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Engaging Elementary School Students in Scientific Argumentation: Effectiveness and Limitations

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Abstract

The study aimed at introducing scientific argumentation to students of elementary level in a private school in Islamabad. The sample consists of 48 students of grade seven divided into two sections serving as control and experimental group. The objectives of the study were to experiment with teaching through argumentation, exploring the difficulty faced by students in constructing argument and the effect of scientific argumentation on students' academic performance. The students in the experimental group were provided intervention for two months (the maximum allowed duration by the school administration). Data were collected through written argumentation reports and students' performance in the bi-monthly examination at the end of the experiment. Data were analyzed using inferential statistics. The findings revealed students' difficulty with constructing rebuttal in an argument. The academic performance of the students in experimental group was significantly higher than the students in the control group using t-test. Moreover, the academic performance of female students in the experimental group was higher than the male students. Scientific argumentation was found an effective instruction method for improving students' understanding, developing critical skills and constructing knowledge.

Keywords: Argumentation, cognitive learning style, academic performance, critical thinking skills

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Introduction

Argumentation in teaching is a newer method of engaging students in learning (Erduran, Simon, & Osborne, 2004; Ryu & Sandoval, 2012). The vast literature in the research journals portrays the success of this method in gaining the attention of educational researchers at present (Kaya, Erduran, & Cetin, 2012; Venvill & Dawson, 2010; Zohar & Nemet, 2002). While, the educationists and researchers are experimenting with different dimensions of argumentation in teaching and in evaluating the effectiveness of this method in improving students' understanding, the method is still yet to get due consideration in developing countries (Faize, 2015). The teaching and evaluation techniques in most classrooms in these countries are still primarily focused on teacher's dialogue with little involvement of students (Duschl & Osborne, 2002). Teaching science in elementary classroom is usually associated with traditional teaching methods which results in cramming and lack of interest among students. Such tradition teaching does not develop critical thinking ability as desired by science teaching and thus expected results are not achieved.

Improving cognitive abilities through indulging in argumentation may be linked to increased interaction during argumentation process (Sampson & Clark, 2009). It is a dialogic process which cannot be conducted by one person (Iordanou, 2013). Argumentation in teaching is a social process that involves the students in an interactive exchange of ideas (Osborne & Patterson, 2011). It is this exchange of ideas that helps in improving conceptual understanding (Faize, 2015; Osborne, Christodoulou, Howell-Richardson, & Richardson, 2013). For this interactive process to follow, there are some components in argumentation. According to Toulmin (1958), there are six parts in a good argument. They are claim, data, warrants, qualifiers, backing and rebuttals. Claim is the decision made by a person on an issue. Data provides the proof to support the claim. Warrants indicate relationship between data and claim. Qualifiers offer statement that shows how much forceful or weak an argument is. Backing gives support to warrant. Rebuttal challenges the opponents' argument by picking weakness into it (von Aufschnaiter, et al. 2008; Toulmin 1958).

However, Toulmin' components are criticized due to the components becoming overlapping and thus the quality of an argument cannot be accurately determined. In the present study, the researchers used a simple structure of argument containing claim, grounds and rebuttal. Claim and rebuttal is already defined while, the grounds consist of elaboration/examples/illustration that the students give to support their claim. This simple structure was adopted due to unfamiliarity of Pakistani teachers with argumentation; and the students in this study belonging to elementary level.

The quality of an argument can also be assessed by the number of parts/components included in the argumentation. However, for making a quantitative analysis of argumentation, these components can be assigned score which can be added for each student to analyze the performance (detail in methodology section).

Understanding argumentation and its right use in teaching is imperative for teachers at present. There are various reasons for emphasizing the importance of argumentation in teaching. The method is used as experimental by various researchers with positive findings of improving conceptual understanding (Newton, Driver & Osborne, 1999; Duschl & Osborne, 2002; Nussbaum, 2011; Driver, Newton & Osborne, 2000). Perhaps, this aspect of cognitive domain is very much needed in Pakistan to prevent students from cramming and rote learning during examination. The reason is very obvious; that by engaging students in an interactive form of argumentation will help in clarifying various dimensions of the topic. People can argue well if they have greater understanding of the topic. On the contrary, it can also be concluded that if one indulges in argument on a topic/issue, one's understanding will improve (Rudsberg, Ohman, & Östman, 2013).

