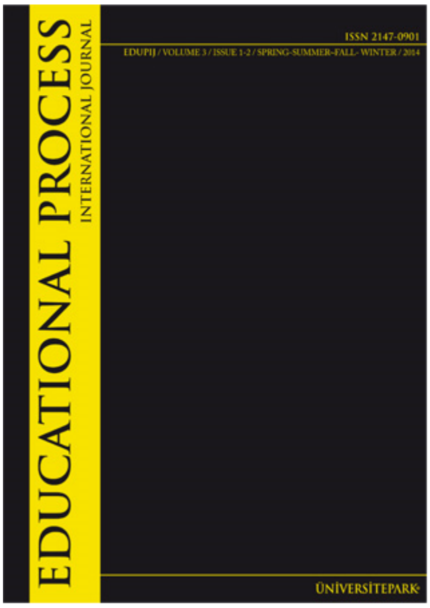

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Impact of Argumentation in the Chemistry Laboratory on Conceptual Comprehension of Turkish Students

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Abstract

Aim of this research is to evaluate the impact of argumentation in the chemistry laboratory on conceptual comprehension of students. This research follows a triangulation design, categorized under mixed-method design variations, which include both qualitative and quantitative research designs. The research is conducted with 91 first grade university students studying in two different classes of the Department of Science Education, Kazım Karabekir Education Faculty at the Ataturk University, located in eastern Turkey. One class was randomly designated as the experimental group, with another as the control group. Research data was collected via a General Chemistry Laboratory Concept Test (GCLCT) containing 33 items, a test containing ten open-ended items, a semi-structured interview form, and a written feedback form, all designed by the researchers. Data from the GCLCT were analyzed through predictive statistics method, while data from the open-ended questions, semi-structured interview and written feedback form were analyzed through the descriptive analysis method. It is concluded from this research, that there is statistically significant difference between the GCLC post-test averages of the experimental and control groups. It was found that when compared to the control group, the proportion of experimental group students who answered the GCLC post-test items correctly is higher. In addition to this, the proportion of students who demonstrated misconceptions were higher in the control group students compared to the experimental group. It is concluded by this research, that argumentation provides more effective results in terms of comprehension of fundamental chemistry concepts, when compared to a traditional approach.

Keywords: argumentation, chemistry laboratory, conceptual comprehension, mixed design.

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Introduction

Science may be considered an interactive process in which claims are discussed and evidence-based knowledge is reviewed together with these claims (Driver, Newton, & Osborne, 2000). In order to establish such a process, science-literate individuals who critically seek for validity of claims, query, and know how the information is acquired are needed. Such science-literate individuals should have excitement of understanding the real world and a 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 (National Research Council [NRC], 1996).

In order to develop science-literate individuals in teaching media, it is reported in various studies that utilization of learning approaches like collaborative learning (Fang & Wei, 2010; Guo, 2007; Lederman et al., 2014), problem based learning (Allen, Duch, & Groh, 1996), and 5E (Harlen, 2009; Skamp & Peers, 2012) instructional active learning methods provides effective results.

Argumentation is yet another commonly referred approach in recent years that enhance students' science literacy (Driver, Newton, & Osborne, 2000; Duschl & Osborne, 2002; Erduran & Jiménez-Aleixandre, 2007). Argumentation has benefits in terms of improving their conceptual comprehensions, their research skills, scientific epistemology, and their understanding of science as a social application and developing a positive attitude towards science (Driver et al., 2000; Tumay & Koseoglu, 2011).

Nowadays, argumentation is becoming increasingly essential in science education. This situation has led to a significant number of research studies completed on argumentation’s influence on science education, both at national and international levels (Aufschnaiter, Erduran, Osborne, & Simon, 2008; Aydeniz, Pabuccu, Cetin, & Kaya, 2012; Cetin, 2014; Dawson & Venville, 2010; Demircioglu & Ucar, 2012; Demircioglu & Ucar, 2015; Eskin & Ogan-Bekiroglu, 2013; Eskin & Bekiroglu, 2009; Groom, Sampson, & Golden, 2014; Gultepe & Kilic, 2013; Kaya, 2012; Yalcin Celik, 2010).

