EFFECTS OF PROMOTING ARGUMENTATION ON STUDENTS' REASONING IN PHYSICS

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Abstract

The purpose of this research was to examine the effects of implementation of argumentation in a physics classroom on students' reasoning. This research is both quantitative and qualitative in nature. Experimental design was used for the study. For the quantitative aspect of the research, students' prior knowledge in the beginning of the instruction and their knowledge after the instruction were measured and compared. For the qualitative part, students' reasoning was analyzed at the end of the instruction. The results of this study show that promoting argumentation in a classroom can enhance students' reasoning in science. Reasoning can lead to construction of scientific knowledge. Consequently, there can be significant gains in students' conceptual development by explicating, comparing and challenging ideas.

Introduction

Current trends in science education have shifted from a positivist perspective to seeing science learning as construction of scientific knowledge claims. Such changes have suggested that "the focus of student's work should transcend the declarative to include procedural and strategic knowledge-that is to enable students' abilities to reason and reflect metacognitively on their own learning and the construction and evaluation of scientific knowledge" (Duschl & Osborne, 2002, p. 39).

Language plays a significant role in learning (Newton, Driver & Osborne, 1999). The language of science is a discourse that critically examines and evaluates the numerous and at times iterative transformations of evidence into explanations (Duschl, Ellenbogen & Erduran, 1999). Studies (Dushcl & Osborne, 2002; Driver, Asoko, Leach, Mortimer & Scott, 1994; Mason, 1998) have highlighted the importance of discourse in the acquisition of scientific knowledge. According to Driver et al., learning science requires students' participation through talk and writing, in thinking through and making sense of the scientific events, experiments and explanations to which they are being introduced. Discourse is not only language but also attitudes, beliefs and values. In other words, discourse is the way of an individual's expression. Argumentation is a form of discourse that needs to be embedded through instruction. Pedagogical emphasis on argumentation is consistent with general education goals that seek to equip students with capacities for reasoning about problems and issues (Jimenez-Aleixandre, Rodriguez & Duschl, 2000).

What is Argumentation?

A common aspect of argumentation drawn from its various definitions (Krummheuer, 1995; Kuhn, 1993; Suppe as cited in Nieswandt, Shanahan & Sharkawy, 2005) is that argumentation includes a reasoning process in order to justify or refute a claim. If this reasoning process is in terms of single line thought and is being used to persuade (the others), this argumentation is referred to as rhetorical. If a number of people are involved in the reasoning process (there will be a number of contrasting lines developed), this argumentation is referred to as dialogical argumentation.

The Place of Argumentation in Science Education

A plenty of research has been conducted to examine the effects of promoting argumentation in classroom environment. Nussbaum and Sinatra (2003), for example, presented that argumentation promoted conceptual change. In their research, participants who were asked to argue in favor of an alternative explanation of a physics problem were more likely to show improved reasoning on that problem than control participants who were asked to solve the problem without argumentation. Similarly, Niaz, Aguilera, Maza and Liendo (2002) found that given the opportunity to argue and discuss, students' understanding of atomic structure could go beyond the simple regurgitation of experimental details. Mason (1998) investigated the role of oral and written discourse in constructing scientific knowledge and showed that while reasoning and arguing collectively, the students constructed more advanced knowledge by sharing cognition. The common result emerged from these research is that argumentation has positive effect on students' learning.

Argumentation has also used to bring out students' way of thinking (Kuhn, 1992) and their epistemic operations (Jimenez-Aleixandre, Rodriguez & Duschl, 2000).

Purpose of the Research

Engaging in reasoning processes, such as seeking information to support claims, can multiply and strengthen connections within a person's cognitive framework of ideas (Hogan & Fisherkeller, 2000). Therefore, the purpose of this research was to examine the effects of implementation of argumentation in a physics classroom on students' reasoning.

Methodology

This research is both quantitative and qualitative in nature. Experimental design was used for the study. For the quantitative aspect of the research, students' prior knowledge in the beginning of the instruction and their knowledge after the instruction were measured and compared. For the qualitative part, students' reasoning was analyzed at the end of the instruction.

Participants and Settings

The participants of the study were 52 tenth-grade students from two physics classrooms in a high school. The population of the classrooms was the same. Experimental and control groups were determined randomly.

Instructional Context

One of the authors of this paper was the teacher of both groups. Unlike the control group, argumentation was embedded in the instruction given to the experimental group. Kuhn, Shaw and Felton (1997) state that if both the number of argumentation and intervention time are raised, the quality of participants' argumentation increases. The context and content of argumentation also affect participants' argumentation quality (Duschl & Osborne, 2002; Kelly, Druker & Chen,1998). For that reasons, five argumentations were used in the different contexts through dynamics unit in ten-week duration. The contents of the argumentations were related to the following subjects: free fall, Newton's Second Law, Newton's Third Law, motion in the space, and rotational motion. Same concepts with the same teaching methods were mentioned in both groups. For example, both groups conducted an experiment related to Newton's Second Law; however, the students in the control group did not argued during the process.

Data Collection

Force Concept Inventory (FCI), which is composed of 30 multiple choice questions and designed to monitor students' understanding of force and related kinematics, was used both in the beginning and at the end of the instruction. The time between the pre- and post-applications was adequate to diminish the instrument effect. Mortality was eliminated by requesting attendance from all of the subjects during the applications.

Data Analysis

Independent t-test analysis was performed to compare students' knowledge before and after the instruction. The students were required to give their reasons for their choices during the post-application of FCI to determine their reasoning about dynamics concepts.

