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Investigation of A Pattern Between Students' Engagement in Argumentation and Their Science Content Knowledge: A Case Study

Handan Eşkin
Çemberlitaş Anatolian High School, Istanbul, TURKIYE

Feral Ogan-Bekiroğlu
Marmara University, Istanbul, TURKIYE

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The aim of this study was, first, to investigate any pattern between students' quantitative contribution to argumentation and their science understanding, and second, to analyze any relationship between students' qualitative contribution to argumentation and their scientific knowledge. Participants of the study were four tenth-grade students. The participants were videotaped during the argumentations embedded in the physics class. Two interviews were conducted with each participant in order to examine their scientific understanding deeply. Argumentations were analyzed as quantitative and qualitative by using Toulmin's Argument Pattern. Results from the study illustrate no significant relationship between students' engagement in argumentation and their science content knowledge.

Keywords: Argumentation, Engagement, Contribution, Physics, Scientific Knowledge

ARGUMENTATION IN SCIENCE EDUCATION

While the traditional alternative for concept learning has been process learning, newer ideas in cognitive and social psychology emphasize instructional sequences/units that seek outcomes related to students' reasoning and communication in science contexts (Duschl, Ellenbogen & Erduran, 1999). It is in argument that higher order thinking and reasoning figure in the lives of most individuals (Kuhn, 1992). If students are to develop the skills of scientific argument for themselves, and not just provide an audience for the teachers' reasoning, then science classrooms need to offer opportunities to practice such reasoning for themselves (Driver, Newton & Osborne, 2000). Argumentation is a reasoning strategy and comes under the reasoning domains of informal logic and critical thinking (Jimenez-Aleixandre, Rodriguez & Duschl, 2000). Students in an argumentation process articulate reasons for supporting a particular claim, attempt to persuade or convince their peers, express doubts, ask questions, relate alternate views, and point out what is not known (Driver, Newton & Osborne, 2000). Erduran, Simon and Osborne (2004) claim that when students engage in a reasoning process and support each other in high-quality argument, the interaction between the personal and the social dimensions promotes reflexivity, appropriation, and the development of knowledge, beliefs, and values.

There is ample research on the investigation of effects of promoting argumentation on students' learning. Niaz, Aguilera, Maza and Liendo (2002), for instance, found that given the opportunity to argue and discuss, students' understanding of atomic structure

Correspondence to: Feral Ogan-Bekiroğlu, PhD in Science Education, Marmara Üniversitesi, Atatürk Eğitim Fakültesi, OFMAE Bölümü, Fizik Eğitimi AD, Göztepe İstanbul , TURKEY
E-mail: feralogan@yahoo.com

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went beyond the simple regurgitation of experimental details. Similarly, Nussbaum and Sinatra (2003) showed that argumentation endorsed conceptual change. In addition, Mason (1998) discovered that while reasoning and arguing collectively, students constructed more advanced knowledge by sharing cognition. Eskin and Ogan-Bekiroglu (2007) revealed that the students in the experimental group, where argumentation was embedded in the instruction, developed more correct and detailed reasoning of the physics concepts they argued than the students in the control group. Literature review presents positive effects of argumentation on construction of scientific knowledge. That is, explicating, comparing and challenging ideas can improve students' learning.

Purposes of the Study

Studies show that different types of groupings, in terms of ability levels, gender, and the number of participants affect group discussion and individuals' behavior (amount of verbal participation, giving and receiving explanations, etc.) (Alexopoulou & Driver, 1996). In addition, students' willingness to acknowledge and deal with situations that may involve argument depends on their perceptions and interpretations of the purpose and the context of the task, and the learning situation (Perret-Clermont, Perret & Bell, 1991). However, within both Vygotskian and Piagetian traditions, the focus has been on the interaction process itself so that cognitive capacities of the individuals have not been examined (Kuhn, Shaw & Felton, 1997). A small number of studies examined the relationship between students' contribution and their scientific knowledge. Eichinger, Anderson, Palinscar and David (1991), for example, found that the students who were already skillful in constructing scientific arguments participated more. Sadler and Fowler (2006) suggested that science content knowledge could affect the manner in which individuals defended and justified their positions. Therefore, the aim of this study was, first, to investigate any pattern between students' quantitative contribution to argumentation and their science understanding, and second, to analyze any relationship between students' qualitative contribution to argumentation and their scientific knowledge.

