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The Influence of Argumentation on Understanding Nature of Science

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The aim in conducting this study is to explore the effects of argumentation on pre-service science teachers' views of the nature of science. This study used a qualitative case study and conducted with 20 pre-service science teachers. Data sources include an open-ended questionnaire and audio-taped interviews. According to pretest and posttest scores, 3 participants were selected for gathering qualitative data and follow-up interviews. Analyses of the findings revealed that the argumentation based instruction was effective in 2 of 3 participants' views of the nature of science. According to the results, 2 aspects of the nature of science were the most developed aspects of the nature of science assessed in this study; the social and cultural and the creative and imaginative nature of science. These findings highlight the need for teacher preparation programs to incorporate argumentation based instruction that promotes the development of the nature of science views.

Keywords: argumentation, elementary science education, nature of science, pre-service science teachers.

INTRODUCTION

The goal of enhancing students' views of nature of science has been investigated over the last century. The importance of the nature of science is also recognized by major science education policy documents by putting the nature of science at the center of scientific literacy (American Association for the Advancement of Science, 1993; National Research Council, 1996). Science reform documents recommend that teachers provide appropriate instruction for students to reach adequate level of understanding of the nature of science to be able to deliver necessary instruction; teachers themselves need to have informed views of the nature of science (Akerson, Buzzelli, &Donnelly, 2008). But science teachers were found to hold several naive views of the nature of science (Abd-El-Khalick, Bell & Lederman, 1998). For these

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reasons, the major goals of most science education researches were to help teachers develop informed views of the nature of science.

Argumentation plays a vital role in science learning because teachers/students who are engaged in argumentation not only advance in the social construction of scientific knowledge but also learn the nature of scientific enterprises (Bell & Linn, 2000). Over the past few decades, numerous studies have focused on the analysis of argumentation discourse in educational contexts (Driver, Newton, & Osborne, 2000; Duschl, Ellenbogen & Erduran, 1999; Jiménez-Aleixandre, Rodríguez, & Duschl, 2000). But few studies investigated the effectiveness of argumentation on views of the nature of science (Bell & Linn, 2000; Yerrick, 2000, McDonald, 2010; Ogunniyi, 2006). There exists a consensus in these studies' results that suggest a relationship between participants' argumentation and their nature of science understandings. The studies dealing with argumentation and the nature of science suggest that one might influence the other (Bell & Linn, 2000; McDonald, 2010; Zeidler, Walker, Ackett & Simmons, 2002).

Despite numerous studies pointed out the importance of argumentation, it is scarcely considered in teaching (Newton, Driver, & Osborne, 1999; Sandoval & Millwood, 2005). Ultimately, the incorporation of argumentation in the science classroom involves a shift in the classroom from what we know about science to how we know and why we believe in science (Duschl, 2008). Integration of argumentation in science classrooms was difficult mainly due to current teachers in classrooms who need to be trained in such issues (Driver et al., 2000). As a result, it is of importance to educate science teachers in implementing argumentation into their own classrooms in order to fulfill the objectives of the elementary science education policy presented in national curriculum.

METHODOLOGY

This study focused on exploring the effect of argumentation based science instruction on pre-service science teachers' views of the nature of science. The use of qualitative research is appropriate for the aims of this research. Qualitative researches are concerned primarily with process rather than outcomes or facts and meaning about how people construct as a matter of context or natural settings (Bogdan & Biklen, 1998; Creswell, 1994). Among qualitative research designs, a case study design enables researchers gaining an indepth understanding and interpreting the educational phenomenon within its real life context (Merriam, 1998). According to Stake (1995), the most important role of the case study researcher was that of interpreter. His vision of this role was not as the discoverer of an external reality, but as the builder of a clearer view of the phenomenon under study through explanation and descriptions. In this study, the researcher implemented all phases of the study and she was the course lecturer, interviewer and data collector of this study. The study applied trustworthiness criteria (Guba & Lincoln, 1989), and methodological triangulation protocols (Denzin, 1984) to ensure the studies' results and interpretations were valid.