Moreover, the process of argumentation involves use of critical skills (Nussbaum & Sinatra, 2003). The students are encouraged to make a claim on an issue and then to provide necessary justification to support their claim. Further, a good argument will be one which challenges the claim of the opponent by providing counter argument. It is through these interactive engagement, that the students learn critical skills and the way of proving justification to support their claims (Newton, Driver, & Osborne, 1999; Osborne et al., 2013).

Herrenkohl and Cornelius (2013) conducted their study to explore the relationship between epistemic cognition and argumentation practices in the subject of science and history with elementary students. The sample was taken from two classes of grade 5 and grade 6. They found that students learned complex argumentation which was consistent though out the class. The students developed scientific thinking like a scientist and critical reflection of historians. However, further research was needed to explore understanding of students on argumentation practices and conceptual understanding. A similar study was conducted by Hong et al. (2013) with 115 students of grade 5. The experimental group was involved in argumentation process for 12 weeks while the control group comprised of 107 students. The research found that the experimental group revealed a higher quality of arguments and attitude towards science as compared to control group. Moreover, the quality of argumentation was significantly higher in boys as compared to girls in the

control group. Thus, practice with argumentation helps in improving academic performance as well as developing a positive attitude in students towards science.

Rationale of the Study

Most of researches on the use of argumentation in teaching are conducted with high school, college and university students. However, the research studies with elementary school students are very few. The reason for this is one of the necessary condition of possession of previous knowledge that is required to engage in argumentation (Osborne, Erduran, & Simon, 2004). Without previous knowledge, the students cannot indulge in argumentation and critiquing other arguments (Sadler, 2004; von Aufschnaiter, Erduran, Osborne, & Simon, 2008). Feeling the need of introducing argumentation in teaching at elementary level in Pakistan, the present research was conducted as an introductory phase with students of grade 7 from a private education system. Elementary School girls and boys differ in their understanding and use of argumentation skills; hence both male and female students were included in the study to examine gender difference. The students' ages range between 12 to 14 years. Introducing argumentation to these students may enable these students to construct and explain knowledge themselves rather than receiving it (Herrenkohl & Cornelius, 2013). The findings from the present study will be useful to teachers of elementary level and teacher educators about getting insight with the use of this newer technique of teaching elementary level students; and to find the effectiveness of this method in academic achievement.

Aim and Objectives of the Study

Aim of the study was to engage elementary school students in scientific argumentation and examine effects of the intervention. The objectives of the study were to:

1. introduce argumentation method to elementary level students in Islamabad
2. explore the difficulty faced by the students in writing argumentation reports
3. explore the academic effectiveness of teaching through argumentation at elementary level.

Hypotheses

The following two hypotheses were further formulated:

H_0: There is no significant difference in the academic performance of students in the control and experimental group at the end of intervention.

$H_{0:}$ There is no significant difference in the academic performance of male and female students in the experimental group at the end of intervention.

Methodology

For testing the two hypotheses, the researchers used experimental design with 7^{th} grade students. The researchers used treatment-post-test design. Pre-test was not used as the two sections were already made by the school on equivalent performance level.

Population and Sample

The population comprised the students and teachers of elementary schools in Islamabad. However, due to constraint of time, energy and money, the researchers purposively selected a private school in Islamabad in which the school administration and the parents were willing to experiment with this newer technique. The researchers convinced the school administration about the use and application of this newer method in learning and also volunteer to train the teacher involved in the use of argumentation. After taking the necessary administrative approval and written consent from parents, the researchers conducted a three days intensive training with the teacher that was allotted by school for the specific experimental group.

