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Effect of Argumentation on Prospective Science Teachers' Scientific Process Skills and Their Understanding of Nature of Scientific Knowledge in Chemistry Laboratory

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Abstract

The aim of this research is to analyze the effect of Argumentation on prospective science teachers' scientific process skills and their understanding of the nature of scientific knowledge in the chemistry laboratory. In this study, non-equivalent pre-test post-test control group approach, which is one of the quasi-experimental methods, is used. The study group contains 91 college freshmen students studying in the Department of Science Education of the Kazim Karabekir Education Faculty, Ataturk University, which is located in the Eastern Anatolian Region of Turkey. Data of the study is collected through scientific process skill test (SPST) and the nature of scientific knowledge test (NSKT). Data from SPST and NSKT are analyzed through inferential statistics method. A statistically significant difference is found between experimental and control groups' SPS post-test mean scores ($t_{(89)}$= 4.943; p= .000). A statistically significant difference is found between experimental and control groups' NSK post-test mean scores (t(89)= .819; p= .05). It is shown in this study that the argumentation contributes to the scientific process skills of the students, but does not have a significant influence on their understanding of the nature of scientific knowledge.

Keywords: argumentation, chemistry laboratory, scientific process skills, nature of the scientific knowledge.

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Introduction

The main purpose of science education is scientific literacy for students. Scientific literacy refers to students' understanding of the concepts, principles, theories, and processes of science, and one's awareness of the complex relationships between science, technology, and society (Klopfer, 1969). Moreover, scientific literacy defines the values and beliefs naturally existing in the epistemology of the science, the science as a means of knowledge, or scientific knowledge (Abd-El-Khalick, Bell, & Lederman, 1998). Scientific literacy includes understanding not only scientific knowledge, but also understanding the nature of science-'knowledge of both why science believes what it does and how science has come to think that way' (Duschl, 1988). Bell and Lederman (2003) describe the nature of the science as the most fundamental component of the scientific literacy. Improving students' conceptions of nature of science (NOS) is considered a principal target in science education (Abd-El-Khalick & Lederman, 2000). This target is stressed on current science education reform documents around the world (American Association for the Advancement of Science [AAAS], 1993; Millar & Osborne, 1998; National Research Council [NRC], 1996). Furthermore, scientifically literate individuals should have an understanding of the real world and diverse life-experience, utilize scientific principles and scientific process skills while making decisions, discuss scientific issues, and use science and technology for resolution of societal problems (NRC, 1996). The argumentation has been recently playing a major role in terms of improving the scientific literacy of students (Driver, Newton, & Osborne, 2000; Duschl & Osborne, 2002; Shieh & Demirkol, 2014; Erduran & Jiménez-Aleixandre, 2007). According to Erduran, Osborne, and Simon (2004), students tend to occupy themselves with rational thinking processes and may improve their own process for the interaction between the individual and social dimensions, value judgments, beliefs and taking advantage of knowledge, if they support each other's high quality arguments. Moreover, students develop strategies to judge the opposing ideas. Students use proofs to support their claims, and they continuously communicate with each other to evaluate the knowledge they received. Since argumentation is a process, students collaborate with each other or disprove some other person's ideas to come up with new arguments (Maloney & Simon, 2006). Thus, students, just like scientists may have the chance to understand how ideas are created and to become involved in the argumentation during this creation. Their understanding of the nature of the science may also change.

Laboratories are at the heart of science education. Science teachers promote the laboratories as a prominent factor in terms of the comprehension of the nature of science (Hofstein, Kipnis, & Kind, 2008; Hofstein & Lunetta, 2004; Mamlok-Naaman & Barnea, 2012). In the case of inductive open-ended type laboratories, students are not informed about what is coming at the end of the experiment. The teacher is responsible for determination of the equipment and tools required for the experiment. And the student is responsible for experimenting, recording the data, and for analyzing and interpreting the data. At the end of the experiment, the student is asked to make a descriptive generalization over a chemical law or principle. Students are given information on how to do this type of experiment. Most of the time they do not even think about the steps (Hofstein et al., 2008; Hofstein & Lunetta, 2004; Walker, Sampson, Grooms, Anderson, & Zimmerman, 2010; Walker, Sampson, Grooms, & Zimmerman, 2011; Walker, 2011).

