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Designing and evaluating a specific teaching intervention on chemical changes based on the notion of argumentation in science

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Abstract

The present study aimed to investigate the feasibility of a teaching intervention based on argumentation in a typical Turkish classroom setting. The teaching intervention focused on the concept of chemical changes. It involves 6 arguments in total. The teaching intervention was implemented in a class of first year upper secondary school (aged 14-15) students during the time provided by normal chemistry curriculum. The findings indicated that argumentation improved students' chemistry knowledge and promoted their conceptual understanding. Findings also revealed that students who followed instruction based on argumentation significantly out-perform others who followed the constructivist teaching in terms of conceptual understanding.
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1. Introduction

Developments in history of science highlight the importance of teaching students the nature and practices of science. The idea that in learning science, students, as well as having the opportunity to learn about the concept of science, must also be given some insight into its epistemology, the practices and methods of science have come to the fore (Erduran, Simon & Osborne, 2004; Kuhn, 1992; Driver, Newton & Osborne, 2000). Within this theoretical perspective, argumentation is viewed as an important issue (Driver, Newton & Osborne, 2000; Erduran et al., 2004; Jimenez-Aleixandre, Rodriguez & Duschl, 2000; Kuhn, 1993). It is believed that argumentation can raise science education standards by increasing conceptual learning, critical thinking and scientific reasoning. Research on the investigation of the effectiveness of argumentation on students' learning provides evidence to support this contention. Several studies reported positive effects of argumentation over students' conceptual understanding. Mason (1998), for instance, found that involving in argumentation activities 5th grade students advanced conceptually. She in another study (2001) revealed that 4th grade students constructed advance scientific understanding and developed meta-conceptual awareness after the instruction based on argumentation. Studies reported that argumentation has potential for promoting high engagement (Baker, 1999) and conceptual change

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(Alexopoulou & Driver, 1996; Nussbaum & Sinatra, 2003). Nussbaum and Sinatra (2003), for instance, found that undergraduate students who solved physics problem by arguing alternative explanations showed improved reasoning on the topic as compared to control students who solved the same problem without argumentation. Similarly, Eşkin (2008) revealed that students who involved in argumentation activities developed detailed reasoning of the physics concepts than that of the control group who received the traditional teaching based on transmission view.

Having accepted the constructivist philosophy in education, starting from 2005 in Turkey, the primary aim of the instruction has become helping students acquire skills rather than gain scientific knowledge (MEB, 2008). The traditional Turkish teaching has therefore become constructivist. It might be expected that this new programme would address argumentation in teaching science and schools stimulate thinking and reasoned debate. But it seems that this is not the case despite the strong emphasis made on the history and nature of science on theoretical grounds in the secondary science curriculum. This study was therefore designed in order that a teaching intervention based on argumentation could be developed and evaluated with the aims of promoting conceptual understanding of chemical changes. The study also aimed to compare students' gains after involving argumentation with the outcomes of a constructivist teaching suggested by the new chemistry programme. In this respect, the study will also provide research findings regarding the effectiveness of the constructivist view on students' understanding of chemical changes.

2. Method

The study was conducted in a secondary school which is a public one located in İstanbul. The teaching intervention was put into practice in a 9th grade class whose students' aged 14–15 (n = 27; 16 boys, 11 girls). Students in a similar class, aged 14-15, formed the control group (n = 28; 16 boys, 12 girls). The equivalence of two groups was tested via a number of instruments. These were achievement test, probing questions and logical thinking test. These data were used as a baseline for comparison, although we acknowledge that the sample design is not that of a controlled, experimental study. Kolmogorov-Smirnov test results indicated that there were no statistical differences between the two classes in terms of the scores taken from each test/scales aforementioned. Therefore, two groups of students were accepted as equivalent. The teaching intervention lasted 6 weeks in total as provided by existing chemistry curriculum. One of us (A.G.) who is chemistry teacher of the school, with 15 years of experience, implemented the teaching intervention. The teaching intervention was video-taped and discussions as in the form of pair, group or whole class were audio-taped for both future reference and argumentation analysis. Students in the control group, taught by the same teacher, who were following the school's programme of teaching about chemical changes which was based on constructivist view. She encouraged students share their ideas with their classmates, discuss their observations and interpret findings of the experiments carried out. Students completed the same data collection instruments before and after instruction so that changes in their chemistry knowledge and conceptual understanding can be spotted. The effectiveness of the teaching intervention was therefore tested via two different instruments; achievement test and probing questions. Both of the instruments were designed by the authors. The test included 60 multiple choice questions at the outset. After piloting and reliability analyses, 20 questions were discarded from the original test. The reliability (cronbach alfa coefficient) was found as 0.711. Concept questionnaire consisted of 11 open-ended probing questions. Data obtained via the instruments mentioned above were analyzed with SPSS 16.0 program. Mean and standard deviations of the test scores were calculated. It was observed that the scores are distributed normally. Therefore, the paired-samples T test was conducted to figure out whether there is a significant difference between the pre and post-tests scores of the students involved in the study. Independent-sample T test was conducted to figure out whether there is a significant difference between the post-test scores of the experimental and the control groups.