The students of grade seven were selected because the selected school had two sections of grade seven while the other grades had only one section. Moreover, the school administration confirmed that the two sections of grade seven consisted of students with equivalent performance level. Thus, the two sections could be conveniently taken as experimental and control group. One of the class was randomly assigned as experimental and the other control group. The number of students in the control group was 23 and in experimental group were 25.

Procedure

The teacher in the control group used the traditional lecture method in the class while, the teacher for the experimental group was guided to introduce and teach through argumentation while teaching science subject. One of the researchers also ensured their regular presence during the intervention period. In order to help elementary students learn argumentation skills effectively, relevant and experience based activities were incorporated in science lesson (von Aufschnaiter et al., 2008).

This included the use of multimedia animation, cartoon clips and colorful illustrations. The students were guided about the structure of argumentation and how to support their claim. In order to facilitate students in writing argumentation report, a written backup form was distributed for each topic. The form mentioned the space for writing claim, explanation and rebuttal. The experimental phase continued for two months (the maximum duration allowed by the school administration for intervention) followed by a comprehensive bi-monthly school examination. All the students were given reports same in nature and concept. The following reports/documents were handed over by the teachers at the end examination.

1. Written argumentation report filled by students (only for experimental group)
2. The achievement marks of students in experimental and control group in the bi-monthly examination in science subject.

Data Analysis

The written argumentation reports were carefully examined by the researcher for argumentation components to observe difficulty faced by the students in writing argumentation. For making analysis simpler for elementary level students, we agreed to check for claim, grounds (for supporting claim) and rebuttal. The following score was assigned to each component.

Table 1
Score Assigned to Argumentation Component

Component	Score Assigned
Claim	1
Ground	2
Rebuttal	4

Claim was assigned 1 score as it was easy to make any claim whether in favour or against an issue. Ground requires more thinking and was harder to form to support claim and was assigned 2 score. While, rebuttal as being the most difficult to construct was assigned 4 marks. The total number of argumentation report for each student was four. Each argumentation report was collected by the teacher after two weeks to provide ample time for developing of argumentation skills in students. An example of scientific argumentation is explained for understanding the components.

Issue/Question: Is it good to sleep under tree in the night?

Claim: No

Ground 1: because tree gives out Carbon dioxide and takes in oxygen.

Ground 2: Human beings need oxygen to breathe.

Ground 3: Tree will take more oxygen leaving less for human being to breath.

Ground 4. Carbon dioxide released by tree is also dangerous for us.

Rebuttal: If tree can exhale oxygen and take in carbon dioxide, then we can sleep under tree.

The example shows many grounds/examples to support the claim. The more the number of grounds, the stronger will be the argument and vice versa.

The achievement marks taken by students in the experimental and control group in the bi-monthly examination was tabulated and analyzed using SPSS PSAW 18 (Reg) software. The score of the experimental and control group was analyzed through'*t*' test for comparing the means and to see if there exist any significant difference in the performance of the two groups.

Results and Discussion

The written argumentation reports were closely observed for argumentation components. Table 2 shows the frequency of components used by students in each session.

Table 2
Frequency of Argumentation Component used in each Session by Students

Component	Session 1	Session 2	Session 3	Session 4	Mean
Claim	48	46	50	47	47.75
Grounds	36	54	72	75	59.25
Rebuttal	2	9	12	19	10.5

In each session, two socio scientific issues were given by the teacher. The frequency of claim made by the students reflects that the students could easily make a claim/decision on the issue given. However, the ground presented by students is less than the claims made in Session 1. This means that a good number of students were not able to support their claims. However, in proceedings sessions, the frequency of grounds increased. In session 3 and 4, the frequency of grounds was greater which shows that the students were giving more grounds/elaboration/examples to support their claim. It can be concluded that the students were improving in developing argumentation skills as they practice with argumentation. This supports Chen, Ku, & Ho (2009) that argumentation ability of elementary students improves with time.

Thus, argumentation skills can be learned and improved with practice (Hong, Lin, Wang, Chen, & Yang, 2013).