METHODOLOGY

This qualitative research was utilized as a case study design focusing on one group during the argumentation process.

Instructional Context

The first author was the physics teacher of the class where there were 26 tenth-grade students in a state high school. Five argumentations were embedded through the dynamics chapter in ten-week duration. All of the argumentations were dialogical where different perspectives were being examined and the purpose was to reach agreement on acceptable claims or courses of action (Driver, Newton & Osborne, 2000). 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. As the context and content of argumentation may affect participants' argumentation quality (Duschl & Osborne, 2002), argumentations were promoted in different contexts. According to Kuhn et al. (1997), the number of argumentation is directly proportional to the quality of participants' argumentation. Therefore, the third and fourth argumentations were taken into account in this study under the assumption that the students got used to argue. The third argumentation was related to Newton's Third Law and promoted in the prediction-observation-explanation context. The fourth argumentation, on the other hand, was related to motion in the space and promoted in the competing theory context. Students worked as groups in the beginning of the argumentations and then, each group expressed their ideas in a whole-discussion. There were three or four students in each group.

Participants

Participants of the study were four students in one group. They were volunteers for the study and coded as P1, P2, P3 and P4. Since it was an all-girls school, all of the participants were female. In order to be able to work with the participants having different levels of science content knowledge, the students in the class answered Force Concept Inventory (FCI) before the instruction. FCI is composed of 30 multiple-choice questions and designed to monitor students' understanding of force and related kinematics. The students were required to give their reasons for their choices during the implementation of the inventory. Based on the results of the implementation, P1's content knowledge was determined as moderate, while P2's content knowledge was diagnosed as very high. Furthermore, P3's content knowledge was found as high, whereas P4's level of knowledge was low.

Data Collection

Due to the fact that the participants were in the same group through the instruction, some of the factors that might affect contribution, such as group dynamics, gender and number of the participants, were kept constant in the research. The participants were videotaped during the argumentations. Data for this research were gathered from their group discussions.

Two interviews were conducted with each participant in order to examine their science understanding deeply. Think-aloud protocol was used in the interviews where the explanation questions were asked. Four questions, all had a few sub-questions, related to Newton's Third Law were asked in the first interview. Likewise, five questions about motion on a frictionless area were used in the second interview's protocol. However, because of the content of the questions, the students needed to use other dynamics concepts, such as Newton's First and Second Laws, in order to answer the questions. Most of the questions were the generation of the previous question and prepared by changing the condition of one parameter in that question. The interviews were done in the physics laboratory and lasted 20 to 30 minutes. The interviewer was the teacher; hence, the participants were ensured that their answers would not affect their grades in any way.

Data Analysis

Erduran et al. (2004)'s methodological approach was used in the argumentation analysis. In their approach, they contextualized the use of Toulmin's Argument Pattern (TAP) and analyzed argumentation as quantitative and qualitative. Transcripts of the video recordings of the argumentations were divided into sub-arguments and each sub-argument was analyzed. There were six sub-arguments in each argumentation. Content was the factor in determination of sub-arguments.

Regarding components of TAP, data supports the claim and warrant provides a link between the data and the claim. In addition, backing strengthens the warrant and is a generalization making explicit the body of experience. Erduran et al. (2004) state that rebuttal points to the circumstances under which the claim would not hold true. In other words, rebuttal is the extraordinary or exceptional circumstance that might undermine the force of the supporting arguments (Erduran et al., 2004). Qualifier, on the other hand, is a phrase that shows what kind of degree of reliance is to be placed on the conclusions (Erduran et al., 2004). Figure 1 represents Toulmin's Argument Pattern.

An episode is given below from one sub-argument in the motion in the space argumentation. Students were working on the following question: "What would happen if the astronaut trying to reach the satellite was three times heavier? Please describe his motion (from the scene of "Mission to Marst" movie)".