For this reason, traditional experiments contribute poorly to the cognitive development of the students. When the experiments are performed in this manner, students' skills develop only to a limited extent. Moreover, it may be said that students are not provided with sufficient chance to generate arguments and to evaluate each other's arguments in the traditional laboratory, and that their scientific process skills, understanding of the nature of scientific knowledge, critical thinking, research and judgment skills develop poorly. Challenging and complex problems may be introduced to the students during the tests. The traditional laboratory environments are not sufficiently qualified to help students overcome their problems, or to support them in acquiring the aforementioned skills. For this reason, students require a laboratory environment that could reinforce their skill-development process, apart from the approach and model previously mentioned. Such a laboratory may have enough room for argumentation. An argumentation-oriented laboratory is based on the inquiry-based learning approach (Katchevich, Hofstein, & Mamlok-Naaman, 2013; Katchevich, Mamlok-Naaman, & Hofstein, 2014; Kind, Wilson, Hofstein, & Kind, 2010; Ozdem, 2009; Sekerci & Canpolat, 2014). In an inquiry-based argumentation laboratory, students may develop features of a scientist; learning how to be a scientist and to contribute to science. Moreover, an inquiry-based argumentation laboratory may effectively engineer the scientific process skills of the students. Laboratories that spare enough room for argumentation may provide students with major contributions to enable them to generate arguments (Jiménez-Aleixandre & Erduran, 2007; McNeill, Lizotte, Krajcik, & Marx, 2006), gain a sense of scientific discussion, and to better understand the nature of the scientific knowledge (Osborne, 2009; Osborne, Erduran, & Simon, 2004; Zohar & Nemet, 2002). In other words, today's laboratories should feature student-oriented, inquiry-based argumentation in order to allow them make choices, become involved in discovery-driven activities before and after the experiments, to perform exciting live rather than dull or boring experiments, and to create more designs and think up more ideas.

There are studies in the literature showing the effect of laboratory argumentation on conceptual understandings (Demircioglu, 2011; Hand, Nam, & Choi, 2012; Sekerci & Canpolat, 2014), attitudes (Demircioglu & Ucar, 2012; Kaya, Dogan, & Kilic, 2005), scientific process skills (Demircioglu & Ucar, 2015; Gultepe & Kilic, 2015; Kaya, 2009), and the nature of science. There are a limited amount of studies on the effect of argumentation in the chemistry laboratory on students' scientific process skills and their understanding of nature of science (Walker, 2011), so a new study is required to open up the horizons for science teaching, and for chemistry teachers, tutors and students. Therefore, the aim of this research was to analyze the effect of argumentation in a chemistry laboratory on students' scientific process skills and the nature of the science. In accordance with this purpose, answers to the following research questions are sought:

- Is there any statistically significant difference in terms of students' scientific process skills between argumentation-oriented experimental group and traditionally educated control group?
- Is there any statistically significant difference in terms of students' perspectives on the nature of the scientific knowledge between argumentation-oriented experimental group and traditionally educated control group?

Methodology

The quasi-experimental method included in the quantitative design was employed in this study. Non-equivalent pre-test post-test control group approach was used, which is one of the quasi-experimental methods (McMillan & Schumacher, 2014).

The study group for this research was formed of 91 first grader students, studying in two different classes of the Department of Science Education during the 2011-2012 spring semester of Kazım Karabekir Education Faculty at Ataturk University, located in the Eastern Anatolian Region of Turkey, and taking the course titled "General Chemistry Laboratory-II". One of the classes was designated as the experimental group and the other as the control group, in a random manner. There are 47 students (33 females, 14 males) in the experimental group and 44 students (34 females, 10 males) in the control group. Students in the experimental group vary between 19 and 24 years old, while students in the control group vary between 18 and 27.

The experimental group was chosen via the convenience sampling method (of random sampling methods) (Buyukozturk, Kilic-Cakmak, Akgun, Karadeniz, & Demirel, 2012; McMillian & Schumacher, 2014). Choosing the convenience sampling method plays an important role for the study as the samples should easily be accessible, convenient and feasible. However, the convenience sampling method's demerit is the generalization of research-based results to the population (McMillan & Schumacher, 2014).

Data of the study was collected through scientific process skill test (SPST) and nature of scientific knowledge test (NSKT).