These research are mainly conducted within theoretical courses, emphasizing significant contributions to students' conceptual comprehensions by argumentation. In laboratory courses, there has been only one study that examined the effects of argumentation students' conceptual understanding (Hand, Nam, & Choi, 2012).

However, this research did not study the in-depth conceptual understanding of students. There is no existing research that deals with argumentation in terms of conceptual comprehension of students on laboratory courses. Research conducted in laboratory environments has examined the development of students' argumentation skills (Groom et al., 2014) in chemistry laboratories via open-ended inquiry and confirmatory tests (Katchevich, Hofstein, & Mamlok-Naaman, 2013; Katchevich, Mamlok-Naaman, & Hofstein, 2014), the influence of argumentation on students' understanding of nature of science, their argumentation and quizzical skills (Walker, 2011), and students' argumentational qualities (Kind, Wilson, Hofstein, & Kind, 2010; Kind, Kind, Hofstein, & Wilson, 2011).

In the present study considers the chemistry laboratory on students' conceptual understanding of argumentation aimed at in-depth examination. In parallel with this aim, the research aims to see whether or not there is a statistically significant difference between conceptual understanding of argumentation-based experimental group students, and control group students treated with traditional methods of education.

Methodology

Triangulation design categorized under mixed-method design variations, which include both qualitative and quantitative research designs, has been applied. In triangulation design, quantitative and qualitative data collection techniques are used simultaneously for data acquisition (Buyukozturk, Kilic Cakmak, Akgun, Karadeniz, & Demirel, 2012; McMillan & Schumacher, 2014). Then, quantitative and qualitative data are analyzed comparatively, monitoring to see whether or not they support each other (Creswell, 2002, 2012; Creswell & Plano Clark, 2007). In this approach, weaknesses and strengths of quantitative and qualitative data are complemented with each other, ensuring more reliable results. This method is also used in order to compare similarities and contrasts of statistical quantitative and direct qualitative data, or to extend or validate qualitative data with quantitative data (Creswell & Plano Clark, 2007).

The study group for the research was formed of 91 first grade university students studying in two different classes of the Department of Science Education in the Kazım Karabekir Education Faculty at Atatürk University, located in eastern Turkey. The course the students were taking is titled "General Chemistry Laboratory-II". One of the classes is designated as the experimental group and the other as the control group. There are 47 students (33 females and 14 males) in the experimental group, and 44 students (as 34 females and 10 males) in the control group. Students' ages in the experimental group vary between 19 and 24, while students' ages in the control group vary between 18 and 27.

The study group was chosen via convenience sampling method (of random sampling methods) (Buyukozturk et al., 2012; McMillian & Schumacher, 2014). Convenience sampling is a method that avoids loss and wastes of time, money, and labor force. The most important aspect of convenience sampling method is easy-accessibility of samples, and its convenience and suitability for the relevant research. Despite this, convenience sampling method's demerit is the generalization of research-based results to the population (McMillan & Schumacher, 2014).

