Implementation of Argument-Driven Inquiry as An Instructional Model in A General Chemistry Laboratory Course

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ABSTRACT: This study examined the effectiveness of Argument-Driven Inquiry (ADI) as an instructional model in a general chemistry laboratory course. The study was conducted over the course of ten experimental sessions with 125 pre-service science teachers. The participants' level of reflective thinking about the ADI activities, changes in their science process skills, changes in their argumentativeness, their ability to identify flaws in an argument and their views on ADI are assessed. Results show that the participants' oral and written remarks shed light on the effectiveness of the model and provide positive and negative characteristics associated with the model. Recommendations are put forward regarding the usability of the ADI model by professionals who may consider applying it in practice.

KEY WORDS: argumentation, critical thinking, inquiry based learning, laboratory instruction, pre-service science teachers

INTRODUCTION

In traditional laboratory classes, verification type experiments are designed and performed in a deductive manner and the general aim is to examine the related scientific principles, which were known in advance of the lesson. Studies have revealed, however, that traditional laboratory classes are not very effective in achieving a range of learning objectives, such as: science process skills, achievement and attitudes towards the subject matter (Chang, & Mao, 1999; Gormally, Brickman, Hallar, & Armstrong, 2009). In this context, inquiry-based activities and argumentation have gained importance (McDonald, 2013; Walker, Sampson, Grooms, Anderson, & Zimmerman, 2012).

 Including argumentation into the inquiry process is one of the ways in which students' conceptual attainments can be taken into account. Argument-Driven Inquiry (ADI) is a new instructional model, for which its effectiveness is still under investigation (Sampson & Gleim, 2009; Sampson & Walker, 2012; Walker, et. al., 2012). ADI aims at:

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- enabling students to determine their own method to make observations and measurements;,
- do their investigation, use their findings in order to answer a research question;
- share and defend their own opinions about the hypothetical and methodical framework;
- write the results of their investigation in a scientific way, and
- be more reflective as they work

(Walker, Sampson & Zimmerman, 2011).

ADI is seen as a challenging model for students to learn through inquiry and argumentation together. However, there are few studies related to ADI. This study focuses on investigating the effectiveness of ADI and identifying views of pre service science teachers about the ADI model.

Aim of the Study

The aim of this study was to determine ADI's usefulness as a model to train pre-service science teachers and to enable identification of :

- participants' levels of reflective thinking in the activities;
- changes in their science process skills and argumentativeness;
- their performance for identifying flaws in an argument, and
- their views on the model.

The study was undertaken by examining several variables using qualitative or quantitative approaches.

LITERATURE REVIEW

Argument-Driven Inquiry

The effectiveness of an inquiry-based approach has been analyzed over the last fifty years, whereas the effectiveness of argumentation has only been studied more recently. Nonetheless, studies on the implementation and effectiveness of ADI, which combines these two approaches, are even more recent and have largely taken place for the last eight years. When these studies are analyzed, it is seen that ADI is often examined in terms of its effects on argumentation abilities of students, the quality of the arguments they construct or their ability to write in science. Improvement of these skills can be associated with the argumentation process of ADI in general. Those which are associated with the inquiry process need also to be included in studies, in addition to the variables related to argumentation.

One study on the effectiveness of ADI in science undertaken by Sampson and Walker (2012) examined the effect of the model on students' ability to write in science. In the study, investigation reports, prepared by students on chemistry topics, were examined in terms of their overall

quality. Results of the study examined qualitatively and quantitatively, revealed that students' writing skills improved.

Another study conducted by Walker et al. (2012)was on the extent to which ADI enhanced students' conceptual understanding of concepts, argumentation skills and attitudes towards chemistry. These were examined in comparison with the traditional laboratory approach. According to the traditional approach, a chemistry laboratory session was seen as an environment where students usually practiced the theoretical concepts associated with chemistry, found opportunities to observe important chemical phenomena and gained the ability to use chemical tools, materials and substances in an appropriate and timely way (Domin, 1999). In Walker et al.'s (2012) study, although fewer experiments were performed in the group in which ADI was applied, it was surprising for the researchers to find out that conceptual understanding achieved in this group was close to what was achieved in the control group. Another finding of the study was that ADI was effective in enhancing the attitude of female students towards chemistry, compared with the traditional laboratory approach. Similarly, it was also identified that this model improving argumentation skills compared with the traditional laboratory approach.