Participants

The study was conducted with 20 pre-service science teachers. According to pretest and posttest scores of the Views of Nature of Science-C (VNOS-C), 3 participants were selected for the process of gathering qualitative data with questionnaires and follow-up interviews.

Context

The courses were held weekly in 2 hour sessions, and covered a 14-week period. First week, participants read and signed the consent forms and were provided

detailed information about the courses. Second week, 20 pre-service teachers completed the VNOS-C questionnaire and participated in interviews. The intervention session of the study was conducted over an 11-week period.

First 2 weeks of the intervention session, 2 socio-scientific scenarios (classroom and baby sitter) developed by Yeşiloğlu (2007) and Demirci (2008) were implemented in order to form a substructure of argumentation. Following 4 weeks, four socio-scientific scenarios developed by Bell and Lederman (2003) were implemented. These 4 socio-scientific scenarios were concerned with science and technology issues, including (a) fetal tissue implantation, (b) global warming, (c) diet and cancer, (d) cigarette smoking and cancer. At the end of each scenario, 3 questions were designed to configure group discussions and these scenarios were contextually combined with relevant scientific concepts (Bell & Lederman, 2003).

Following 5 weeks, 5 scientific-scenarios (Mixtures, elements, and compounds, snowmen, circuits, sound travel, candle) were implemented from the Ideas, Evidence and Argument in Science Project "IDEAS" (Osborne, Erduran & Simon, 2004). These scenarios were sourced from a set of curriculum materials (Osborne, Erduran & Simon, 2004b) that were developed to support teaching of ideas, evidence and argument in school science education. During the implementation of each scientific scenario, group work was applied to allow participants to express and defend their views. Last week after the intervention session, participants took part in a final interview and completed the VNOS-C.

Data sources

Data sources of this research include an open-ended questionnaire named "Views of Nature of Science-C" with audio-taped follow-up interviews. VNOS-C (Abd- El-Khalick, 1998) and associated interviews were utilized to assess participants' nature of science views. The VNOS-C questionnaire lasted approximately 40 minutes. Participants were informed that there were no correct answers. After the participants finished the written questionnaire, they were individually interviewed to justify their responses to the questionnaire. Open-ended questions were aimed to gather information about the following eight aspects of science: the empirical nature of science, the methods of science, theories and laws, the tentative nature of science, the inferential and theoretical nature of science, the subjective and theory-laden nature of science, the social and cultural nature of science, and the creative and imaginative nature of science.

During the interviews, the selected participants were provided with a copy of their pre and post VNOS-C questionnaire responses and asked to read, explain, and justify their answers to each of the questions. The interview schedule developed by Abd-El-Khalick (1998) was often utilized to get a better understanding of their views on the nature of science and the changes, if any, they had after the nature of science intervention. The follow up interviews took approximately 30 minutes to complete, and all interviews were audio-taped and fully transcribed for analysis.

Additional data were gathered by interviewing a subsample of the students before and after the intervention phase of the study. Before the intervention, participants asked about their demographical and socioeconomic status, backgrounds about science education, their views about the nature of science and argumentation instruction. After the intervention, final interview consisted of 10 questions was designed to provide information about participants' perceptions of the course and changes in the nature of science views over the course. Initial and final interviews were audio-taped and fully transcribed for analysis.

Data analysis

Data analysis in qualitative research consists of preparing and organizing the data for analysis, reducing the data into themes through a process of coding and

condensing the codes, and representing the data in figures, tables, or a discussion (Creswell & Plano, 2007). The interviews and the questionnaires were analyzed in accordance with analytical induction presented by Bogdan and Biklen (1998). All participants' questionnaires and interviews were analyzed separately to summarize each participant's views of nature of science which were then searched for similar categories. Several categories were performed to sort out the data. The categories generated based on participants' responses to the questionnaires were compared to the categories generated based on the interviews. All the data were analyzed by the researcher and a science education researcher to assess the reliability of the categorization scheme. Only few differences emerged and consensus was reached after discussions. Participants' responses were categorized into naive, limited, partially informed and informed for each nature of science aspect.