Research data are collected via different data collection tools depending on the questions and aim of the research. Data acquisition in this research is handled depending on 'data diversity' principle via General Chemistry Laboratory Conceptual Test (GCLCT), semi-structured interviews, an open-ended test containing ten items and a written feedback form. In this way, the aim is to get beyond the limits of data collection techniques and increase validity and reliability of the findings (Creswell, 2012). GCLCT is formed by researchers taking into account the tests in relation with pH, hydrolysis, acid-base titration, colligative properties such as freezing point depression, factors affecting reaction rate, factors affecting chemical equilibrium and collectibility of reaction heats provided during the General Chemistry Laboratory-II course. Test items are created pursuant to acquisitions given in relation to the mentioned topics. During this stage, researchers created a 33-item test following evaluation of national and international dissertations, papers, general chemistry books, and chemistry test books (Canpolat et al., 2009; Ebbing & Gammon, 2009; Huddle, 1998; Pinarbasi, 2002; Thorpe, 2006; Zumdahl & Zumdahl, 2007), and websites. Misconceptions commonly experienced among students are used as distractors while the GCLCT items are designed. A table of specifications was designed to check the GCLCT's content validity and the questions' scientific accuracy, and to determine convenience of each inquiry according to target acquisitions and cognitive learning degrees of Bloom's revised taxonomy (Kogce, Aydin, & Yildiz, 2009; Krathwohl, 2002). Tests based on the table of specifications was evaluated by eight professors who are specialists in the field of chemistry teaching, and their opinions subsequently taken into account. In line with the feedback from professors, the GCLCT was revised. Content validity of the test has been ensured via evaluation based on the table of specifications, while content accuracy of the test has been ensured via evaluation based on expert opinion. In order to identify the reliability of the GCLCT, the test was applied to a total of 181 students who took the General Chemistry-II and General Chemistry Laboratory-II courses and are now in the 2nd grade of the Department of Science Teaching and the 2nd, 3rd and 4th grade of the Department of Chemistry Teaching at Ataturk University. Scoring is '1' for true answers and '0' for false or blank answers. The reliability coefficient of the GCLCT (KR-20) is determined as .583, using SPSS/PC (Statistical Package for Social Sciences for Personal Computers). Reliability coefficient for tests containing conceptual inquiries might be identified as low. Even so, a reliability coefficient of around .50 could be accepted for teacher-made tests (Frisbie, 1988). GCLCT is applied as both a pre-test and post-test for the experimental group and the control group as well.

A test of 10 open-ended items, some of which contain sub-queries, was designed in order to determine conceptual comprehensions of students in the argumentation-based experimental group and the control group that followed traditional education methods. This test was implemented on both experimental and control group students within three weeks following the application. In order to determine students' conceptual comprehensions, semi-structured interviews were also performed. For this purpose, a semi-structured interview form was designed and utilized by researchers. A semi-structured interview would provide flexibility depending on individuals and cases, and opportunity to change the order of the questions and explain questions in detail. Face-to-face semi-structured interviews were held three weeks following the application with six students, chosen as having low (2), medium (2) and high (2) conceptual success based on their GCLC post-test results from both the experimental and control groups. Students' voices were recorded with permissions taken prior to the interviews. All semi-structured interviews lasted approximately 25 minutes. A written feedback form was designed to determine the experimental group students' opinions on the argumentation, how it works, and how it is practiced after implementation.

Application is performed in two first grade classes of the General Chemistry Laboratory-II course within the Department of Science Teaching of Kazım Karabekir Education Faculty, Ataturk University. One of the classes is randomly designated as the experimental group and the other is as the control group. Argumentation is used for the experimental group and the traditional education approach is used for the control group during the tests within the research. Since the control group students are not familiar with argumentation-based tests, an informatory presentation is shown with the intention of ensuring they had sufficient knowledge on this approach. Furthermore, a test was conducted to enable them to gain experience relevant to this approach. The same test was applied to the control group students through the traditional approach. Then, 7 tests were conducted within the scope of this research on both the experimental and control groups.

Tests applied during application include:

- pH, hydrolysis and acid-base titration (Alkan, Bayrakceken, Gurses, & Demir, 1997),
- colligative properties: Freezing point depression (Gurses & Bayrakceken, 1996),

- factors affecting reaction rate and collectibility of reaction heats (Bayrakceken, Gurses, & Doymus, 1999),
- Variants affecting chemical equilibrium (concentration and temperature) (Canpolat, 2002; Summerlin & Ealy, 1985).

Research papers are argumentation designs for experimental groups based on these tests. Tests were applied as argumentation. Tests were applied to the experimental group following particular application guides. But for the control group, most of the tests were applied as they are at source, and some of them were applied with minor modifications. Each of the tests were applied in one week during the application process. Tests were conducted in both groups within the times of the two courses. Applications in both the experimental and control groups were guided by the same professor. Researchers served as participant observer during the application.