SPST was developed by Burn, Okey, and Wise (1985), and translated and adopted into Turkish by Geban, Askar, and Ozkan (1992). SPST consists of 36 multiple-choice items: defining the variants (12 questions), suggesting scientific explanations (6 questions), formulating hypothesis (9 questions), drawing and interpreting (6 questions), and research design skills (3 questions). Geban et al. (1992) defined SPST's reliability coefficient (Cronbach alpha) as .82. SPST was applied as both a pre-test and post-test for both the experimental group and also the control group as well.

NSKT was developed by Sampson and Clark (2006), and translated and adapted into Turkish by Akyol, Tekkaya, and Sungur (2010). NSKT consists of 26, 5-point, Likert-type items: nature of the scientific knowledge (6 questions), methods for producing scientific knowledge (6 questions), reliability and validity of the scientific knowledge (7 questions), and roles of the scientist regarding creation of scientific knowledge. All items in the NSKT have two contradicting ideas. One of these is the scientific idea as an argument and descriptive process, and the other is the epistemological idea regarding the nature of the science. Akyol et al. (2010) defined NSKT's reliability coefficient (Cronbach alpha) as .75. This test was applied both as a pre-test and post-test for both the experimental group and also the control group as well.

Application was performed on the General Chemistry Laboratory-II course in the two college freshmen classes of the Department of Science Teaching, Kazım Karabekir Education Faculty at Ataturk University, taught during the 2011-2012 spring semester. One of the classes was designated as the experimental group and the other as the control group, in a random manner. Argumentation approach was used for the experimental group and traditional approach used for the control group during the research. Experiments chosen for this study are pH, Hydrolysis and Acid-Base titration (Alkan, Bayrakceken, Gurses, & Demir, 1997), colligative propertied, freezing point depression (Gurses & Bayrakceken, 1996), factors effecting reaction rate (Bayrakceken, Gurses, & Doymus, 1999), variants affecting the chemical equilibrium (concentration and temperature) (Canpolat, 2002; Summerlin & Ealy, 1985), and addition of heat of reactions (Bayrakceken et al., 1999). For the experimental group, argumentation-oriented worksheets were prepared, and the experimental group designed the tests themselves. But for the control group, most of the tests were applied as they found in the sources, and some of them were applied with minor modifications. All experimental and control group experiments included “how-to” guidance.

The experimental group students were separated into 12 groups. There was one group of three students, and 11 groups of four students; based on their General Chemistry Laboratory-I scores (low, intermediate and high). These groups were heterogeneously formed for the interactions among the peers and collaborative learning within each group. In order for the effective performance of the activities (active learning, argumentation-oriented intra- and inter-group discussions, etc.), the experimental group was divided into two, with each containing six students. During the application, the first group performed the experiment and the other were taken to the laboratory. Thus, both groups were unable to communicate. Through the application, the experimental group students received the worksheets of the next experiment, and the experiment was explained in detail. Students individually conducted their research in line with these worksheets. Then, each group was separately interviewed the day before laboratory day, and they were asked about their experiment plan confirming with the problems, and concepts regarding the experiment were discussed within the group. After the intra-group discussions, the groups were asked about the design of their experiment, their rationale and the concepts given on the worksheet. On the laboratory day, the worksheets were handed to each group, and each were asked to jointly complete the worksheets as a group. When the worksheets were filled, these groups had argumentation-oriented discussions over the experiment designs. Everything was set and clear before the experiment phase. Following the experiments, these groups had argumentation-oriented discussions over the experiment results. Then worksheets of the next experiment were handed out. This process was repeated until the end of the last experiment. The students were encouraged to suggest claims, counter claims, rationales and supporting ideas, refutes during the intra- and inter-group argumentation-oriented discussions.

Students in the control group were divided into 11 groups, based on their General Chemistry Laboratory-I scores (low, intermediate and high). The control group was divided into two, with five and six student groups respectively. The groups in the first part performed their experiments, and the groups in the second part were taken to the laboratory. Students in the control group received sheets of the experiments and were asked to be prepared. The experiment sheets carried the name of the experiment, information, purpose, tools and equipment, how-to, data regarding the experiment, results, and evaluation inquiries. As for the experimental group, the application guide asked the students, of the control group, questions and their answers were collected. They were informed about the experiments; after which, the groups performed the experiments. Each of the tests was applied for one week during the application process. Tests were conducted in both groups on two courses at the same time. Applications in both the experimental and control groups were guided by the researchers.