A study on how ADI affected argumentation skills was conducted by Sampson et al. (2011), in which the model was examined in terms of its effect on students' abilities to participate in scientific argumentation and crafting a written argument. In the study, high school students were given written argument assignments at the beginning of the study and during the laboratory experiments, and then these assignments were assessed. According to the result of the study, students' ability to participate in scientific argumentations and to produce more qualified arguments were enhanced.

In Walker and Sampson's (2013) study, ADI's effectiveness on the quality of the written and oral arguments by students was examined. For this purpose, chemistry laboratory classes of post-secondary students were conducted using the ADI approach. Video recordings of the students' oral arguments and the reports prepared by them during the experiments were assessed. It was found that the argumentation skills of the students improved over time. In a similar study, ADI's effect on the quality of university students' arguments in socio-scientific issues was examined (Grooms, Sampson & Golden, 2014), in which the researchers compared the traditional approach with ADI, The students in the control group were found to produce better arguments.

Hasnunidah, Susilo, Irawati, and Sutomo (2015) investigated the effect of ADI and "ADI with scaffolding" on pre-service science teachers' argumentation and critical thinking skills. In the study, the researchers

found positive contributions of these instructional methods to the variables.

Under-researched Variables on which ADI may have an Effect

Students are usually busy in laboratories with activities like doing experiments, observing and measuring, following their peers and instructor. During these activities, they are expected to be reflective, that is to say, to think about what they are doing and apply personal change accordingly (McCollum, 2002). Students' active participation in the activities in the laboratory, their efforts to understand what is happening, questioning and comparing them with their own experience, and applying personal change, are associated with reflective thinking (Kember, McKay, Sinclair, & Wong, 2008). One of the aims of ADI, developed as an alternative to the traditional laboratory approach, is to enable students to be more reflective workers, in addition to enabling them to conduct an investigation and support their thoughts (Sampson & Grooms, 2008).

Through construction of specific learning environments in the laboratory, students can develop skills such as asking questions, critical thinking and metacognition (Katchevich et al., 2013). For instance, both inquiry and argumentation contribute to students' development of science process skills, since they allow them to arrive at conclusions with the help of experimental findings, or to build and support arguments based on different types of data (Unal-Coban, 2013). Accordingly, it can be expected that ADI can also impact on students' science process skills (Sampson & Gleim, 2009; Demircioglu & Ucar, 2015).

The personal characteristic of students and their environment are important factors related to varying communication skills. For this reason, students with poor communication skills can sometimes avoid constructing arguments. This can also affect the argumentation process in a negative way (Nusbaumm & Bendixen, 2003). Infante and Ranger (1982) refer to the tendency to argue or avoid the constructing of arguments as the level of argumentativeness. Argumentativeness, albeit seemingly like a personal characteristic, can be improved through promoting the number of arguments constructed by the students (Levine & Boster, 1991). Additionally, there is also a correlation between argumentativeness and explicit training on argumentation (Infante, 1982). It can be expected that ADI positively builds on students' argumentativeness, as it improves their argumentation skills.

An argument can be weak due to its bad structure, logical inconsistency and implicit assumptions (Cottrel, 2005). Producing a counter argument, as a natural step in argumentation, often requires assessment of the quality of that argument. Interrogation of the accuracy and validity of an argument, that is to say, assessment of an argument through the identification of its flaws, is accepted as an important aspect

of critical thinking (Chaffee, 2010; Cottrel, 2005). Noting ways of supporting students in critical thinking is one of the main objectives of science education (Bailin, 2002), through using the ADI instructional model in laboratory classes, students have opportunities for thinking critically through the structured process of constructing and assessing arguments.

METHODOLOGY

Research Method

Quantitative and qualitative methodologies were used to investigate the changes of participants' science process skills and argumentation skills during the course, their reflective thinking, ability to find flaws in an argument and views on ADI after the course.

The effectiveness of the model was demonstrated without a comparison with the control group, since the aim of the study was not to compare ADI with another instructional model. Therefore, this study sought to demonstrate the levels of, and changes in participants, in terms of different variables through applying a model.

Participants

The study was conducted with pre-service science teachers who attended a one-term general chemistry laboratory (GCL) course in the faculty of education in a state university in Turkey, during a two year period. In the GCL course, each laboratory instruction session lasted two hours per week and an experiment was performed during each session, totally involving 10 experiments throughout the term. The students worked in collaborative groups of 3-4 individuals.

The participants' laboratory lessons were conducted by two researchers and 125 pre-service science teachers (30 female, 95 male) participated in the study. Participant groups and the studied variables were as given in Table 1. In the formation of the working groups, students' willingness to work together was taken into account regardless of their gender, previous knowledge and their level of success in chemistry. There were a few exchanges of participants between groups during the study. The participants were concurrently enrolled in a general chemistry course, in addition to the laboratory classes.