Data from GCLCT were analyzed via predictive statistical approach. Data from this test was statistically analyzed using SPSS/PC. In order for post-determination of normality of score distribution relevant to each of the tests, box-plot, Q-Q plot, Shapiro-Wilks test and skewness value "z" obtained through division of skewness coefficient by standard error (z_s) are taken into consideration and z_s values of each test are reported. Distribution may be accepted normal if skewness value (z_s) is found lower than 1.96 on .05 significance level, 2.58 on .01 significance level and 3.29 on .001 significance level (Field, 2013).

Table 1. z_s values by GCLC pre-test and post-test scores

	Experimental Group(EG)	**Control Group(CG)**
	$\mathbf{z_s}$	$\mathbf{z_s}$
Pre-test	.406	.305
Post-test	1.02	.048

Skewness coefficient (SC), standard error of skewness coefficient (SE_s)

It is understood from the z_s values of Table 1 that pre-test and post-test scores of both groups demonstrate normal distribution. As pre-test and post-test scores of the test applied to both experimental and control groups demonstrate normal distribution, independent t-test is applied. All predictive statistical analyses are tested against a .05 significance value.

Descriptive analysis method is used for analysis of the open-ended questions and semi-structured interview data. Data derived from open-ended questions and semi-structured interviews were analyzed and divided into five categories of clear understanding, partial understanding, misconception, incomprehension and blank/unanswered (Abraham, Grzybowski, Renner, & Marek, 1992; Abraham, Williamson, & Westbrook, 1994; Demircioglu, 2008; Demircioglu, Demircioglu, Ayas, & Kongur, 2012). Categories used for analysis of open-ended questions and interviews and their explanations are provided in Table 2.

Table 2. Categories used for analyses of open-ended questions and interviews, and their explanations

Categories (Levels of Understanding)	Explanations
Clear Understanding	Answers containing all aspects of the anticipated answer
Partial Understanding	Answers containing only one aspect of the anticipated answer Answers containing particular aspects and particular misconceptions of the anticipated answer
Misconception	Scientifically incorrect answers
Incomprehension	Repetition of inquiry, irrelevant or unclear answers
Blank/Unanswered	Left blank I don't know or I didn't understand

The frequency and percentage values of data derived from analyses of semi-structured interview and open-ended questions are presented in tabular format. In descriptive analyses, qualitative software named Nvivo is used for category designs. Nvivo is computer software that enables the storage of various documents in a single place, and facilitates interlinking documents, ensuring easy operation of the processes during the analysis (Walsh, 2003).

Findings

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

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

	Group						95% CI for Mean Difference		
	Experimental			Control					
	M	SD	n	M	SD	n		t	df
Pre-test	8.45	2.44	47	7.59	2.47	44	-1.88, .17	-1.66	89
Post-test	18.98	3.88	47	14.75	2.80	44	-5.65,-2.80	-5.92*	89

*p < .05

A statistically insignificant difference is found between the experimental and control groups' GCLC pre-test mean scores, as represented in Table 3 ($t(89)= -1.659$; $p > .05$). On the other hand, a statistically significant difference is found between the experimental and control groups' GCLC post-test mean scores ($t(89)= -5.916$; $p= .000$). As may be understood from the analysis results, the experimental group's GCLC post-test mean scores (M= 18.98, SD=3.88) are higher than for the control group's GCLC post-test mean scores (M= 14.75, SD= 2.80). In order to determine how effective argumentation is on the experimental group students' conceptual comprehensions, its effect sizes (d) are referred. For effect sizes, .01 is interpreted as little effect, .05 as intermediate effect and .08 as strong effect (Cohen, 1988, 1992; Buyukozturk et al., 2012). For the GCLC post-test, effect size of argumentation-based teaching is calculated as Cohen's d= 1.24. It may be interpreted that argumentation is strongly effective on students' conceptual comprehensions. Notwithstanding, these results reveal that the experimental group is more successful than the control group, in terms of general chemistry concepts relevant to the conducted tests. As a result, it may be interpreted that argumentation is more effective than traditional approach in the case of comprehension of general chemistry concepts. This may also be clearly understood from the proportion of experimental and control group students giving true answers in the GCLC post-test, as demonstrated in Table 4, and the proportion of experimental and control group students who made misconceptions in the GCLC post-test as shown in Table 5.