Data from SPST and NSKT were analyzed via inferential statistical approach. Data collected by this test were analyzed via the statistics program. After application of each test, in order to identify if the distributed test scores were normal, the z skewness value (z_S) which was obtained via the skewness coefficient divided into the standard error was assessed, and z_S for the each test was defined. z_S proves that ±1.96 is a normal distribution at the significance level of .05 (Field, 2013). With reference to these findings, SPST and NSKT z_S values are tabulated below:

Table 1. z_S values by SPS pre-test and post-test scores

	Experimental Group	Control Group
	z_S	z_S
Pre-test	.640	.090
Post test	.242	-.213

Note: Skewness coefficient (SC), standard error of skewness coefficient (SE_S)

It is understood from the z_S values of Table 1 that NSK pre-test and post-test scores of both groups demonstrate normal distribution. For this reason, an independent *t*-test was performed to identify if there was a statistically significant difference between pre-test and post-test scores of the groups.

Table 2. z_S values by NSK pre-test and post-test scores

	Experimental Group	Control Group
	z_S	z_S
Pre-test	-2.07	-.63
Post test	.54	-.34

It is understood from the z_S values given in Table 2, that NSK pre-test results of the control group demonstrate normal distribution, whereas NSK pre-test results of the experimental group does not demonstrate normal distribution, and NSK post-test results of both of the groups demonstrate normal distribution. Mann-Whitney U-test was then performed to identify if there was a statistically significant difference between pre-test results. An independent *t*-test was performed to identify if there was a statistically significant difference between post-test results of both of the groups. The significance level in the study was taken .05.

Findings

In order to form answers to the research inquiries, results of the independent *t*-test conducted for SPS pre-test and post-test scores are given in Table 3.

Table 3. Independent *t*-test results by SPS pre-test and post-test averages

	Group						95% CI for Mean Difference		
	Exp.			Control					
	M	SD	n	M	SD	n		t	df
Pre-test	21.51	3.44	47	20.48	4.21	44	-.564, 2.63	1.29	89
Post-test	24.11	3.32		20.68	3.39		2.07, 4.87	4.94*	89

*p < .05.

A statistically insignificant difference was found between the experimental and control groups' SPS pre-test mean scores, as shown in Table 3 ($t(89)= 1.29$; $p>.05$). On the other hand, a statistically significant difference was found between the experimental and control groups' SPS post-test mean scores ($t(89)= 4.94$; $p= .000$). As may be understood from the analysis results, experimental group's SPS post-test mean scores (M= 24.11, SD=3.32) are higher than control group's SPS post-test mean scores (M= 20.68, SD= 3.39). In order to determine how effective argumentation approach is on the experimental group students' scientific process skills, its effect sizes (η^2) are referred. For effect sizes, .01 is interpreted as little effect, .05 as intermediate effect and .08 as strong effect (Cohen, 1998, 1992). For SPS post-test, effect size of the argumentation-oriented teaching approach was calculated as $\eta 2= .26$. Interpretation of this condition may be "the variance in the average SPS post-test scores can be explained by the approach, 26% of which was applied". It may also be said that the argumentation-oriented teaching approach massively contributes to the scientific process skills of the students.

Findings of the Mann-Whitney U-test applied on the NSK pre-test scores are shown in Table 4, and findings of the independent *t*-test applied on the NSK post-test scores are shown in Table 5.

Table 4. Findings of Mann-Whitney U-test for the NSK pre-test findings

Group	n	Mean Rank	Sum of Ranks	U	p
Exp.	47	46.51	2186.00	1010.00	.849
Control	44	45.45	2000.00		

An insignificant difference is found between the experimental and control groups' NSK pre-test mean scores, as represented in Table 4 (U= 1010.00; $p>.05$).

Table 5. Independent *t*-test results by NSK post-test findings

	Group						95% CI for Mean Difference		
	Exp.			Control					
	M	SD	n	M	SD	n		t	df
Post-test	84.26	7.18	47	82.98	7.70	44	-4.38,1.82	-.82*	89

A statistically insignificant difference is found between the experimental and control groups' NSK post-test mean scores, as represented in Table 5 ($t(89)= -.82$; $p > .415$).