Table 1.   Participant Groups and the Variables Studied

Years	Participants	N	Variables Studied
First	Group 1	22	(i) Reflective Thinking, (ii) Identifying Flaws in an
	Group 2	32	Argument and (iii) Views of Participants
	Group 3	20	

| Second | Group 4 | 22 | Variables dealt within the first year, plus |
| | Group 5 | 29 | additionally (iv) Science Process Skills and (v) Argumentativeness |

Implementation of ADI in GCL

Ten verification type experiments, which had been performed in previous years' GCL classes, were transformed into inquiry experiments by the researchers and were processed in accordance with ADI. For this transformation process, a research question, which could be answered and discussed by the participants after performing the experiment, was generated for each experiment. The ten experiments and theirresearch questions were as given in Table 2.

Table 2.   Experiment List and Guiding Questions for ADI Approach

Expt.	Topic	Guiding question at first step of ADI
1	Particulate structure of matter	How might the submicroscopic structure of the matter be considered?
2	Physical and Chemical Changes	What are the basic differences between physical and chemical changes?
3	Chemical Reactions	What are the types of chemical reactions?
4	Stoichiometry	What are the percentages of $KClO_3$ and KCl in the mixture provided?
5	Distillation	How do the temperature and the composition of a homogenous liquid mixture change during the distillation?
6	Determination of molecular mass usingfreezing point depression	What is the molar mass and the particulate structure of elemental sulfur?
7	Determination of the molar mass of a metal	What is the name of the metal used in the reaction that reacts with hydrochloric acid?
8	Boyle's law	What is the relationship between the pressure and volume of an amount of gas at a constant temperature?
9	The rate of chemical reactions	What is the effect of the catalyst on the chemical reaction rate?
10	Chemical equilibrium	Which variables affect the chromate/dichromate equilibrium and in what way?

ADI was undertaken using the following seven steps:

Step 1 (identification of the task): At the beginning of the lesson, participants were introduced to the research question. They were then asked to design an experiment in order to answer this question.

Step 2 (generation of data): Participants formed groups of three or four and planned the experiment through group discussions. They decided how to collect data and which observations and measurements to take.

Step 3 (production of a tentative argument): After performing the experiment, students prepared an A3 paper size presentation sheet, which included the research question and the components of their argument like the claim, evidence and justification, in order to present their arguments to the other groups and support them. An example of a presentation sheet was as given in Figure 1.

Step 4 (interactive argumentation session): Drawing on the presentation sheets, argumentations took place between the groups. This step was performed in two ways in the various classes:

(i) In some lessons, each group presented their argument to the other groups, who were given an opportunity to refute the argument of that group.

(ii) For some experiments, all groups went to other groups to listen to their arguments (leaving one person in the group) and in so doing tried to refute the arguments of the other groups. The groups reviewed their argument after listening to the arguments of other groups and revised it, if needed. In both cases, a mutual argument, accepted by all participants, was constructed at the end of the lesson.

Step 5 (creation of a written investigation report): Participants prepared an investigation report in their extracurricular time, explaining their research on an individual basis.

Step 6 (double-blind peer review): At the beginning of the next lesson, these reports were assessed by their peers, according to an assessment criteria list developed by Sampson and Gleim (2009).

Step 7 (the revision process): Participants were asked to revise and complete their reports according to the feedbacks obtained from the assessments.

Figure 1.   An example of presentation sheet

Data Sources and Analysis

The study was conducted over a two years period. As the results in the first yearwere as expected, in terms of the variables studied, the second year involved, additionally, the investigation of science process skills and argumentativeness variables. A reflection questionnaire, a science process skills scale and an argumentativeness scale were used as quantitative data sources, while an activity for identifying flaws in an argument about Boyle's law and participant views on ADI were used as qualitative data sources in the study.

The Reflection Questionnaire (RQ)

This instrument was originally developed by Kember, Wong, Sinclair and McKay (2000) in order to measure participants' level of reflective thinking. The questionnairewas composed of four dimensions:habitual-action (no-reflection), understanding, reflection, and critical reflection. These dimensions represent the levels of reflective thinking in an ascending order.