Table 4. Proportion of experimental and control group students who gave true answers in GCLC post-test

Topics	Item	EG (%)	CG (%)
Acid-base	1	70.2	36.4
	2	44.7	27.3
	3	85.1	43.2
	4	12.8	18.2
	5	63.8	59.1
	6	44.7	50.0
	7	36.2	11.4
	8	46.8	27.3
	9	91.5	79.5
	10	31.9	31.8
	11	63.8	34.1
Colligative properties: Freezing point depression	12	85.1	75.0
	13	34.0	4.5
	14	8.5	13.6
	15	61.7	38.6
	16	46.8	29.5
	17	80.9	54.5
Factors affecting reaction rate (concentration, temperature and contact surface)	18	74.5	72.7
	19	70.2	61.4
	20	87.2	95.5
	21	38.3	13.6
Variants affecting chemical equilibrium (concentration and temperature)	22	66.0	38.6
	23	27.7	27.3
	24	59.6	68.2
	25	89.4	77.3
	26	29.8	34.1
	27	53.2	59.1
	28	42.6	27.3
Collectibility of reaction heats	29	66.0	38.6
	30	53.2	52.3
	31	29.8	6.8
	32	87.2	77.3
	33	93.6	86.4

When Table 4 is evaluated, it is found that when compared to the control group, the proportion of experimental group students who gave true answers to the GCLC post-test items is higher.

Table 5. Proportion of experimental and control group students who have misconceptions in GCLC post-test

Topics	Misconceptions	EG (%)	CG (%)
Acid-base	For weak acid-strong base titration, pH of environment in equivalence point is 7.	14.9	45.5
	An acidic indicator may be used for monitoring inflexion point for weak acid-strong base titration.	14.9	11.4
	Equivalence point and end point are the same.	12.8	40.9
	In titration, if acid or base is weak, full neutralization does not occur.	12.8	13.6
	Concentration is a measurement of acidity-alkalinity strength.	46.8	65.9
	Salts are neutral.	12.8	25.0
	A substance should have "H" in its structure in order to demonstrate acidic character, or should have "OH" for basic character.	27.7	45.5
Colligative properties: Freezing point depression	When a non-volatile substance is dissolved in pure water, steam pressure of the solution goes higher in comparison with the pure water.	6.4	11.4
	Since particles of the solute retain solvent molecules and inhibit transition to solid phase, freezing point changes.	34.0	40.9
	A solution shall freeze in a temperature between freezing points of solvent and solute, freezing point changes.	21.3	31.8
	Since density changes if solute is added, the freezing point will change.	10.6	20.5
	Temperature of a solution remains still at freezing point, because in the first instance solvent freezes and then solute freezes in the freezing phase of the solution.	38.3	11.4
	Due to the heat exchange between solvent and solute, temperature of the solution does not remain unchanged while freezing.	46.8	56.8
	Since molal concentration increases due to the temperature increase, molal concentration is utilized for the calculations relevant to colligative properties.	31.9	53.5
	Degree of change for the aqueous solutions depends on load, quantity and size of the particles in solution.	27.7	45.5
Factors affecting reaction rate	A solid substance does not influence reaction rate, in the case of solid reacting with acid.	51.1	63.6
	Catalyst does not change activation energy.	2.1	20.5

Topics	Misconceptions	EG (%)	CG (%)
Variants affecting chemical equilibrium	In an equilibrium-reaction, concentrations of reactants and products are equal.	31.9	25.0
	In equilibrium position, rate of forward reaction is higher than backward reaction.	21.3	18.2
	When temperature of an equilibrium-exothermic reaction increases, value of K_c (equilibrium) constant increases.	6.4	13.6
	When temperature of an equilibrium-exothermic reaction increases, value of K_c constant remains unchanged.	36.2	29.5
	If product is added to the equilibrium-system providing constant temperature, value of K_c increases.	12.8	22.7
Collectibility of reaction heats	Strong acid-base neutralization heats are approximately the same, because energies of the refracted bonds are the same.	23.4	34.1