Conclusion and Discussion

Aim of this research was to analyze the effect of Argumentation on students' scientific process skills and their understanding of nature of scientific knowledge in chemistry laboratory. Findings of this study reveal that argumentation approach is more effective than the traditional approach in terms of the scientific process skills. According to this result, the argumentation-oriented teaching approach massively contributes to the development of students' scientific process skills.

In terms of the scientific process skills, argumentation-applied experimental group students are more successful compared to argumentation-applied control group students, because:

- They design experiments to support their claims;
- They make use of tools and equipment, effectively and correctly;
- They take the required safety precautions;
- They can relate reasons and results in the experiments;
- They demonstrate results of their experiments during the post-experiment discussions, in figures, charts or graphics;
- They collaborate throughout the experiments.

A literature review revealed that the number of studies analyzing the effect of argumentation on the scientific process skills to be quite limited (e.g., Gultepe & Kilic, 2015; Yılmaz, 2013; Kaya, 2009). Demircioglu and Ucar (2015) revealed that students' scientific process skills could be develop in one study, and results of this study is in compliance.

In the study, performance of the experiments of the General Chemistry Laboratory-II with either argumentation approach or traditional approach does not significantly affect control and experimental group students' understanding of the nature of scientific knowledge. Most of the studies dealing with this subject (e.g., Bell & Linn, 2000; Ozer, 2009; Tekeli, 2009; Ozdemir, Boydak Ozan, & Aydogan, 2013; Ulucinar Sagir, 2008; Buran, 2012; Yerrick, 2000) conclude that argumentation is more effective over the traditional approach in terms of students' development of understandings of the nature of scientific knowledge, which differs to the results of this study. However, results of Yesiloglu (2007) and this study are in compliance. Application length of some of the studies concluding that argumentation is better over traditional approach in terms of students' understanding of the nature of scientific knowledge are longer; for example, Ulucinar Sagir's (2008) was performed over two years and Yerrick (2000) for one year.

This highlights how important the application length is in terms of students' development of understanding the nature of scientific knowledge. In other words, long-term applications were required for the development of their understanding of the nature of scientific knowledge. Based on these results, the effect of argumentation regarding the students' chemistry, physics and biology questions during the laboratory courses on their scientific process skills and their understanding of the nature of scientific knowledge may be studied. Through long-term studies during the laboratory courses, effects of argumentation on students' understanding of the nature of scientific knowledge can be researched. Moreover, inter-group discussions on the results of the studies regarding the argumentation-oriented teaching approach may highlight the nature of the scientific knowledge.

Notes

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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*(4), 417-436.

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

Akyol, G., Tekkaya, C., & Sungur, S. (2010). The contribution of understandings of evolutionary theory and nature of science to pre-service science teachers: Acceptance of evolutionary theory. *Procedia Social and Behavioral Sciences, 9*, 1889-1893.

Alkan, M., Bayrakceken, S., Gurses, A., & Demir, Y. (1997). *Deneysel kimya [Experimental chemistry]* (Second Edition). Erzurum: Ekev Publishing.

American Association for the Advancement of Science (1993). Benchmarks for Science Literacy. New York: Oxford University Press. Retrieved from http://www.project2061.org/tools/benchol/bolframe.htm

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.

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.

Bayrakceken, S., Gurses, A., & Doymus, K. (1999). *Genel kimya laboratuvari [General chemistry laboratory].* Erzurum: Egitim Copy.

Buran, N. H. (2012). Bilirkişi: Sorun mu? Çözüm mü? *Üniversitepark Bülten, 1*(1).

Burn, C. J., Okey, J. R., & Wise, K. C. (1985). Development of an integrated process skill test: TIPS II. *Journal of Research in Science Teaching, 22*(2), 169-177.

Buyukozturk, S., Kilic-Cakmak, E., Akgun, O. E., Karadeniz, S., & Demirel, F. (2012). *Bilimsel arastirma yontemleri [Research methods]* (11th edition). Ankara: PegemA Akademi.

Canpolat, N. (2002). *Kimyasal denge ile ilgili kavramların anlasilmasinda kavramsal degisim yaklasiminin etkinliginin incelenmesi [Investigation of effectiveness of conceptual change approach on understanding of chemical equilibrium concepts]*. (Doctoral dissertation) https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp (Thesis no. 121470)

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* (2nd ed.). New York: Academic Press.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155-159.