2.1. Rationale for the teaching intervention

Two main perspectives informed the teaching intervention. The first of these was the notion of "argumentation in science". Thus, we reviewed the literature on argumentation with special focus on its theoretical aspects. The nature of arguments to be benefited and evaluation issues were decided upon the examination of the existing literature (Erduran, Simon & Osborne, 2004; Kuhn, 1992; Driver, Newton & Osborne, 2000; Jimenez-Aleixandre, Rodriguez

& Duschl, 2000). Another principle drawn on involves the notion of "learning demand" (Leach & Scott, 1995). So as to decide on the learning demands existing literature concerning students' ideas were reviewed.

2.2. Designing the teaching intervention

The very first step in designing the teaching intervention was to carry out a conceptual analysis of the demands of Turkish curriculum for first year upper secondary (aged 14-15) programme of study to identify the key scientific ideas that constitute the domain. These key ideas were then re-formulated or extended on the basis of students' existing thinking in the area of chemical changes to identify the 'learning goals' to be taught. Then, the nature of the intellectual demands involved in developing each scientific idea from existing understandings was analyzed (i.e. the 'learning demands'). Finally, decisions regarding the nature of the argumentation materials and the ways in which it might be used were made to address the learning demands identified. The overall teaching approach adopted involved the use of argumentation but a number of different teaching strategies were drawn upon in achieving this in addition to those suggested to be used as argumentation frameworks by educators (Erduran, Simon & Osborne, 2004). The overall teaching approach comprises three phases. Phase 1 involves "introduction and creating a need for argumentation in science". Phase 2 involves "training on argumentation" and Phase 3 involves "learning to construct arguments". The teaching approach begins with an introductory phase that aims to set the scene for the work to come, especially in terms of the teaching/learning strategies. The second phase is designed to give training to students on argumentation. In this phase, Toulmin's Argument Pattern (TAP) was used so as to introduce the elements of an argument. The third phase of the teaching intervention involved argumentation activities focusing on teaching the topic of chemical changes. The instructional activities used throughout the teaching were in the form of discussion, investigations, writing and teacher demonstration. Different strategies were used for supporting argumentation such as competing theories, predict-observe-explain and concept cartoons. During the teaching activities, steps in applying an argument which was stated by Niaz et al. (2002) were used.

3. Findings

Effectiveness of the teaching intervention was taken to mean helping students to produce correct answers to the chemistry achievement test as required by the chemistry curriculum. The term was also taken to mean promoting students' conceptual understanding by helping them justify their answers to probing questions. Students' responses were further examined in terms of the change in their pre-instructional misconceptions. Due to space constraints the results of this analysis specifically carried out for each probing question were not reported in the present paper.

3.1. Effectiveness of the teaching intervention based on argumentation on students' chemistry achievement

Students' responses to the questions appear on the achievement test were examined and scored regarding the correctness of their answers. The paired-samples T test was used to compare the change in the means of pre and post test scores of the students. The results are presented in Table 1.

Table 1. The paired samples T test results concerning the achievement test scores of the two group students

Class/Instruction	Tests	N	Mean	Std. Deviation	df	T	p
Argumentation	Pre-Test	27	16.44	3.142	26	-13.869	0.000
	Post-Test	27	27.00	3.000			
Constructivist	Pre-Test	28	15.68	3.198	27	-10.130	0.000
	Post-Test	28	26.61	5.238			

Table 1 shows that there is a significant difference in both experimental and control group students' pre and post-test chemistry achievement scores. The difference is in favor of their post-test scores. The arithmetic average of experimental group students' achievement test scores was 16.44 prior to the teaching intervention. This mean was increased to 27.00 after the instruction. Similarly, the mean of the control group students' chemistry achievement test score was also raised after the constructivist teaching (from 15.68 to 26.61) by producing statistically significant change in their test scores. So as to compare the two teaching interventions in terms of their success in helping students produce correct answers to chemistry achievement test questions, independent-sample T test was benefited. The results of this analysis were presented in Table 2.

Table 2. The independent-sample T test results concerning the achievement post-test scores of the two group students

Groups	N	Mean	Std. Deviation	df	t	p
Experimental Group	27	27.00	3.000	53	0.343	0.733
Control Group	28	26.61	5.238			

According to Table 2, there is no statistically differences between experimental and control groups' chemistry achievement post-test scores [$t_{(53)}$= 0.343; p > .05]. It seems that both teaching approaches were equally successful in helping students to produce correct answers to achievement test questions. Argumentation based teaching seems to be as effective as the constructivist teaching in supporting an increase in students' chemistry knowledge.