When answers given to the GCLC post-test (Table 5) are evaluated, it is understood that the proportion of control group students demonstrating misconceptions are higher than for the experimental group. It is seen that particular mistakes mostly remain in both experimental and control groups despite teaching. It is identified that, in acid-base topic, 46.8% of experimental group students and 65.9% of control group students say *"concentration is a measurement of acidity-alkalinity strength"* as a misconception. Colligative properties: In the topic of freezing point depression, it is identified that 56.8% of control group students and 46.8% of experimental group students say *"due to heat exchange between solvent and solute, temperature of solution does not remain unchanged while freezing"* as a misconception. In the topic of factors affecting reaction rate, it is identified that 51.1% of experimental group students and 63.6% of control group students say *"for a solid reacting with acid, amount of solid does not affect reaction rate"* as a misconception.

In order to deeply examine conceptual understandings of experimental and control group students in relation to the tests, a test formed of open-ended questions was applied to both groups and semi-structured interviews applied to six students from each group. Findings derived from answers given to the open-ended questions are presented in Table 6, findings from the interviews are presented in Table 7.

Table 6. Distribution of answers given to open-ended questions by categories

	Categories									
	Clear Understanding		Partial Understanding		Misconception		Incomprehension		Blank/Unaswered	
Items	EG (%)	CG (%)	EG (%)	CG (%)	EG (%)	CG (%)	EG (%)	CG (%)	EG (%)	CG (%)
1	63.83	40.91	19.15	25.00	6.38	34.09	10.64	-	-	-
2	25.53	11.36	25.53	22.72	36.17	54.56	10.64	11.36	2.13	-
3	36.17	4.54	29.79	31.82	2.13	45.46	31.91	13.64	-	4.54
4a	8.50	2.27	74.50	81.82	-	15.91	-	-	17.0	-

4b	36.17	15.91	-	13.64	27.66	63.63	29.79	6.82	6.38	-
4c	70.21	59.10	-	9.09	19.15	20.45	10.64	6.82	-	4.54
5	8.50	-	4.26	2.27	80.86	97.73	6.38	-	-	-
6	-	-	19.15	11.36	57.45	75.01	21.27	4.54	2.13	9.09
7	48.94	27.27	51.06	70.46	-	-	-	2.27	-	-
8a	40.44	20.45	31.91	40.91	14.89	31.83	12.76	2.27	-	4.45
8b	42.57	13.64	40.42	65.91	2.13	2.27	8.50	11.36	6.38	6.82
9a	51.08	15.89	6.38	31.83	31.91	45.46	8.50	6.82	2.13	-
9b	46.80	4.54	23.40	54.56	6.38	11.36	14.89	27.27	8.50	2.27
10a	30.38	27.27	6.38	4.54	-	6.82	55.32	59.10	-	2.27
10b	17.00	-	78.74	56.83	-	-	-	40.90	4.26	2.27

It may be understood from Table 6 that proportion of answers by experimental group students categorized under clear understanding is higher compared to control group students for almost all open-ended questions. In other words, it may be confirmed that experimental group students' answers for open-ended questions are more scientific compared to control group students. On the other hand, proportion of answers of experimental group students categorized under misconception is higher compared to control group for most of the open-ended questions.

Table 7. Distribution of answers given to questions included in semi-structured interview form by categories