RESULTS

Analysis of the findings revealed that at the beginning of the study almost all participants reported naive or limited views of all of the nature of science aspects. But the argumentation based science instruction was effective on activating the positive development of 2 of 3 participants' views of the nature of science from naive nature of science views to more informed views. According to the results, as seen in Table 1, 2 aspects of the nature of science were the most developed aspects of the nature of science assessed in this study; the social and cultural nature of science and the creative and imaginative nature of science. Therefore, the results of this study constituted some evidence that incorporating scientific and socio-scientific scenarios to argumentation based science instruction could lead pre-service science teachers to improve their nature of science views.

According to the results of the empirical nature of science aspect, before the intervention session, all 3 cases expressed limited views. These participants emphasized that science is more concrete than religion and philosophy. According to their views, religion and philosophy indicate personal beliefs. They failed to refer that is based on evidence and scientific knowledge is affected by prior knowledge. Case 2 stated that science is proven with experiments but religion and philosophy are not.

"Science investigates phenomena in our lives. But religion and philosophy depend on emotional thoughts" (C2).

Table 1. Changes in participants' nature of science views

	Case 1			Case 2			Case 3		
	Pre	**Post**	**Change**	**Pre**	**Post**	**Change**	**Pre**	**Post**	**Change**
Empirical	-	+	PC	-	+	PC	-	-	U
Scientific method	-	+	PC	-	+	PC	--	--	U
Theories & laws	-	-	U	--	+	C	-	-	U
Tentative	+	++	PC	-	-	U	-	-	U
Inference	--	+	C	+	+	U	--	--	U
Theory-laden	+	++	PC	-	+	PC	-	-	U
Social-cultural	-	++	C	-	+	PC	-	+	PC
Creative-imaginative	-	++	C	+	++	PC	--	-	PC

-- *naive*
- *limited*
\+ *partially informed*
++ *informed*

U unchanged
PC partially changed
C changed

After intervention phase, 2 of 3 case (case 1 and case 2) showed development from a limited to a partially informed views of the empirical nature of science. Case 2 was aware of the impact of prior knowledge on empirical views of the nature of science:

"Science explains what is going on around us. People who live in different societies may explain the same things in different ways. I think science, religion and philosophy are completely different things because science does experiments but religion and philosophy cannot do that" (C2).

The results of the methods of science aspect provided that before the intervention session, 2 of 3 cases expressed limited views, 1 case expressed naive views of this aspect of the nature of science. None of the 3 cases got a clear idea what an experiment is and what is the role of experiments inside science, and, in particular, inside physics.

Also all 3 cases were not aware of the role of observations on the development of scientific knowledge. They believed that experiments must be done in order to achieve scientific knowledge.

Answers of 2 cases (case 1 and case 2) imply that experiments require certain processes that must be followed strictly. Case 3 argued that scientific knowledge must be obtained from an experiment. He/she described experiment as a tool in order to test hypothesis. Only Case 2 stressed that the experiments are done to prove the hypotheses and mentioned the term "evidence".

"I think experiment is an evidence. So if we do not have an evidence, we cannot verify our hypothesis" (C2)

'When a hypothesis was proven with an experiment, we can say that it is scientific' (C3).

After intervention phase, 2 of 3cases (case 1 and case 2) showed development from a limited to a partially informed views of the methods of science aspect. But case 3 did not show any change. Case 1 highlighted that there are different perspectives of scientific research approach and there may be different methods used by scientists to answer their questions.

"Scientists have used different methods to answer their questions" (C2).

"I think the observations are at least as important as experiments" (C1).