The means of the components in table 2 reflects the average frequency of each component in the argumentation report with grounds having the highest mean followed by claim and rebuttal with lowest mean. The students easily learnt to make claims and construct grounds to support claim. However, the argumentation reports were weak in mentioning rebuttal. This was not surprising as rebuttal is difficult to construct and involves higher order thinking skills (Faize, 2015; Foong & Daniel, 2013). Another reason for difficulty in constructing rebuttal might be the small period of intervention (2 months) which is not enough to develop this difficult aspect of argumentation (Ryu & Sandoval, 2012).

Table 3

Analysis of Students' Performance in Experimental and Control Group

	Group	N	Mean	Std. Deviation	T	Sig. (2 tailed)	df
Test Score	Exp. Group	25	18.28	2.35	3.18	.003	46
	Control Group	23	15.26	4.06			

The data in table 3 shows that the mean of experimental group was 18.28 which was higher than the mean of control group (15.26). Thus, the students in the experimental group performed better as compared to students in control group with less scattered of scores (SD=2.35). The practice with argumentation with the experimental group helped in improving the academic performance of students in the science subject as found by Hong et al. (2013) for elementary students.

The next question is whether the performance of the experimental group is significantly higher than the control group. For this purpose, t test was used to find significant difference. The t value in table 3 shows that there existed significant improvement in the performance of students in experimental group as compared to control group, $t(46) = 3.184$, $p = .003$. It can be concluded that teaching with argumentation is effective than teaching through the traditional method. The same is reported by Chen, Ku, & Ho (2009) for upper graders of elementary students. Hand, Norton-Meier, Gunel, & Akkus (2016) also found the incorporating argumentation in elementary science classrooms improved students' academic performance. Thus, our first null hypothesis was rejected.

Table 4
Gender wise Analysis of Students' Performance in Experimental Group

	Gender	N	Mean	Std. Deviation	t	Sig. (2 tailed)	df
Test Score	male student	11	17.00	2.37	2.71	.013	23
	female student	14	19.29	1.86			

The researchers further investigated how the performance of male and female students in the experimental group is affected by the use of argumentation. It was found that the mean performance of male students was 17.00 as compared to 19.29 for female students in the experimental group (Table 4). Thus, the female students performed better than the male students. This difference in performance was significant when analyzed through t test, t (23) =2.71, p=.013 which is less than .05 alpha level. However, there was no significant difference in the argumentation reports of male and female students as observed from the students' argumentation report. The same finding was also reported by Jeong (2006) that no significant difference existed gender wise in terms of argumentation components. Perhaps, the female students in this study are following the same trend that exists in Pakistan at present, where female students are performing better than male students (Pakistan's medical schools: where the women rule, 2013).

Conclusions

The instruction at elementary level in Pakistan needs to be properly addressed. Introducing argumentation method in teaching science subjects at elementary level carry the promise of improving students' academic performance as found in the present study. The method has the added advantage of developing students' critical skills, improving conceptual understanding and helping students' to make informed decisions. The students in experimental group who were taught with argumentation teaching performed better than those who were in control group which established positive effects of argumentation methods and suggests its use at elementary level. Moreover, argumentation helped the female students more in improving academic performance in comparison to male students in the present study. In argumentation reports, male and female students indicated no difference as observed from their reports. However, there is a need to experiment more with this dimension as generalization cannot be made on the basis of a single study. The findings from the present study provided evidence that elementary level students are capable of involvement in complex and sophisticated learning. Similar results were reported by Levstik & Barton, (2011); Metz, (2004).

Limitations

One limitation of this study was that students of elementary level have writing problems and thus the quality of argumentation report might have affected. The use of argumentation with lower class students thus needs to be further explored to find other alternatives for assessing quality of argument such as oral argumentation. Moreover, students' construction of argument was affected by possession of previous knowledge. Students lacking previous knowledge about the topic for discussion were not able to write good quality arguments (also found by von Aufschnaiter et al., 2008). The teachers thus need to incorporate such topics and activities of which students have prior knowledge to make argumentation useful for students.

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