The original questionnaire comprised 16 items,answered using a 5-point Likert scale. The adapted version of the questionnaire used by the authors in this study in Turkish was applied to the participants at the end

of GLC.The instrument was deemed to satisfy the acceptable levels of validity. When explanatory factor analysis was applied to the items with AMOS software, the dimensions identified gave the anticipated four factor model. As expected from high validity scales, the calculated value of chi-square ($\chi^2(71)=164.49$) was low, and the value of CFI (=0.89) was high. Reliability coefficients of the habitual-action, understanding, reflection, and critical reflection dimensions were identified respectively as follows: $\alpha = 0.56$; $\alpha = 0.80$; $\alpha = 0.78$; $\alpha = 0.80$. These values were indicators of very good reliability, according to Kline (2011).

Science Process Skills Scale (SPSS)

The original instrument was developed by Okey, Wise and Burns (1982). Its translation and adaptation to Turkish language was undertaken by Geban, Askar and Ozkan (1992) and consisted of 36 multiple choice items with four options. The five sub-sections of the instrument aimed to test dimensions of science process skills as: *individual ability for identifying variables in the problem*, *constructing and defining a hypothesis*, *locating operational descriptions*, *designing necessary examination for the problem solving*, and *drawing graphs and interpreting data*. Validity of the test wasdeemed to be high and its reliability was calculated as (KR20) 0.82. The instrument wasgiven to the participants before and after the implementation.

Argumentativeness Scale (AS)

This instrument comprised 20 Likert type items, originally prepared by Infante and Ranger (1982) in order to identify students' willingness to undertake, or avoid producing an argument. The instrument was adapted for use in Turkey by Kaya and Kilic (2008) and included two types of question sets in the instrument related to an inclination to and avoidance of producing an argument. The score from the instrument was determined by subtracting the score of avoidance of producing an argument from the score of the inclination to produce an argument. The validity of the instrument was   determined by factor analysis, and the reliability coefficient of the inclination to create argument dimension was calculated as $\alpha = 0.70$, while avoidance of creating argument dimension was determined as $\alpha = 0.83$. The instrument was applied to the participants before and after the implementation.

Activity for Identifying Flaws in an Argument about Boyle's Law:

Being able to identify flaws in an argument indicated critical thinking ability. Various flaw types, such as falsely assuming a causal relationship, constructing incorrect affinities or overlooking necessary conditions in an argument, were mentioned in the literature (Cottrell, 2005). In this study,

the participants were invited to identify the flaws that occurred when the given information could not support the presented claim (Glassner & Schwarz, 2005).

This activity was applied to the participants after the related experiment was performed. In the activity, participants were asked to read the following expression about Boyle's Law and identify its flaws.

> A person claims that "as the pressure increases, the volume of air confined in an injector can be continuously reduced proportionally to the pressure applied from outside". In support of this argument the person asserts the following information:
>
> "According to Boyle's Law, there is an inverse relationship between the volume and the pressure of an amount of gas at a constant temperature (P α 1/V), that is to say, the pressure-volume product is constant (P. V = k)."

The number of valid flaws generated by the participants was identified through content analysis. Flaws regarding an argument about Boyle's Law, generated by the participants, were found to fit seven clusters, as follows:

- Air is not always a gas at all pressures.
- After a certain point, the volume of air is does not change, even if the pressure increased.
- The product of pressure and volume for air cannot be constant in all situations.
- Air is not an ideal gas.
- Pressure and volume measures with practical validity cannot be obtained for air.
- The temperature cannot be constant throughout the entire experiment.
- The amount of air cannot be constant throughout the entire experiment.

The level of consistency between the scorings by two researchers, in relation to the number of flaws generated by the participants, was 87.5% (Cohen's Kappa 0.78). This result indicated that there was a good level of consistency between the two raters (Landis & Koch, 1977).

Participant Views on ADI Activities

Interviews and written essay assignments were used in the identification of participants' views on the instructional model. Participants volunteered to be interviewed at the end of the first year of the ADI activities. Interviews, lasting 10 minutes, were carried out with 10 selected participants. Interviewees were asked about the way in which GCL lessons were conducted, and the function of argumentation and inquiry in learning chemistry in the laboratory. At the end of the second year, all

participants were asked to write an essay on the perceived contribution of the ADI approach used in GCL towards their personal development.

Interviews and written essay assignments were assessed by both of the researchers through content analysis. Themes regarding participants' views on ADI were identified, drawing on the expressions used in the interviews and the essays. Reliability of the findings was based on the inter-rater agreement (Cohen's Kappa 0.83 for interviews and 0.81 for written essay assignments). Inconsistencies with the interview recordings and the essays were removed, after negotiations among the researchers.