Based on the results of the theories and laws aspect, before the intervention session, 2 of 3 cases expressed limited, 1 case expressed naive views of this aspect of the nature of science. None of 3 cases could make a correct definition of theory or law. All 3 cases were in opinion that one theory would absolutely become a law. Therefore, they did not recognize that theories and laws provide different pieces of information. All of the 3 cases expressed that theories are not clear but laws are absolute. And case 3 believed that there is a hierarchical row between theories and laws.

"Theories are the previous stage of laws. I think there is a hierarchical sequence between them. A hypothesis first becomes a theory than a law" (C3).

"A law has been proven, everyone accepts laws. But the theory has not been proven completely. For example, Newton's laws have been proven but the theory of evolution is still to be proven" (C1).

We remark that this study neglected the role of theories and laws inside science. After intervention phase, only case 2 showed development from a limited to a partially informed view and the other 2 cases (case 1 and case 3) did not show any change on this aspect. Only case 2 was aware of the need of learning theory to improve scientific knowledge with her/his partially informed opinions:

"For example, there is not enough evidence for the theory of evolution, but, perhaps this theory would be proved over time, for this reason we need to know theories" (C2).

The results of the tentative nature of science aspect showed that before the intervention session, case 2 and case 3 expressed limited, but only case 1 expressed

partially informed views of this aspect of the nature of science. Case 2 and case 3 expressed absolutistic views. They expressed limited views of the tentative nature of laws that failed to recognize that laws are tentative.

"I think, nothing can be proved in the world" (C3).

"A law is expected to be constant and absolute" (C2).

After intervention phase, only case 2 showed development from a limited to a partially informed views, case 1 and case 3 did not show any change on this aspect. Case 2 claimed that with the development of technology, theories may change over time. And he/she also implied that learning theories provide us the opportunity of producing new scientific knowledge.

"Yes, theories change... Also one theory can develop the other theories. For example, atomic theory... Scientists have reached this theory by not making the mistakes of the old theories" (C2).

Analysis of results of inference and theoretical entities showed that before the intervention session, 2 cases expressed naive views of inference and theoretical entities. 2 of 3cases (case 1 and case 3) argued that scientists directly observe the structure of an atom so they know precisely the atomic structure. But case 2 expressed partially informed views and was aware that there are some indirect evidences which play role to determine atomic structure. After intervention phase, only Case 1 showed development in his/her view of inference and theoretical entities. Case 1's views of this aspect developed over the course of the intervention from a naive view to a partially informed views. In his/her responses, he/she made references to the concept of models used to explain the atomic structure.

"Scientists obtained some data and use them to build the best atomic model" (C2).

The results of the theory-laden nature of science aspect provided that before the intervention session, 2 of 3 cases (case2 and case3) expressed limited views, but case 1 expressed partially informed views of this aspect of the nature of science. Only 2 of this 3 cases' (case 1 and case2) views of the theory-laden nature of science improved substantially over the course of the intervention. Case 1 showed a change in his/her view of the theory-laden nature of science from partially informed view to an informed view. Case 2 showed a change in his/her view from a limited view to a partially informed view. Case 3 did not show yet a significant improvement in this aspect of nature of science.

"I think science is not universal. Some traditions did not accept the theory of evolution. Because it is contrary to their religion" (C3)

"If scientists' personal beliefs and histories are different; naturally they interpret the same data differently" (C1)

Based on the results, before the intervention session, all of 3 cases displayed limited views of the aspect of the social and cultural nature of science. But all of them showed improvement in their understanding of this aspect, and displayed informed (case 1) and partially informed (case2 and case3) views of this aspect at the conclusion of the study. Case 1 showed a major change in his/her view of the social and cultural nature of science, from a limited view to an informed view. She made numerous references to this aspect during her post-intervention interview.

"Everyone has some prejudices, because everyone is affected by his/her social and cultural values" (C3)

'I think the important thing is that different people have different views. Everyone affects the way they live while understanding the science. So, science varies from person to person' (C1)

According to the examination of cases' expressions in the final interview, when they described the nature of science, all 3 cases referred to the social and cultural nature of science. The reason for this is the social and cultural nature of science was the most developed aspect of the nature of science according to cases' responses.