Bidimensional coding scheme developed by Hogan and Fisherkeller (1996) was used to analyze students' reasoning. Based on this scale, if the choice was correct and the reasoning behind it was given in detail or adequate explanation was based on the correct concepts, it was coded as "compatible elaborate". Although the choice was correct, but the reasoning behind it was superficial or inadequate explanation was based on the correct concepts, it was coded as "compatible sketchy". On the other hand, if the choice was not correct and the reasoning behind it was given in detail or adequate explanation was based on the incorrect concepts, it was coded as "incompatible sketchy". If the choice was not correct and the reasoning behind it was superficial or inadequate explanation was based on the incorrect concepts, it was coded as "incompatible sketchy". If the choice was correct but the reasoning behind it was based on the incorrect concepts, it was coded as ‘‘compatible /incompatible". If there was a choice but the reason behind it was not given, it was coded as "no evidence". If there was no response, it was coded as "nonexistent". The coding procedure was repeated a few times in order to provide reliable analysis of students' reasoning. Once the coding scheme was finalized by one of the authors, it was revised by two of the authors and final scheme was constructed by reaching consensus.

Results

There was not much difference between the control group's prior knowledge (mean=0.14) and the experimental group's prior knowledge (mean=0.18) (t=1.934, df=50, p=0.025, one tailed). However, there was a significant difference between two groups at the end of the instruction (t=3.800, df=50, p=0.00, one tailed). The students in the experimental group gave more correct responses to the FCI questions (mean=0.39) than the students in the control group (mean=0.25). Bias corrected effect size (Hedges & Olkin, 1985) for the post-application was calculated as 1.1. This effect size value was large and indicated that the mean of the experimental group was at the 86^{th} percentile of the control group and a nonoverlap of 58.9% in the two distributions (Cohen, 1988).

Table 1. *The coding scheme of students' reasoning*

Questions and Concepts	Codes	Control Group Freq.(%) N= 26	Experiment. Group Freq.(%) N=26
Q1: Gravitation, acceleration independent of weight	Compatible elaborate	8	16
	Compatible sketchy	35	27
	Incompatible sketchy	14	38
	Incompatible elaborate	8	19
Q4 : Third Law for impulsive forces	Compatible elaborate	46	88
	Compatible sketchy	8	4
	Incompatible sketchy	8	8
	Incompatible elaborate	26	-
	Compatible/Incompatible	8	-
	Nonexistent	4	-
Q7: First Law with no force	Compatible elaborate	8	23
	Compatible sketchy	15	8
	Incompatible sketchy	42	27
	Incompatible elaborate	31	31
	Compatible/Incompatible	4	4
	No evidence	-	8
Q12: Gravitation parabolic trajectory	Compatible elaborate	8	8
	Compatible sketchy	4	4
	Incompatible sketchy	27	15
	Incompatible elaborate	30	27
	Compatible/Incompatible	4	11
	No evidence	27	35
Q15: Third Law for continuous forces	Compatible elaborate	8	50
	Compatible sketchy	12	4
	Incompatible sketchy	23	12
	Incompatible elaborate	46	15
	Compatible/Incompatible	3	15
	No evidence	8	4
Q19: Kinematics	Compatible elaborate	11	62
	Compatible sketchy	8	11
	Incompatible sketchy	31	4
	Incompatible elaborate	31	23
	No evidence	11	-
	Nonexistent	8	-
Q22: Second Law constant force implies constant acceleration	Compatible elaborate	8	27
	Compatible sketchy	4	-
	Incompatible sketchy	53	42
	Incompatible elaborate	35	23
	Compatible/Incompatible	-	4
	No evidence	-	4

Table 1, cont. *The coding scheme of students' reasoning*

Questions and Concepts	Codes	Control Group Freq.(%) N= 26	Experiment. Group Freq.(%) N=26
Q23: First Law	Compatible elaborate	4	15
velocity direction constant	Compatible sketchy	12	-
	Incompatible sketchy	46	35
	Incompatible elaborate	19	19
	No evidence	4	23
	Nonexistent	15	8
Q25: Superposition	Compatible elaborate	-	4
principle	Incompatible sketchy	61	69
canceling forces	Incompatible elaborate	35	23
	No evidence	4	4

The coding scheme given in Table 1 represents students' reasoning for some of the questions in the FCI. Due to the page limitation, students' reasoning for all of the questions in the FCI could not be presented here. The concepts mentioned in the Questions 1, 4, 7, 15, 19, 22 and 23 were discussed during the argumentation process in the experimental group. Regarding these questions, the frequency value of the experimental group for the "compatible elaborate" code was higher than the frequency value of the control group. In other words, the students in the experimental group could develop more correct and detailed reasoning of the concepts they argued than the students in the control group. On the other hand, for Questions 12 and 25, the frequency values of both groups for the codes were similar. That is, the concepts in these questions did not take place in the argumentation process. And, at the end of the instruction, the levels of reasoning of the students in both groups were similar with regards to these concepts.

Conclusion and Implications of the Study

The results of this study show that promoting argumentation in a classroom can enhance students' reasoning in science. A well-structured knowledge base can sustain higher levels of reasoning than poorly structured knowledge (Novak & Gowin as cited in Hogan & Fisherkeller, 2000). This means that reasoning can lead to construction of scientific knowledge. Consequently, there can be significant gains in students' conceptual development by explicating, comparing and challenging ideas.

The conclusion presented here carries implications for science education. Although there is overburdened curriculum, argumentation could be established in the science classroom and its positive effects on conceptual development could be observed.

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