FINDINGS

Group means for the sub-dimensions of reflective thinking were as presented in Figure 2. Using one-way ANOVA we found no significant difference between the participant groups in terms of their means for each sub-dimension of reflective thinking (habitual action $F(4.114)=0.873$, $p>0.05$; understanding $F(4.114)=1.298$, $p>0.05$; reflection $F(4.114)=1.699$, $p>0.05$; critical reflection $F(4.114)=2.208$, $p>0.05$).Thus it was claimed, participant groups were statistically equivalent in terms of the sub-dimensions of the RQ.
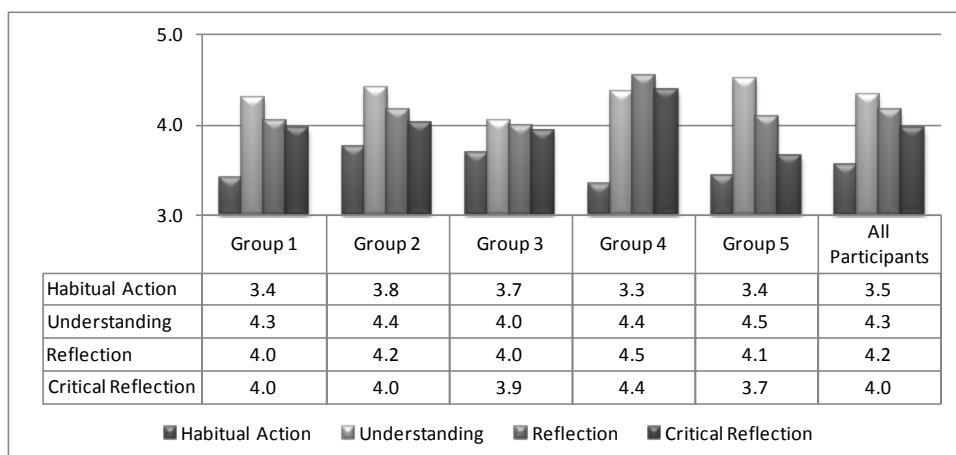

	Group 1	Group 2	Group 3	Group 4	Group 5	All Participants
Habitual Action	3.4	3.8	3.7	3.3	3.4	3.5
Understanding	4.3	4.4	4.0	4.4	4.5	4.3
Reflection	4.0	4.2	4.0	4.5	4.1	4.2
Critical Reflection	4.0	4.0	3.9	4.4	3.7	4.0

■Habitual Action ▨Understanding ▨Reflection ■Critical Reflection

Figure 2. **Means of reflective thinking sub-dimensions for the participant groups**

When the data for all participant groups were taken into account, significant differences were identified between the RQ sub-dimension means through repeated measures ANOVA test [$F(3.118)=.202$, $p<0.05$]. A post-hoc analysis was performed in order to identify the specific sub-dimensions of reflective thinking among those for which this difference

occurred. Significant differences were found between all of the sub-dimensions of RQ. Accordingly, in terms of the sub-dimensions of RQ, the mean scores achieved by the pre-service science teachers, who participated in ADI activities, were sorted in a descending order as follows: understanding, reflection, critical reflection, habitual action.

Pre-post Science Process Skills Scales were conducted in order to assess ADI's effect on the participants' science process skills. The pre-post test scores were found to be normally distributed (Shapiro-Wilk, $p>0.05$). T-test results, performed on the relevant samples, were as given in Table 3. Results showed significant differences between the pre-and post-test scores of the participants in favor of the post-test results ($p<0.05$). These findings indicated that ADI affected the science process skills of the pre-service science teachers.

Similarly the pre-AS and post-AS test scores were calculated in order to assess ADI's effect on argumentativeness. The data were found to be normally distributed (Shapiro-Wilk, $p>0.05$) and t-test results were as given in Table 3. According to the results of the analysis, there was a significant difference between the pre-and post-test scores, calculated in favor of the post-test scores ($p<0.05$). These findings suggested that ADI instruction affected the argumentativeness of pre-service science teachers to produce arguments.

Table 3.   Statistical significance of the Results from administering the Science Process Skills and Argumentativeness instruments

		N	Pre-test		Post-test		df	t	p
			Mean	SD	Mean	SD			
SPSS	Group 4	22	21.00	5.53	24.71	6.56	21	4.067	0.001
	Group 5	29	22.33	3.57	24.15	4.03	28	2.615	0.015
AS	Group 4	22	9.94	10.45	17.83	9.82	21	4.901	0.000
	Group 5	29	11.09	10.48	14.96	8.88	28	2.160	0.042

Participants' generated flaws, about an argument related to Boyle's Law, were analyzed. Participants were grouped into three categories, as follows: those who could not identify any valid flaw; those who identified one valid flaw; and those who identified more than one valid flaw in the argument about Boyle's Law. Chi-square test was used to compare the distribution of flaws in these three categories, which showed there was no statistically significant difference between the participant groups ($\chi^2(4)=5.47$, $p>0.05$). Thus, it was determined that the participant groups were equivalent in terms of the three categories. Merging the data for the three participant groups, we found that 40.2% of the participants could not identify any valid flaws, while 40.2% of the participants identified one valid flaw, and 19.6% of the participants identified more than one valid flaw.

