasoning Posttest (4)				

n = 57, * p< .005.

RESULTS

Comparison of Scientific Reasoning in Traditional and Argumentation-Based Instruction

Descriptive Statistics of pretest and posttest scientific reasoning scores are shown in Table 2. Multivariate Analysis of Variance (MANOVA) was used to examine if there was a significant scientific reasoning difference between students in traditional instruction (SITI) and students in argumentation-based instruction (SIABI). In this analysis, student group type, i.e. SITI and SIABI, was the independent variable and pretest and posttest scientific reasoning scores were the dependent variables. According to MANOVA results, there was no significant difference between SITI and SIABI (*Wilks'* λ was utilized, $F_{(2, 54)} = 2.67$, $p = .08$). A follow-up Analysis of Variance (ANOVA) confirmed this result for the pretest and posttest ($F_{(1, 55)} = 2.18$, $p = .15$; $F_{(1, 55)} = .72$, $p = .40$ respectively).

Table 2 Descriptive Statistics of Scientific Reasoning Pretest and Posttest Scores

	Pretest		Posttest	
	M	*SD*	*M*	*SD*
SITI*	2.45	1.95	2.19	2.04
SIABI**	1.77	1.45	2.62	1.65

* *n* = 31, ** *n* = 26.

Comparison of Conceptual Knowledge in Traditional and Argumentation-Based Instruction

The mean and standard deviation of the pretest and posttest scores of SITI and SIABI are shown in Table 3 and seemed to indicate a difference between these student groups on the pretest. However this difference seemed to have narrowed on the posttest. To test if the pretest difference was significant, MANOVA was performed on conceptual knowledge pretest and posttest scores. No significant difference between student groups on the set of dependent variables was found (*Wilks' λ* was utilized, $F_{(2, 54)} = 2.08$, $p = .14$). Follow-up ANOVA results also confirmed this result for pretest and posttest ($F_{(1, 55)} = 3.33$, $p = .07$; $F_{(1, 55)} = .01$, $p = .93$ respectively).

Table 3 Descriptive Statistics of Conceptual Knowledge Pretest and Posttest Scores

	Pretest		Posttest	
	M	*SD*	*M*	*SD*
SITI*	7.45	2.43	10.48	4.71
SIABI**	6.35	2.08	10.58	3.37

* *n* = 31, ** *n* = 26.

Scientific Reasoning and Conceptual Knowledge Gains

Pair-wise *t* tests were performed to examine if scientific reasoning and conceptual knowledge scores of SITI and SIABI developed during the instruction. According to *t* test results on scientific reasoning, SIABI raised their scientific reasoning scores from pretest to the posttest ($t = 2.26$, $p = .03$), whereas no significant change was noted for SITI ($t = -.82$, $p = .42$). On the other hand, other *t* test results for conceptual knowledge revealed that both SITI and SIABI enhanced their conceptual knowledge scores from pretest to posttest ($t = 4.10$, p = .00; $t = 6.42$, p = .00 respectively).

Comparison of Concrete and Formal Reasoning SITI and SIABI

Descriptive statistics related to formal and concrete reasoning SITI and SIABI on scientific reasoning and conceptual knowledge are shown in Table 4. Two separate MANOVA's were performed to compare concrete and formal reasoning SITI on pretest and posttest scientific reasoning and conceptual knowledge scores. According to the result of the first MANOVA, the concrete and formal reasoning groups indicated significant mean differences across pretest and posttest scientific reasoning scores *(Wilks' λ* was utilized, $F_{(2, 28)} = 26.55$, $p = .00$). In fact, the results of the follow-up ANOVA's showed formal reasoning group outperformed concrete reasoning group on both the scientific reasoning pretest and posttest ($F_{(1, 29)} = 54.79$, $p = .00$; $F_{(1, 29)} = 8.44$, $p = .01$ respectively). The result of the second MANOVA demonstrated that both reasoning groups differed on the set of conceptual knowledge measures (*Wilks' λ* was utilized, $F_{(2, 28)} = 4.84$, $p = .02$). In addition, follow-up ANOVA results showed that the formal reasoning group scored higher than the concrete reasoning group on both conceptual knowledge pretest and posttest ($F_{(1, 29)} = 4.46$, $p = .04$; $F_{(1, 29)} = 8.91$, $p = .01$ respectively).

Table 4 Scientific Reasoning and Conceptual Knowledge Scores of Concrete and Formal Reasoning SITI and SIABI

	SITI				SIABI			
	Concrete ^{a}		Formal ^{b}		Concrete ^{c}		Formal ^{d}	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
S. R. Pretest	.36	.50	3.60	1.39	.62	.51	2.92	1.12
S. R. Posttest	.91	1.14	2.90	2.10	2.54	1.85	2.69	1.49
C. K. Pretest	6.27	2.72	8.10	2.05	5.31	1.55	7.38	2.06
C. K. Posttest	7.45	4.46	12.15	4.04	9.62	3.40	11.54	3.18

Key. S.R. = Scientific Reasoning and C.K. = conceptual knowledge. $^a n = 11$, $^b n = 20$, $^c n = 13$, $^d n = 13$.