The aspect of creative and imaginative nature of science was the other most developed aspect of the nature of science assessed in this study. Before the intervention session, all of 3 cases displayed different views of the aspect of creative and imaginative nature of science. Case 3 displayed naive, case 1 displayed limited and case 2 displayed partially informed views. Case 3 failed to understand the role of creativity and imagination at all stages of scientific research. But all of them showed improvement in their understanding of this aspect, and displayed informed views (case 1 and case2) of this aspect at the conclusion of the study.

"…but I guess they use their imagination to interpret the data but in my opinion it is not appropriate" (C3).

"I think creativity and imagination are required at every stage of scientific research" (C2).

DISCUSSION AND CONCLUSION

As stated previously, the aim of this study was to investigate the effect of argumentation based science instruction on pre-service science teachers' views of the nature of science. With this aim, this study has made a contribution to the field that has investigated argumentation in both scientific and socioscientific contexts. At the beginning of this study, all of the participants expressed limited views of the examined nature of science aspects which were consistent with previous research (Abell & Smith, 1994; Akerson, Morrison & McDuffie, 2006; Gess-Newsome, 2002). But according to the findings of this research, argumentation-based science instruction develops pre-service science teachers' views of the nature of science. Argumentation is seen as an effective way of analysis and interpretation of discourse in science classrooms. It helps to understand how teachers and students engage in the construction and evaluation of scientific knowledge claims (Duschl, 2007). Also Zohar (2007) indicated that teachers themselves must be able to engage in high quality argumentation before they can support students' successful argumentation. Moreover, Osborne et al. (2004), Zohar and Nemet (2002), Jime'nez-Aleixandre, Rodriguez and Duschl (2000) are some of the most important researchers who have been studying argumentation in science education literature. Also some similar results were reported by Ogunniyi (2006) and McDonald (2010) who provide some evidence to support the claim that argumentation instruction incorporating scientific and socioscientific scenarios provides opportunities for participants to develop their nature of science views. Future studies designed with the aim of improving participants' nature of science views should investigate the influence of previous knowledge. More extensive studies are needed to determine the impact of argumentation-based instruction on participants' nature of science views in different disciplines and participants (inservice science teachers, elementary school students).

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REFERENCES

Abd-El-Khalick, F., Bell, R.L., & Lederman, N.G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education 82*, 417–436.

Abd-El-Khalick, F., & Lederman, N. G. (2000a). Improving science teachers‟ conceptions of nature of science: A critical review of the literature. *International Journal of Science Education 22*(7), 665-701.

Abell, S., Smith D., (1994). What is science? Pre-service elementary teacher' conceptions of the nature of science*. International Journal of Science Education, 16*, 473–487.

Akerson, V. L., Morrison, J. A., & Roth McDuffie, A. (2006). One course is not enough: Pre-service elementary teachers‟ retention of improved views of nature of science. *Journal of Research in Science Teaching 43*(2), 194-213.

Akerson, V. L., Buzzelli, C. A., & 1, Donnelly, L. A. (2008). Early childhood teachers' views of nature of science: The influence of intellectual levels, cultural values, and explicit reflective teaching. *Journal of Research in Science Teaching, 45*(6), 748 – 770.

(AAAS) American Association for the Advancement of Science (1993). *Benchmarks for science literacy: A Project 2061 report.* New York: Oxford University Press.

Bell, R. L., & Lederman, N. G. (2003). Understandings of the nature of science and decision making on science and technology based issues. *Science Education, 87,* 352-377.

Bell, P., & Linn, M.C. (2000). Scientific arguments as learning artifacts: Designing for learning from the web with KIE. *International Journal of Science Education, 22*(8), 797–817.

Bogdan, R. C., & Biklen, S. K. (1998). *Qualitative Research for Education: An Introduction to Theory and Methods.* Needham Heights, MA: Allyn and Bacon, Inc.

Creswell, J. W. (1994). *Research design: Qualitative and quantitative approaches.* Thousand Oaks, CA: SAGE Publications.