Items	Categories									
	Clear Understanding		Partial Understanding		Misconception		Incomprehension		Blank/Unaswered	
	EG (f)	CG (f)	EG (f)	CG (f)	EG (f)	CG (f)	EG (f)	CG (f)	EG (f)	CG (f)
1a	4	1	2	5	-	-	-	-	-	-
1b	6	2	-	-	-	4	-	-	-	-
2	4	-	1	2	1	2	-	2	-	-
3a	4	-	2	3	-	1	-	-	-	2
3b	6	-	-	2	-	3	-	-	-	1
3c	6	2	-	-	-	2	-	-	-	2
4	-	-	3	-	-	-	2	3	1	3
5	2	-	-	1	1	1	3	2	-	2
6a	5	1	1	-	-	-	-	5	-	-
6b	6	2	-	-	-	-	-	1	-	3
6c	3	-	3	4	-	-	-	-	-	2
7a	6	2	-	4	-	-	-	-	-	-
7b	4	-	2	2	-	4	-	-	-	-
8a	2	2	3	1	-	-	-	2	1	1
8b	4	2	1	1	-	-	1	3	-	-

f: frequency

It may be understood from Table 7 that the frequency of answers by the experimental group students categorized under clear understanding is higher compared to the control group students. In other words, it may be confirmed that experimental group students' answers for interview questions are more scientific compared to control group students.

Although, it is seen that answers by experimental group students categorized under misconceptions are lower compared to control group students, it may be confirmed that control group students' answers are more scientifically false compared to those of the control group students.

Conclusion and Discussion

In the study conducted for analysis of influence of argumentation in the chemistry laboratory on students' conceptual understandings, argumentation is proven to be more effective in terms of comprehension of general chemistry concepts (conceptual comprehension) when compared to the traditional approach. This is also supported by the answers given by the experimental and control group students to the GCLC post-test, open-ended questions and semi-structured interviews. Percentage of true answers categorized under GCLC post-test topics given by experimental group students are higher, and their percentage of misconceptions are lower when compared to that of the control group students. It may be confirmed that the experimental group students' answers for open-ended questions and semi-structured interviews are more scientific compared to that of the control group students. Moreover, written feedback from the experimental group's students on argumentation and how it works support this statement. Some of the feedback by the students are shown as follows:

- "With General Chemistry Laboratory-II course, we sweep our parrot-fashion knowledge and learn convenient things."
- "General Chemistry Laboratory-II ensures a permanent learning."
- "Conducting tests by discussions helps learning be effective and permanent. Thus, learning the concepts become easy."
- "Due to researches carried out on topic tests, concepts are permanently learned."
- "I think discussions among test groups are for a good reason. It really helps us to learn permanently."
- "During the discussions prior to tests, we compared what we know and shared literature we have and mentioned our preferences, and we realized during tests that some of our jurisdictions are wrong, and saw at the end of the tests that what we acquired and what we shared was correct or else, all paving the way for us to the true answers."

Argumentation-based experimental group students are more successful compared to traditionally educated control group students, because:

- Students are encouraged to self-learn and self-research;
- Students are individually enabled to access a lot of information on test topics;
- Students are given the opportunity to share information they obtained during intra- and inter-group discussions;
- Students are given the opportunity to share, deeply examine and identify weaknesses and strengths of their ideas during intra- and inter-group discussions;
- Students develop and apply tests on their own, and link what they learned and tests;
- Students look from a different point of view towards circumstances depending on the ideas put forward during intra- and inter-group discussions.

It is reported in the literature that argumentation increases students' conceptual comprehensions in the case of different studies conducted on tertiary, secondary and elementary levels of education (Aydeniz et al., 2012; Demirci, 2008; Demircioglu & Ucar, 2015; Driver et al., 2000; Kaya, 2009; Hand et al., 2012; Jiménez-Aleixandre & Pereiro-Munhoz, 2002; Niaz, Aguilera, Maza, & Liendo, 2002; Osborne, Erduran, & Simon, 2004; Ulucinar Sagir & Kilic, 2012; Yalcin Celik & Kilic, 2014; Yerrick, 2000; Yesiloglu, 2007; Zohar & Nemet, 2002). Therefore, results of the studies already found in the literature and this present study comply with each other. Depending on the results of this study, impact of argumentation on students' conceptual comprehension related with different topics of chemistry in theoretical and laboratory courses may be examined. In addition to this, students should be familiar with relevant concepts concerning the topic in order to allege various arguments as intended. For this reason, a list of the concepts aimed to be comprehended should be included in the research sheets.

Notes

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