Two additional MANOVA studies were performed on dependent variables to examine any difference between concrete and formal reasoning SIABI. The result of the first MANOVA study pointed out that reasoning type made a significant difference on scientific reasoning measures (*Wilks' λ* was utilized, $F_{(2, 23)} = 24.70$, $p = .00$). Although the results of the follow-up ANOVA's showed that the formal reasoning group scored higher than the concrete reasoning group on the scientific reasoning pretest ($F_{(1, 24)} = 46.15$, $p = .00$), this significant difference disappeared on the posttest ($F_{(1, 24)} = .05$, $p = .82$). On the other hand, results of the second MANOVA showed the reasoning groups differed on the set of conceptual knowledge measures (*Wilks' λ* was utilized, $F_{(2, 23)} = 4.45$, $p = .02$). Similar to the results for scientific reasoning, finding of a follow-up ANOVA displayed that formal reasoning groups outperformed concrete reasoning groups on the conceptual knowledge pretest ($F_{(1, 24)} = 8.43$, $p = .01$). However other ANOVA result showed that this difference between reasoning groups was narrowed on the posttest ($F_{(1, 24)} = 2.22$, $p = .15$).

DISCUSSION

The aim of this study was to investigate science learning equity among different science reasoning ability groups in different SES school regions. For this purpose, we compared student conceptual knowledge and scientific reasoning during an argumentation-based instruction taught in a school environment having low SES and a traditional instruction taught in another school environment having high SES. Furthermore, the scientific reasoning and conceptual knowledge of concrete and formal reasoning groups were investigated during both instructions. Results showed no statistical difference between SITI and SIABI on their conceptual knowledge and scientific reasoning pretest and posttest scores. However, whereas SIABI enhanced their scientific reasoning scores, the scientific reasoning of SITI did not change. Nevertheless, it was found that both SITI and SIABI enhanced their conceptual knowledge during instruction. Results also demonstrated that both conceptual knowledge and scientific reasoning gaps between concrete and formal reasoning groups closed in argumentation-based learning environment. However, gaps between reasoning groups continued to exist in traditional instruction.

Taken together, these results imply that argumentation-based instruction, used in this study, was helpful in enhancing students' scientific reasoning and closing conceptual knowledge and scientific reasoning gaps between concrete and formal reasoning groups. On the other hand, neither scientific reasoning nor conceptual knowledge gaps between reasoning groups closed, neither did students develop their scientific reasoning in traditional instruction.

Achieving equity in science classrooms is one of the major problems of science education research. Several studies documented that inquiry instruction can help to close the achievement gap between different student groups (Akkus et al., 2007; Geier et al., 2008; Wilson et al., 2010). In addition, inquiry teaching was found effective for developing student scientific reasoning (Johnson & Lawson, 1998; Liao & She, 2009). In the present study, in addition to development of scientific reasoning of SIABI, the closure of scientific reasoning and conceptual knowledge gaps between concrete and formal reasoning groups occurred. This is not indicated in the scientific reasoning literature. This finding is also noteworthy in that only a study by Zohar and Dori (2003) compared low and high achievers' reasoning scores in an argumentation-based instruction and found that both groups enhanced their reasoning scores. However, the authors did not find a consistent result for the closure of reasoning gaps between these groups. The results of the present study are encouraging for the closure of learning gaps between different science reasoning ability student groups. Furthermore no statistical posttest differences of scientific reasoning and conceptual knowledge were found between SITI and SIABI. This result is also encouraging for achieving science learning equity among school environments with different SES.

There are two issues related to the study results that need to be interpreted. The first is related to the result of no statistical difference for pretest conceptual knowledge and scientific reasoning between SITI and SIABI. The other is related to the scientific reasoning decrease, although not significant, of SITI during the study.

To begin with, we expected that SITI would have scored higher than SIABI on the pretests, because of their SES advantage. However this was not the case. On the other hand, p values of group comparisons of conceptual knowledge and scientific reasoning were closer to the meaningful value of .05. We think that if we had larger sample sizes for each school region, we would have observed statistical difference between these students at the pretest. For the latter issue, Schen (2007) also found a decrease of scientific reasoning skills of undergraduate students who received traditional instruction after taking one semester of biology course (pp. 82-83). Schen (2007) related this result to students' self-efficacy or interest decrease during the course. However, the author did not specifically examine concrete and formal reasoners' scientific reasoning in that study. In our case, only formal reasoners' scores decreased from pre to posttest in both traditional and argumentation-based learning environments (see Table 4). From this result and extending Schen's (2007) interpretation, we could suspect that formal reasoners, in both traditional and argumentation-based learning environments, might not have been sufficiently motivated during the completion of scientific reasoning posttest. This might be an area for further research.

CONCLUSION

This study shows that achieving science learning equity among different SES schools by means of argumentation instruction is possible because we did not find either scientific reasoning or conceptual knowledge difference after instruction between SITI who were in a school located in a region with high SES and SIABI who were in schools located in a region with low SES. Furthermore whereas SIABI enhanced their scientific reasoning, SITI did not.

This study also shows that achieving science learning equity between concrete and formal reasoning students in argumentation-based instruction is possible because concrete and formal reasoning students had similar scientific reasoning and conceptual knowledge scores after argumentation instruction. However pre-instructional scientific reasoning and conceptual knowledge gaps still existed at the end of traditional instruction.

Limitations

The following limitations were recognized:

1. This study used a small sample size of 57 students across the two regions. Larger sample sizes for each school region could be used in this study. In addition, purposeful sampling was utilized. However, inclusion of SITI from a low SES region along with using larger sample sizes for both SITI and SIABI would have strengthened the results.
2. The interventional time devoted in this study could be more than four months. In this way, more powerful results could be obtained regarding the examination of equity in argumentation-based and traditional instructions.

Implications

Argumentation-based instruction may be embedded earlier in the science education curriculum to enhance student scientific reasoning. Consequently science learning gaps between student groups can be prevented from widening in future education years. This study demonstrated that science learning gaps closed between students having different scientific reasoning levels in argumentation-based instruction, whereas those gaps still existed in traditional instruction.

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