3.2. Effectiveness of the teaching intervention based on argumentation on students' conceptual understanding

Students' responses to open-ended probing questions were analyzed and scored with special focus on the nature of their justifications. The paired-samples T test was used to compare the change in the means of pre and post probing questions scores of the students. The results of the analysis are presented in Table 3.

Table 3. The paired samples T test results concerning the probing questions scores of the two group students

Class/Instruction	Tests	N	Mean	Std. Deviation	df	T	p
Argumentation	Pre-Test	27	10.81	2.842	26	-8.665	0.000
	Post-Test	27	17.85	3.929			
Constructivist	Pre-Test	28	10.11	4.049	27	-0.040	0.968
	Post-Test	28	10.14	4.428			

Table 3 shows that there is a significant difference in experimental students' pre and post probing questions scores [$t_{(26)}$= -8.665; p < .05]. The difference is in favor of their post probing scores. Prior to the teaching intervention, the mean of the students' probing questions score was 10.81. This number was raised to 17.85 after the intervention. This change supports the claim that students' conceptual understanding improved after involving in argumentation. On the contrary, there is not a significant difference in control group students' pre and post probing questions scores [$t_{(27)}$= -0.040; p > .05]. Students in control group gave similar kinds of responses to pre and post probing questions as the mean scores before and after the teaching were 10.11 and 10.14 respectively. It seems that the constructivist teaching carried out in the control group did not improve students' conceptual understanding. So as to compare the two teaching interventions in terms of their success in promoting students' conceptual understanding, independent-sample T test was used. The results of this analysis are presented in Table 4.

Table 4. The independent-sample T test results concerning the probing questions post scores of the two group students

Groups	N	Mean	Std. Deviation	df	t	p
Experimental Group	27	17.85	3.929	53	6.820	0.000
Control Group	28	10.14	4.428			

Table 4 shows that there is statistically difference between experimental and control groups' post probing questions scores [$t_{(53)}$= 6.820; p < .05]. It seems that students in the experimental group outperformed the control group students in justifying their answers and in offering conceptual accounts. Thus, it is possible to claim that the argumentation was more effective than the constructivist teaching in promoting students' conceptual understanding.

4. Conclusion and Recommendation

When students are given the opportunity to verbalize their ideas, justify their views, take alternative positions and use evidence to support their claims they are in fact given a chance to communicate their conceptions and reasoning.

Thus, it is expected that such learning environments promote students' conceptual understanding. The existing argumentation literature provides empirical evidence supporting this expectation, if not beyond (Mason, 1998; 2001; Nussbaum & Sinatra, 2003). The findings also provided evidence for the progression in students' conceptual understanding after having involved in argumentation. Students' responses to post probing questions were advanced in reasoning. They justified their answers by providing conceptual accounts for the issue and in some cases even used more than one reason in their justification. Students seem to start to use elements of a scientific argument.

Another important finding of this study might be the difference between the two teaching intervention in relation to conceptual understanding. As compared to argumentation based teaching intervention, constructivist teaching conducted in the control group was found to be less effective in promoting students' conceptual understanding about chemical changes. Control group students' post probing questions did not differ much from their pre instructional probing responses on conceptual accounts and the level of reasoning. This finding is astonishing as constructivist view by its nature targets promoting conceptual understanding. The teacher used student-centered teaching strategies in the control class. She encouraged them to make their minds public, to comment on ideas put forward by their classmates and to carry out investigations to construct more acceptable way of thinking about the issue. Being aware of the constructivist role played by the teacher, it is difficult to spot the teaching pedagogy as a reason for ineffectiveness of the teaching in the control group. The chemistry content might be another source for the unsuccessfulness. The chemistry programme designed in the line of constructivist view was the first time to put into practice in Turkish educational system. We did not interfere or attempt to change the content of the programme as it was conducted all over the country. However, we think the chemistry programme needs to be developed further. Studies focusing on curriculum content analysis through the constructivist eyes might illuminates this issue. More classroom studies might enrich our knowledge about the way in which the constructivist view conducted.

There are studies arguing that argumentation has potential as a conceptual change intervention. Mason (2001) points out that when constructing an argument, individuals must consider both sides of the issue, produce explanation to the problem that are conflicting with their existing way of thinking and be confronted with the discrepancy between their point of view and the alternative. This naturally occurring argumentation process produces conceptual change. It is difficult to talk about the relationship between argumentation and conceptual change in the light of the findings of the present study. Yet, preliminary findings obtained from ideographic analysis of the probing questions and each student progression towards a more scientifically acceptable way of thinking give signs of students' engagement in conceptual change process. More research needs to be carried out to strengthen the assertion involving argumentation and conceptual change strategies.

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