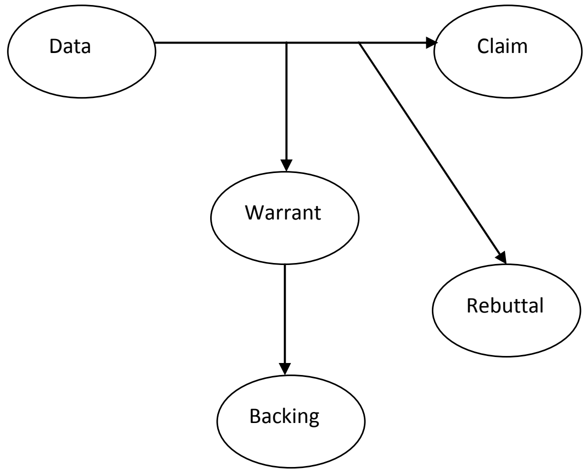

Figure 1. Toulmin's Argument Pattern (Retrieved from Erduran et al., 2004)

P2: If the mass of the astronaut increases, his acceleration will decrease (claim)
P2: If we use f=m.a, it will change. This is more logical. For example, if the force is 10 and the mass is 1, it will move with the acceleration of 10. OK? This time, the force is 10 but the mass is 2. It will move with the acceleration of 5. OK? (data). Therefore, he (the astronaut) would move slower (warrant).
P3: To me, it (velocity) does not change according to mass (rebuttal). I will say something: If we leave a hammer and a quill at the same time, will both of them drop with the same velocity? (rebuttal).
P1: They will drop at the same time in the space (qualifier).
P3: It will be the same on the frictionless area..... I mean, If there is air maybe it will change..... There need to be gravitation in order to be acceleration, right? They will drop at the same time (warrant)...............

For the quantitative measure, the features of TAP scheme were determined. For example, if the sub-argument was composed of the claim (C) and data (D), it was coded as C.D. Nonetheless, if the sub-argument was composed of the claim (C), data (D), warrant (W), backing (B) and rebuttal (R), it was coded as C.D.W.B.R. Counter-claims were coded as CC and qualifiers were coded as Q. Total number of the components in one sub-argument was equaled to 100 and then, each student's contribution to the sub-argument was calculated as a frequency percent value. Overall contribution of the student to the argumentation was determined by calculating the average of six percentage values.

The qualitative measure focused on the quality of rebuttals. According to Erduran et al. (2004), if the sub-argument included a claim versus a counter-claim or a claim versus a claim, it was coded as Level 1. If the sub-argument was composed of a claim versus a claim with either data, warrants, or backings but did not contain any rebuttals, it was coded as Level 2. If the sub-argument had a series of claims or counter-claims with either data, warrants, or backings with the occasional weak rebuttal, it was coded as Level 3. Moreover, if the sub-argument consisted of a claim with a clearly identifiable rebuttal, it was coded as Level 4. Finally, if the sub-argument displayed more than one rebuttal, it was coded as Level 5. Each student's contribution to the sub-argument was determined. Then, the student's overall contribution to the argumentation was found by calculating the average of six values.

Bidimensional coding scheme developed by Hogan and Fisherkeller (1996) was used to analyze students' science content knowledge. Based on this scale, the participant's understanding concurring with the scientific proposition and having sufficient detail to show the thinking behind them was coded as compatible elaborate. However, if the essential details were missing, it was coded as compatible sketchy. The participant understands disagreeing with the scientific proposition and having details or coherent logic was coded as incompatible elaborate. Nevertheless, if very few details or logic were given for the participants' nonscientific understanding, it was coded as incompatible sketchy. If the participant made sketchy statements concurring with the scientific proposition and also made sketchy statements disagreeing with the scientific proposition, his/her understanding was coded as compatible/incompatible.

P4's excerpts from the first interview related to Newton's Third Law were given below as an example. The question was as following: Are there any forces exerting on the table, which is stationary and being pushed by a person? What would you do to move the table? Why?