In the interviews performed at the end of the first year of the study, participants were asked to compare ADI with the traditional instructional approach that they had experienced in their previous laboratory classes, and to express their positive and negative impressions about the model. Participants had different levels of exposure to laboratory practice, since they had studied at different types of high schools in different regions. Some participants stated that they attended regular laboratory classes in high school whereas other participants had limited laboratory experience.

All participants stated that the other laboratory courses they attended before were conducted with the traditional instructional approach i.e. first, the relevant theoretical information was recapitulated, then followed an exposition of the experimental procedure and the expected results. They stated that they had first become acquainted with ADI during the GCL. Each of them indicated that the ADI model was the most effective model in attaining the course objectives through exposure to laboratory practice.

According to the participants, the fact that the expected results were not expressed in advance was a positive aspect of the ADI model. They stated that in their previous experiences the existence of an expected outcome did not motivate them to think, that they used to focus on the expected result, even to memorize the result they were expected to get. They stated that when the result of the experiment was not known in advance, they had an opportunity to test themselves and in this way they were able to learn better. They also stated that when different groups obtained different results in the experiments, this generated an effective argumentation environment that made it possible for them to identify their mistakes and this facilitated communication in the classroom.

Some participants stated that classes became more instructive and enjoyable when the instructor was not lecturing all the time and when everyone was expected to be prepared to complete the tasks, thus making an effort in class. One of the pre-service science teachers stated that under a traditional instructional approach, in which the theoretical information was completely provided by the instructor, it was not possible to correct the mistakes in the students' knowledge that escaped the instructor's notice. He concluded that under ADI, the experiment design and finalization stages were similar in this respect; however, the inter-group argumentation stage created an environment that facilitated the correction of mistakes.

Similarly, participants found ADI more suitable for their personal development in the field of science. They stated that previously they used to simply follow the experimental procedure, step-by-step, without generating ideas, or thinking too much. They stated that this model helped them to understand the concepts rather than memorize them. Furthermore, participants stated that they started doing research in a more systematic

way, and that doing research became more fun and 'catchy'. However, while some saidthey benefitted from the absence of a clear-cut experiment plan, others stated that this had caused difficulties because at times they did not understand how to perform the experiment without explicit instruction.

Another issue on which the participants had different opinions was the group-work environment. Some participants stated that they preferred working individually, and that there was an opportunity to work alone in the experiments performed with the traditional instructional approach, while they did not have such an opportunity with ADI activities. Thus they felt they experienced difficulties. Some participants, on the other hand, stated that working in a group was good and instructive.

One negative view on ADI was that this model was not very suitable for inexperienced students. Participants said that the model could cause difficulties for unprepared students; in fact, they stated that in the case of unprepared students being present, instructors should pay more attention to safety and help students who needed assistance. Another negative feedback was that the assessment of students' reports by peers was not very objective,due to the reports being prepared after class.

Expressions in the essays, which were assigned to students at the end of the second year with the aim of assessing the participant views on the effectiveness of ADI, were analyzed by closed coding. Seven themes were identified in the course of the analysis. The findings were as summarized descriptively in Table 4.

Table 4.   Results of the content analysis of the participant views

Themes	Frequency
Argumentation and the benefits of the argumentation process	37.3%
Self-awareness	23.5%
Interest in science	17.6%
Attitude towards the chemistry course and laboratory	13.7%
Social interaction	7.8%
Persistence	5.9%
Creativity	3.9%

In the written essay, participants (P) mostly expressed views on the theme of argumentation and the benefits of the argumentation process. Participants expressed these views, using expressions such as: "*doing research on a problem and thinking about finding a way to solve the problem is really both fun and instructive; we either refuted the findings of the other groups, or learn something from them (P1)*", "*...we refute what seemed wrong to us,...and verifyour hypotheses by undertakingexperiments in line with our claims (P2),*" or "*I have learned to build my claims on a solid basis by considering simultaneously the*

reasons behind my assertion, the possible ways to support these reasons, and the justifications of my assertion (P3)."