Creswell JW, Plano Clark VL. *Designing and Conducting Mixed Methods Research.* 1nd ed. Thousand Oaks, CA: Sage Publications; 2007.

Demirci, N. (2008). *Toulmin'in Bilimsel Tartışma Modeli Odaklı Eğitimin Kimya Öğretmen*

Adaylarının Temel Kimya Konularını Anlamaları ve Tartışma Seviyeleri Üzerine Etkisi. Yüksek Lisans Tezi. Ankara: Gazi Üniversitesi Eğitim Bilimleri Enstitüsü.

Denzin, N. (1984). *The research act.* Englewood Cliffs, NJ: Prentice Hall.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*(3), 287-312.

Duschl, R., Ellenbogen, K., & Erduran, S. (1999, April). *Understanding dialogic argumentation.* American Educational Research Association, Montreal.

Duschl, R. A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education 38,* 39-72.

Duschl, R. A., (2007). Quality argumentation and epistemic criteria. In S. Erduran, & M. P. Jiménez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (pp. 159-175). Dordrecht, The Netherlands: Springer.

Duschl, R. (2008). Science education in 3 part harmony: Balancing conceptual, epistemic and social learning goals. *Review of Research in Education 32,* 268-291. Washington, DC: AERA.

Gess-Newsome, J. (2002). The use and impact of explicit instruction about the nature of science and science inquiry in an elementary science methods course. *Science & Education 11,* 55-67.

Guba, E. G., & Lincoln, Y. S. (1989). *Fourth generation evaluation.* CA: Sage.

Jimenez-Aleixandre, M. P., Rodrigues, A. B. & Duschl, R. (2000). "Doing the lesson" or "doing science": Argument in high school genetics. *Science Education*, *84*(6), 757-792.

McDonald, C. V. (2010). *The influence of explicit nature of science and argumentation instruction on pre-service primary teachers' views of nature of science*. *Journal of Research in Science Teaching 47*(9), 1137–1164.

Merriam, S. B. (1998). *Qualitative research and case study applications in education.* San Francisco: Jossey-Bass Publishers.

National Research Council. (1996). *National science education standards.* Washington, DC: National Academic Press.

Newton, P., Driver, R., & Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education 21*(5), 553–576.

Ogunniyi, M.B. (2006). *Using an argumentation-instrumental reasoning discourse to facilitate teachers' understanding of the nature of science.* National Association for Research in Science Teaching (NARST), San Francisco, CA.

Osborne, J., Erduran, S., & Simon, S. (2004a). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching 41*(10), 994-1020.

Osborne, J., Erduran, S., & Simon, S. (2004b). *Ideas, Evidence and Argument in Science (IDEAS) Project.* London: University of London Press.

Sandoval,W.A., & Millwood, K.A. (2005). The quality of students' use of evidence in written scientific explanations. *Cognition and Instruction 23*(1), 23–55.

Stake, R. E. (1995). *The art of case study research.* Thousand Oaks, CA: Sage.

Yerrick, R.K. (2000). Lower track science students' argumentation and open inquiry instruction. *Journal of Research in Science Teaching 37*(8), 807–838.

Yeşiloğlu, S. N. (2007). *Gazlar Konusunun Lise Öğrencilerine Bilimsel Tartışma (Argumentasyon) Odaklı Öğretimi.* Yüksek Lisans Tezi, Gazi Üniversitesi Eğitim Bilimleri Enstitüsü Kimya Eğitimi Anabilim Dalı.

Zeidler, D.L., Walker, K.A., Ackett, W.A., & Simmons, M.L. (2002). Tangled up in views: Beliefs in the nature of science and responses to socioscientific dilemmas. *Science Education 86,* 343–367.

Zohar, A. (2007). Science teacher education and professional development in argumentation. In S. Erduran & M. P. Jiménez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (pp.245-268). Dordrecht, The Netherlands: Springer.

Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching 39*(1), 35-62.

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