P4: ……. I would push the table more to move it.
Teacher: What would you do to push it more?
P4: I would get a support from somewhere. I would lean on the wall.
Teacher: Why would you need a support?
P4: It would give me an impulse and I apply it to the table.
Teacher: Why?
P4: I don't know. We did something like that in the experiment. Maybe it (the wall) would give me an impulse, a support, and I would take power from it. If I lean on the wall, it would give me an impulse. If I take power from the wall, I would push the table.

P4 did not consider the function of the frictional force in moving the table. Although her answer was correct, she did not use much conceptual knowledge in generating her explanations. Instead, she tried to explain the reasons based on her observations in the experiment. Therefore, P4's knowledge related to Newton's Second Law was coded as compatible sketchy.

The dialogue between the teacher and P4 from the second interview related to motion on a frictionless area was provided for another bidimensional coding example. The participant was answering the following question: Explain the motion of an object that is placed on a frictionless inclined plane of angle θ and subjected to one constant force.

Teacher: What do you think about the values of velocity and acceleration of two objects on a frictionless area; one is subjected to one constant force, while the other one is subjected to one instant force?
P4: According to the law, when an instant force acts on an object at rest, it remains at rest; on the other hand, when an instant force acts on an object in motion, it continuous its motion. Because of the frictionless area, it moves until it comes across with an obstacle. However, when a constant force acts on an object I think it (the object) moves continuously with the velocity caused by the constant force. But I cannot think the difference between the two. What is the difference?
Teacher: What do you think?
P4: I think, both objects move with a constant velocity.

Since P4 had alternative conceptions about the acceleration of the object subjected to one constant speed and was not sure about her explanations, her knowledge related to Newton's Second Law was determined as incompatible sketchy.

The first author coded both the arguments and the students' understanding and then, the codes were revised by two authors many times. High agreement was achieved. Comparisons were made between the argumentations as well as within the argumentation in order to detect any pattern between students' engagement in argumentation and their scientific knowledge.

RESULTS

Table 1 and Table 3 illustrate the quantitative and qualitative analyses of argumentations. Table 2 and Table 4, on the other hand, present the coding schemes of the participants' science content knowledge. Comparison of argumentation tables and knowledge tables enabled to trace any relationship between two phenomena.

P1's scientific understanding was moderate according to other students' understanding. Although her understanding of Newton's Third Law and measure of inertia somewhat concurred with the scientific propositions, her understanding of effects of force on motion was not completely compatible with scientific knowledge. Regarding the argumentations, she was always the third contributor in terms of quantity (25.6% and 24.3%). The average Level of her qualitative contribution was 2 (Level 2.5 and Level 2). Thus, P1's both quantitative and qualitative contributions to

Table 1. The quantitative and qualitative analyses of the Newton's Third Law argumentation

SA	TAP	P1	QNC (P1)	QLC (P1)	P2	QNC (P2)	QLC (P2)	P3	QNC (P3)	QLC (P3)	P4	QNC (P4)	QLC (P4)	LSA
SA_1	C.D. W. CC.	CC. C.	18.2	1	C.D. W.	27.3	2	C.D. C.D.	36.4	2	C.W.	18.1	2	2
SA_2	C.D. W. CC. R.	C.R. D. CC	20	3	C.D. R.R (CC. D.W. B)	35	5	C.D. C.D. W.	25	2	C.R. C.D.	20	4	5
SA_3	C.D. W.	D.W.	33.3	2	C.C. D.	50	2	C	16.7	1	-	-	-	2
SA_4	C.D. W. CC. R.	CC.	5	1	R (CC. D.W) C.D. W.R.	35	5	D.C. D.C. D. C.C.	35	2	C.D. C.D. W.	25	2	5
SA_5	C.D. W.R.	C.D. C.D. R.	38.4	4	C	7.7	1	C.D. W. C.D. W.	46.2	2	R.	7.7	4	5
SA_6	C.D. W. CC. R.	C.D. R.CC D.C. D.	38.9	4	C.D. W. D.W. CC	33.3	2	C.C.	11.1	1	C.D. D.	16.7	2	4
AQNC			25.6			31.4			28.4			14.6		
AQLC				2.5			2.8			1.7			2.3	3.8