Self-awareness was identified as the second most frequent theme. Some relevant participant views were as follows; "*I have gained self-confidence, I can feel the positive changes in me (P4)*", "*I can say that my life philosophy has changed as a result of what we have experienced. So much so that, I now think that the truth is hidden in the details (P1)*", "*I have gained the spirit of a researcher as a result of the chemistry laboratory class (P5)*" or "*this lab has enabled me see problems I encounter in other courses with a different eye than I used to do (P3)*"

Participants stated that ADI had increased their interest in science, using expressions such as: "*It was a great pleasure for me to set-up the experiment, thinking like a scientist (P6)*", "*with some effort and determination I was able to do scientific work (P7)*", "*... it has increased my willingness to think more, make more comments and research the topics I hear about....my inquisitive side developed even more as a result of these experiments, my inquisitive side and I started getting clearer answers when I asked "why"(P8),*" or "*I have learned how to look at ordinary phenomena with the eyes of a scientist, how to posit different ideas about such phenomena and to think about these ideas (P9).*"

Participants illustrated how they developed more positive attitudes towards chemistry, or chemistry labs as a result of the implementation of ADI, by using the following expressions: "*I have realized the importance of the Chemistry course (P10)*", "*...I regret that I did not choose to study Chemistry Education :((P11)*", "*I started to like chemistry in this course (P12),*" or "*this laboratory course both illustrated and applied how chemistry is actually not just a boring theoretical course (P13)*".

Another theme was social interaction. Participants expressed views pertaining to this theme as follows: "*I have become able to express myself more comfortably (P7)*", "*I have learned how to do group work (P14)*" or "*doing experiments within groups strengthened our relationships with our friends (P15)*".

Aside from the above-mentioned themes, only a few participants stated that ADI increased the staying power of their chemistry knowledge.They used phrases such as: "*it was helpful both in terms of memorization and... to try to apply practically, in the laboratory, what we had learned theoretically (P16)*" and "*I believe that what we learn becomes more persistent when the classes are conducted with this model (P17).*" A few participants stated that it enhanced creativity, with expressions such as: "*It definitely enhances creativity (P18)*" and "*under this approach we have seen that the claims that we put forward can be different from how the experiments are planned; I think this unleashes creativity (P19)*".

DISCUSSION AND CONCLUSION

In this study, pre service science teachers' levels of reflective thinking in the activities, changes in their science process skills and argumentativeness, their performance for identifying flaws in an argument and their views on the model were investigated towards the effectiveness of ADI and the identification of the views of pre service science teachers about this model.

One of the finding of this study was to assess the level of reflective thinking of the participants in relation to their experiences with ADI activities. Because, although one of the main reasons underlying the design of this model is to enable students to be more reflective in their studies (Sampson, et al., 2011; Walker, et al., 2011), there is no study on this matter. It is crucial to show that the model does indeed attain this aim,as predicted in the literature. Due to these considerations, we determined the level of reflective thinking of the participants in all participant groups that were used to conduct this two-year study. The habitual action dimension, which was the lowest amongst the four sub-dimensions of reflective thinking, could be considered no-reflection (Wittich et al., 2011). The behaviors of the pre-service science teachers during the ADI activities could be more readily characterized in terms of the other dimensions like understanding, reflection and critical reflection, rather than as habitual action. Thus, it can be said that, by using ADI it was possible to attain this goal projected by the literature to a considerable extent.

This result suggests that, ADI creates a suitable environment in the laboratory for helping the participants to think reflectively. ADI provides students with various opportunities in the laboratory since it includes such activities as producing an argument, performing experiments in order to support this argument with empirical results, discussing the findings of the experiment and reporting these findings. In all of these activities, participants are both mentally and physically active. This may give them the opportunity to be reflective. In this respect, ADI gives students, with different characteristics, the opportunity to participate in the process of doing science (Walker, et al., 2012).

Another finding of the study regarded the assessment of how the pre-service science teachers' science process skill level changed during ADI activities. It was established that the mean score of science process skill level of the participant groups for which this variable had been measured was higher after the implementation than before. The basis of ADI was the inquiry approach, which gave students the opportunity to perform the experiments actively. Consequently, participants frequently used science process skills like constructing a hypothesis, designing and performing experiments, collecting and interpreting data in their laboratory practice (Kolkhorst, Mason, DiPasquale, Patterson & Buono,

2001). This situation might have given rise to the increased development of their science process skills. Similarly, Demircioglu & Ucar (2015) found that ADI was an effective method for improving the science process skills of pre-service science teacher.