Demircioglu, T. (2011). Fen ve teknoloji ogretmen adaylarinin laboratuvar egitiminde arguman temelli sorgulamanin etkisinin incelenmesi [To investigate the effect of argument-driven inquiry on pre-service science teachers' laboratory instruction] (Master's thesis) https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp (Thesis no. 387974).

Demircioglu, T., & Ucar, S. (2012). The effect of argument-driven inquiry on pre-service science teachers' attitudes and argumentation skills. *Procedia Social and Behavioral Sciences, 46*, 5035-5039.

Demircioglu, T., & Ucar, S. (2015). Investigating the effect of argument-driven inquiry in laboratory instruction. *Educational Sciences: Theory & Practice, 15*(1), 267-283.

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

Duschl, R. A. (1988). Abandoning the scientistic legacy of science education. *Science Education, 12,* 51-62.

Duschl, R. A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education, 38*(1), 39-72.

Erduran, S., & Jiménez-Aleixandre, M. P. (2007). *Argumentation in science education: perspectives from classroom-based research*. Dordrecht: Springer.

Erduran, S., Osborne, J., & Simon, S. (2004). Tapping into argumentation: developments in the application of toulmin's argument pattern for studying science discourse. *Science Education, 88*(6), 915-933.

Field, A. (2013). D*iscovering statistics using SPSS* (4th Edition) (p. 26). London: SAGE Publications.

Geban, O., Askar, P., & Ozkan, D. (1992). Effects of computer simulations and problem solving approaches on high school students. *Journal of Educational Research, 86*(1), 6-10.

Gultepe, N., & Kilic, Z. (2015). Effect of scientific argumentation on the development of scientific process skills in the context of teaching chemistry. *International Journal of Environmental and Science Education, 10*(1), 111-132.

Gurses, A., & Bayrakceken, S. (1996). *Deneysel fizikokimya [Experimental physical chemistry]*. Erzurum: Ekev Publishing.

Hand, B., Nam, J., & Choi, A. (2012). Argument-based general chemistry laboratory investigations for pre-service science teachers. *Quimica Education, 23,* 96-100.

Hofstein, A., Kipnis, M., & Kind, P. (2008). Learning in and from science laboratories: enhancing students' meta-cognition and argumentation skills. In C. L. Petroselli (Ed.), *Science education issues and developments* (pp. 59-94). New York: Nova Science Publishers.

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education, 88*(1), 28-54.

Jiménez-Aleixandre, M. P., & Erduran, S. (2007). Argumentation in science education: an overview, In S. Erduran & M. P. Jiménez Aleixandre (Eds.), *Argumentation in science education*, (pp. 3-28). Dordrecht: Springer.

Katchevich, D., Hofstein, A., & Mamlok-Naaman, R. (2013). Argumentation in the chemistry laboratory: inquiry and confirmatory experiments, *Research in Science Education, 43*(1), 317-345.

Katchevich, D., Mamlok-Naaman, R., & Hofstein, A. (2014). The characteristics of open-ended inquiry-type chemistry experiments that enable argumentative discourse. *Sisyphus - Journal of Education, 2*(2), 74-99.

Kaya, B. (2009). Arastirma temelli ogretim ve bilimsel tartisma yonteminin ilkogretim ogrencilerinin asitler ve bazlar konusunu ogrenmesi uzerine etkilerinin karsilastirilmasi [A comparison of effects of teaching interventions designed in the line of inquiry-based learning and scientific argumentation on primary school students' learning acids and bases] (Master's thesis). https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp (Thesis no. 231850).

Kaya, O. N., Dogan, A., & Kilic, Z. (2005). University students' attitudes towards chemistry laboratory: Effects of argumentative discourse accompanied by concept mapping. *Gazi University Journal of Gazi Educational Faculty, 25*(2), 201-213.

Kind, P., Wilson, J., Hofstein, A., & Kind, V. (2010, March). *Stimulating peer argumentation in the school science laboratory: exploring the effect of laboratory task formats.* Paper presented at the meeting of the National Association for Research in Science Teaching, Philadelphia, USA.

Klopfer, L. E. (1969). The teaching of science and the history of science. *Journal of Research for Science Teaching, 6,* 87-95.