SA: Sub-Argumentation; TAP: Components of Argumentation; P1-P6: Participants; QNC: Quantitative Contribution (%); QLC: Qualitative Contribution; AQNC: Average Quantitative Contribution; AQLC: Average Qualitative Contribution; LSA: Level of Sub-Argumentation

Table 2. The Coding Scheme of The Participants' Understanding of Newton's Third Law

Subjects	P1	P2	P3	P4
Newton's First Law of Motion	Compatible / Incompatible	Compatible / Incompatible	Compatible elaborate	Compatible elaborate
Measure of inertia	Compatible sketchy	Compatible elaborate	No evidence	Compatible sketchy
Newton's Second Law of Motion	Compatible sketchy	Compatible sketchy	Compatible sketchy	Compatible sketchy
Kinematics	Compatible sketchy	Compatible / Incompatible	Compatible / Incompatible	Compatible / Incompatible
Newton's Third Law	Compatible elaborate	Compatible elaborate	Compatible elaborate	Compatible elaborate

argumentation and her science content knowledge were directly proportional.

P2's scientific understanding was higher than P1's understanding. While her understanding of Newton's Second and Third Laws was scientific, her understanding of Newton's First Law and effects of force on motion integrated many non-scientific claims. P2 was the one who quantitatively contributed most to two argumentations (31.4% and 46.9%). Likewise, P2's qualitative contribution was the highest among the other participants. The average Level of her qualitative contribution was 3 (Level 2.8 and Level 3.2). There seemed to be no correlation between P2's both quantitative and qualitative contributions to argumentation and her scientific knowledge.

P3's scientific understanding was the highest among four participants' understanding. None of her codes was completely incompatible. That is, she had some scientific propositions for every concept discussed in the argumentations. On the other hand, she was the second contributor in two argumentations regarding

Table 3. The quantitative and qualitative analyses of the motion in the space argumentation

SA	TAP	P1	QNC (P1)	QLC (P1)	P2	QNC (P2)	QLC (P2)	P3	QNC (P3)	QLC (P3)	P4	QNC (P4)	QLC (P4)	LSA
SA_1	C.D.W. CC. R.Q.B	CC. W.B. R.R	31.2	5	C.D. C.D. C.D.W.	43.8	2	W.Q. CC. W.	25	2	-	-	-	5
SA_2	C.D. W.R.	-	-	-	W.R (CC. D)	50	3	C.D. C.	50	2	-	-	-	3
SA_3	C.D. W.R.	C.D. W	50	2	R (CC. D.W)	50	4	-	-	-	-	-	-	4
SA_4	C.D. W.R.	C.D	25	2	C.D. W.	37.5	2	R (CC. D.W)	37.5	4	-	-	-	4
SA_5	C.D. W.R.	C.D. W	30	2	C.D. W.R (CC. D)	50	3	C.D.	20	2	-	-	-	3
SA_6	C.D.W. CC. R.B.	B	10	1	C.D. W. R.B.	50	3	CC. R.W. B.	40	3	-	-	-	5
AQNC			24.3			46.9			28.8			0		
AQLC				2			3.2			2.2			0	4.0

SA: Sub-Argumentation; TAP: Components of Argumentation; P1-P6: Participants; QNC: Quantitative Contribution (%); QLC: Qualitative Contribution; AQNC: Average Quantitative Contribution; AQLC: Average Qualitative Contribution; LSA: Level of Sub-Argumentation

Table 4.The coding scheme of the participants' understanding of motion in the space

Subjects	P1	P2	P3	P4
Newton's First Law of Motion	Compatible elaborate	Compatible / Incompatible	Compatible elaborate	Compatible elaborate
Measure of inertia	Compatible sketchy	Compatible / Incompatible	Compatible / Incompatible	Compatible sketchy
Newton's Second Law of Motion	Incompatible sketchy	Compatible elaborate	Compatible elaborate	Incompatible sketchy
Kinematics	Compatible / Incompatible	Compatible sketchy	Compatible elaborate	Incompatible elaborate
Effects of force on motion	Compatible / Incompatible	Compatible / Incompatible	Compatible / Incompatible	Incompatible sketchy

quantity (28.4% and 28.8%). Like P1's situation, the average Level of P3's qualitative contribution was 2 (Level 1.7 and Level 2.2). Hence, there seemed to be no correlation between P2's both quantitative and qualitative contributions to argumentation and her science content knowledge.