Most studies on the application of ADI in science laboratories are about the effect of the model on the students' abilities to participate in argumentation or to producing an argument (Walker et al., 2012; Sampson, et al., 2011; Walker & Sampson, 2013). As distinct from the previous works, we have followed an approach by examining the change in our participants' argumentativeness as a result of their participation in ADI. The results of our study reveal that participants' argumentativeness has changed in a positive way. There can be a few reasons for this change. For instance; argumentativeness is related to argumentation training and an individual's participation in argumentation (Infante, 1982) and it is a behavior that can be developed over time (Levine & Boster, 1991). ADI may have developed the argumentativeness of the participants since it gives them the opportunity to produce and justify an argument. There is a direct relationship between argumentativeness and communication apprehension (Infante & Rancer, 1982),defined as the level of fear and anxiety an individual feels during communication with other people (McCroskey, 1977). Another reason can therefore be the way ADI gives participants the opportunity to overcome this fear/anxiety by providing occasions to engage in inter- and intra- group interactions. However, it needs to be remembered that in both cases, ADI develops argumentativeness in a social learning environment.

Another goal of the study was to explore the ability of identifying flaws in an argument, which could be considered a critical thinking ability of the pre-service science teachers who participated in ADI activities. In a previous study (Kadayifci, Atasoy, Akkus, 2012), a moderate correlation was found between the number of flaws that pre-service science teachers identified in an argument and their critical thinking abilities. The reason why we examined this variable was that the development of critical thinking was one of the main objectives in science education; moreover, the identification of flaws in an argument was related to argumentation in general. Being able to identify flaws in an argument that at first sight seemed unproblematic, could be seen as a difficult task that required thinking critically about that argument. Nevertheless, similarly to the findings of Glassner and Schwarz's (2005) study, most participants in the present study were able to demonstrate one or more flaws. Each flaw expressed by participants indicated that they approached the matter from different points of view and thus generated different ideas. In the argumentation part of their activities the pre-service science teachers in this study gained experience in refuting arguments that they disagreed

with. This stage of the model might have helped the participants to identify flaws about an argument regarding Boyle's Law.

Lastly, the views of pre-service science teachers on ADI were identified in this study. Determining the views of the participants, who were potential future implementers of ADI, also gave an idea about whether they were going to use the model in the future when they became practitioners. Because pre-service science teachers had, up to that point, only participated in traditional laboratory classes, encountering a different model, developing a positive opinion about it and witnessing its effectiveness, these were all sources of motivation that might lead the participants to give preference to this model in their future teaching career. Our results, based on an analysis of the interviews and of the written essay assignments, showed that, with the exception of a couple of issues, the participants expressed positive opinions about ADI. For example, participants stated that the laboratory activities performed under ADI motivated them to think and created a better environment for learning. Similarly, in Choi, Klein & Hershberger (2014) study, which engage argumentation and inquiry as an instruction model, they found the same findings.

Another positive view of the participants was that the chemistry labs started to take place in a quite fun way and that they developed positive attitudes towards chemistry and laboratory. This finding was underpinned by Walker, et al.'s (2012) study, which showed that the model enhanced female students' attitudes towards science. According to the participants, this model supported the improvement of oral communication skills by strengthening the interclass communication. The reason for these two findings could be participating in the inter- and intra-group argumentations, where participants could express themselves comfortably. Students who could express themselves comfortably developed positive attitudes (Yalcin-Celik & Kilic, 2014). This situation was actually an expected result for ADI, which gave various opportunities for social interaction (Sampson & Gleim, 2009; Sampson et al., 2009).

A significant limitation of the study was that not all research questions were investigated for the same group of participants. Instead, the study was planned in such a way that answers to different research questions were based on participant groups. This was due to the positive results we obtained from the variables we examined in the first year, which then encouraged us to include different variables in our study in the second year by increasing the number of the participant groups. In this way, we had the chance to investigate ADI's effectiveness on the variables that were not studied before. These were reflective thinking, science process skills, argumentativeness and identification of flaws in an argument. A recommended for future studies could be to demonstrate the

effectiveness of the model with larger participant groups and in comparison with a control group.

Finally, in this study, ADI contributed to development of pre-service science teachers' argumentativeness skills, science process skills, reflective thinking and abilities to identify flaws in an argument during a chemistry course. Also participants had generally positive views about this instructional model. In the light of the above discussion, for this study, we can conclude that ADI was an effective instructional model in term of both argumentation and inquiry skills.

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