Maloney, J., & Simon, S. (2006). Mapping children's discussions of evidence in science to assess collaboration and argumentation. *International Journal of Science Education, 28*(15), 1817-1841.

Mamlok-Naaman, R., & Barnea, N. (2012). Laboratory activities in Israel. *Eurasia Journal of Mathematics, Science & Technology Education, 8*(1), 49-57.

McMillan, J. H., & Schumacher, S. (2014). *Research in education: evidence-based inquiry* (pp. 298-300) (Pearson new international edition). Essex: Pearson Publishing.

McNeill, K. L., Lizotte, D. J., Krajcik, J., & Marx, R. W. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *Journal of the Learning Sciences, 15*(2), 153-191.

Millar, R., & Osborne, J. (1998). Beyond 2000: Science education for the future. Retrieved from http://www.nuffieldfoundation.org/sites/default/files/Beyond%202000.pdf

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

Osborne, F. J. (2009). An argument for arguments in science classes. *Phi Delta Kappan 91*(4), 62-65.

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

Ozdem, Y. (2009). *The nature of pre-service science teachers' argumentation in inquiry-oriented laboratory context.* (Master's thesis). https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp (Thesis no. 250714).

Ozdemir, T. Y., Boydak Ozan, M., & Aydogan, I. (2013). Influences of Multimedia Lesson Contents On Effective Learning. *Educational Process: International Journal, 2*(1-2), 47-58.

Ozer, G. (2009). Bilimsel tartismaya dayali ogretim yaklasiminin ogrencilerin mol kavrami konusundaki kavramsal degisimlerine ve basarilarina etkisinin incelenmesi [Investigating the effect of scientific argumentation-based instruction approach on students' conceptual change and success concerning the concept of mole] (Master's thesis). https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp (Thesis no. 234771).

Sampson, V., & Clark, D. (2006). The development and validation of the nature of science as argument questionnaire (NSAAQ). Paper presented at the annual international conference of the national association of research in science teaching, San Francisco.

Sekerci, A. R., & Canpolat, N. (2014). Impact of argumentation in the chemistry laboratory on conceptual comprehension of Turkish students. *Educational Process: International Journal, 3*(1-2), 19-34.

Summerlin, R. L., & Ealy, B. J. (1985). *Chemical demonstrations: a sourcebook for teachers* (Vol 1) Washington, District of Columbia: American Chemical Society.

Shieh, CJ., & Demirkol, M. (2014). Evaluation of the Effectiveness of Social Networks and their Usage by High School Students. Educational Process: International Journal, 3(1-2), 7-18.

Tekeli, A. (2009). *Argumantasyon odakli sinif ortaminin ogrencilerin asit-baz konusundaki kavramsal degisimlerine ve bilimin dogasi kavramalarına etkisi* [The effect of an argumentation-centered class environment on the conceptual change about acid-base and the understanding nature of science] (Master's thesis). https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp (Thesis no. 234446).

Ulucinar Sagir, S. (2008). *Fen bilgisi dersinde bilimsel tartısma odaklı ogretimin etkinliginin incelenmesi* [Investigation of effectiveness of argumentation theory based teaching in science courses] (Doctoral dissertation). https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp (Thesis no. 218463).

Walker, J. (2011). *Argumentation in undergraduate chemistry laboratories*. (Doctoral dissertation). Available from ProQuest Dissertations and Theses database. (UMI No. 3477280).

Walker, J., Sampson, V., Grooms, J., Anderson, B., & Zimmerman, C. (2010). *Argument-driven inquiry: An instructional model for use in undergraduate chemistry labs*. Paper presented at the 2010 Annual International Conference of the National Association of Research in Science Teaching (NARST). Philadelphia, PA.

Walker, J., Sampson, V., Grooms, J., & Zimmerman, C. (2011). Argument-driven inquiry: An introduction to a new instructional model for use in undergraduate chemistry labs. *Journal of Chemical Education, 88*(8), 1048-1056.

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

Yesiloglu, S. N. (2007). *Gazlar konusunun lise ogrencilerine bilimsel tartısma (argumantasyon) odakli yontem ile ogretimi [Teaching gases topic to high school students trough argumentation]*. (Master's thesis). https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp (Thesis no. 207016).

Yılmaz, K. (2013). 10 soruda 4+4+4 eğitim sistemi. *Üniversitepark Bülten, 2*(2).

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