P4's scientific understanding was quite inconsistent comparing the two argumentations. Even though her knowledge related to the concepts discussed in the Newton's Third Law argumentation partially agreed with scientific claims, her understanding in the motion in the space context was mostly incompatible with scientific knowledge. In terms of quantitative contribution, she was always the last contributor (14.6% and 0%). Her qualitative contribution was also low as it matched with Level 1 (Level 2.3 and no contribution). P4's quantitative contribution and her scientific knowledge were inversely proportional for the

Newton's Third Law argumentation and directly proportional for the motion in the space argumentation. In addition, her qualitative contribution and her scientific understanding were directly proportional for the motion in the space argumentation.

In order to make analysis within the argumentations, the participant's content knowledge in each argumentation was determined by assigning numbers to the codes given Table 2 and Table 4 and summing the numbers. In this way, "1" was given to compatible elaborate, "0.5" was given to compatible sketchy, "0" was given to compatible/incompatible, "-0.5" was given to incompatible sketchy, and "-1" was given to incompatible elaborate. The participants were sorted according to their understanding of the concepts in the Newton's Third Law argumentation as the following: P4 > P1 = P2 = P3. Additionally, their order based on their quantity of contributions was as follows: P2 > P3 > P1 > P4. When these two orders were compared, no similarity was found between the students' quantitative contributions and their scientific knowledge regarding the Newton's Third Law argumentation. Moreover, the participants were arranged according to their science content knowledge in the motion in the space argumentation as the following: P3 > P2 > P1 > P4. Their classification based on their quantity of contributions as follows: P2 > P3 > P1 > P4. Similarity was found between two orders for the motion in the space argumentation.

The quality of contributions was identified by probing the level of argument. The participants were sorted according to their qualitative contributions to the Newton's Third Law argumentation as the following: P2 > P1 > P4 > P3. Comparison of this result with the students' understanding in the Newton's Third Law context (P4 > P1 = P2 = P3) did not present any pattern. Furthermore, the participants' order based on their qualitative contributions to the motion in the space argumentation was as follows: P2 > P3 > P1 > P4. There was small pattern between the students' qualitative contributions and their scientific knowledge in the motion in the space context (P3 > P2 > P1 > P4).

CONCLUSIONS AND IMPLICATION

Though some proportions and similarities, results from the study illustrate no significant relationship between students' quantitative contributions to argumentation and their scientific understanding. Equally, there is no consistent pattern between students' qualitative contributions to argumentation and their scientific knowledge. There is consensus that argumentation can facilitate learning. However, research presented here suggests that teachers should not use argumentation as an assessment tool for formative evaluation and they should not try to make decisions about students' content knowledge based on their engagement while they are arguing.

The factors that might affect contribution were taken under control in this research, apart from context. Two argumentations were promoted in the different contexts. Researchers (Duschl & Osborne, 2002; Kelly, Druker & Chen, 1998; Perret-Clermont, Perret & Bell, 1991) mention the relationship betweeen context and participants' argumentation quality. Different contexts in this study might cause unfound patterns and relationships. Further studies are needed to expand this postulation.

Williams (2004) points out that case studies do not depend on statistical generalization from sample to population, as in survey research, but on logical inference from prior theorizing. Consequently, theoretical generalization does not aim to say anything about populations but instead makes claims about the existence of phenomena proposed by a theory (Williams, 2004). Case study methods do present evidence for readers to make their own generalizations based upon the particulars of the case (Faltis, 1997). Theoretical corroboration can be increased by further instances of a phenomenon in repeated case studies (Williams, 1994). This case study adds to the literature investigating the relationship between students' science content knowledge and their quality and quantity of arguments.

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