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Appropriating Epistemic Norms of Science through Sustained Practice with Argumentation: Can It Happen? A Learning Progressions Perspective

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Abstract

The purpose of this study was to explore the effect of sustained practice with argumentation on the quality of students' written arguments. Participants consisted of 37 students; 22 males and 15 females enrolled in a 6th grade middle school classroom. Students completed six argumentation tasks but only four of them were considered for data analyses as the first two tasks were used to get the students familiar with the language and structure of argumentation. Data were analyzed using the Claim, Evidence and Reasoning (CER) Framework. Findings reveal several patterns regarding students' use of claim, evidence, and reasoning across 4 tasks that were subject to our evaluation. First, there was not a consistent pattern of improvement in students' use of evidence. Second, there were not any consistent improvements in students' use of reasoning across four tasks. Our discussion focuses on the role of context, content knowledge and teacher framing in the quality of arguments developed by students.

Key words: Argumentation, Science, Middle school, Learning progressions, Learning

Introduction

There has been an increasing emphasis in helping students in science classrooms to engage in epistemic practices of science in recent years across the globe (Driver, Newton & Osborne, 2000; Duschl, Schweingruber, & Shouse, 2007; Erduran & Jime´nex-Aleixandre, 2008; Larrain, Freire, & Howe, 2014). Kelly (2008) defines epistemic practices as "discipline-specific ways of proposing, justifying and evaluating, knowledge claims" (Kelly, 2008). In the context of science education reform rhetoric, argumentation is viewed as an important epistemic practice that must be practiced by all students while learning science (Driver et al, 2002; Duschl et al., 2007; Kuhn, 2010; Osborne et al., 2013). Argumentation refers to the process whereby students engage in justification of claims to knowledge based on scientific evidence and through warrants that connect evidence to claims (Erduran & Jime´nex-Aleixandre, 2008). While some studies in science education focus on students' construction of written arguments (Chen, Hand, McDowell, 2013; Sampson, Enderle, Grooms & Witte, 2013), others focus on students' construction of scientific arguments verbally through a dialogical process, whereby students are deliberately trying to persuade each others of the validity of their claims (Berland, 2011; Osborne et al., 2013; Ryu & Sandavol, 2012). As Kelly and colleagues argue, studies of students' discourse in in the context of written and verbal argumentation allow us to examine how students appropriate epistemic norms of science (Schwarz, Neuman, Gil, & Ilya, 2003) and identify and characterize the types of challenges they experience and support they may need in constructing quality scientific arguments (Berland & McNeill, 2012).
While there has been a surge in argumentation studies in science education in recent years, the majority of studies focus on teachers' pedagogical knowledge of argumentation (Sampson & Blanchard, 2012; Simon, Erduran, & Osborne, 2006) or the effects of argumentation on students' conceptual understanding of scientific concepts (Venville & Dawson, 2010) or the nature of classroom discourse (Berland, 2011; Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Kuhn, Shaw & Felton, 1997; Larrain, 2014). One of the questions that have not been fully answered in science education literature is whether quality of students' arguments changes over time and with practice. In this study, our analyses focused on students' written discourse in a 6th grade science classroom across five argumentation tasks and over the course of one semester. The research questions that guided our inquiry are:

I. How does the quality of students' written arguments change over time and through sustained practice? (i. e. progressions of the quality of students' written arguments).
II. Which aspects of written arguments did sustained practice help students improve on and which aspects proved to be challenging for students?

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Review of Relevant Literature

While most studies in science education point out the lack of argumentation in regular science classrooms (Berland, 2011; Larrain et al., 2014; Osborne et al., 2013; Sampson & Blanchard, 2012), some empirical research suggests that students' effective engagement in scientific discourse could be enhanced through scaffolding. Sampson et al. (2013) conducted a study in two middle and two high school classrooms in the U.S. The participants consisted of 67 students enrolled in a life science course, 52 students enrolled in a middle school physical science course, 94 students enrolled in a high school biology course and 81 students enrolled in a high school chemistry course. The authors sought to explore the effects of Argumentation-Driven Inquiry (ADI) curriculum on students' argumentation skills as well as their conceptual understanding as measured through students' responses to course specific open-ended questions. ADI is a writing intensive laboratory-based curriculum that engages students in inquiry (see Sampson et al for details). They engaged students in 4 ADI-based laboratory activities in all courses in the first semester. During the second semester, however, while students in enrolled in physical science and chemistry engaged in 2 ADI laboratories, students in life science and biology course engaged in 4 ADI laboratories. The results of their study showed that students made significant improvements in their content understandings between pre and post tests in all courses but middle school physical science course. The authors conducted a one-way, within-subjects analysis of variance (ANOVA) to see if the students made improvements in the quality of their written arguments over time. The results of their study showed that while all students made significant progress during the first semester, they did not observe the same trend in the second semester. While students in middle school life science course and biology course made significant improvements in both semesters, students enrolled in middle school physical science course and high school chemistry course did not make improvements in the second semester. The authors reasoned students' lack of improvement in physical science and chemistry course to "decreased opportunities to write" in the second semester (p. 658). The results of their study showed that the complexity of students' written arguments increased over time with students making most improvements in life science and biology course. The implication of this study is that when students engage in argumentative writing both quality of their arguments and conceptual understanding improves.

McNeill (2011) investigated 5th grade students' views of explanation, argument, and evidence as well as their abilities to engage in argumentation over the course of a year. Pre- and post-student interviews, videotapes of classroom instruction, and student writing were analyzed to understand students' views of explanation, argument, and evidence and improvement in their ability to effectively engage in argumentation. The results suggested that students' understanding of explanation, argument and evidence changed over a time, which highlighted the importance of instruction in supporting students' understanding of argumentation. Moreover, reportedly students were able to write stronger scientific arguments by the end of the school year in terms of the structure of an argument. However, the accuracy, appropriateness, and sufficiency of the arguments varied depending on the assessment task. Overall, the study has drawn attention to the importance of support that should be provided for students to more effectively engage in argumentation practices. Similarly, one such study (Songer, Shah, & Fick, 2013) highlighted the importance of scaffolding in elementary students' construction of written scientific explanations. The study focused on three elementary science classrooms in which students were provided written scaffolds to generate scientific explanations. Findings suggested that verbal scaffolds were more helpful for younger students while they were constructing scientific arguments. The work of Howe, Tolmie, Greer and Mackenzie, (1995) with young students has shown that engaging students in dialogical discussions around a scientific phenomenon can result in an improved conceptual understanding of the phenomenon under investigation.

While most theoretical arguments report positive effects of argumentation on students' conceptual understanding, negative cases also exist in the literature. For instance, Osborne and colleagues (2013) recently explored the impact of argumentation on conceptual understanding of more than150 year 7 and year 9 students in UK. Using a two-way ANOVA statistical procedure, they tested to see whether the students in argumentation-based classrooms showed better conceptual understanding of core scientific ideas taught. The results of their analyses showed that there was no significant difference between the experimental and control group students' performance scores because of the intervention for the Year 7 (age 11) students in the study. However, they reported a significant difference in students' test scores for the Year 9 (age 14) students, with control group students performing significantly better than the intervention group. The mixed reports on the effects of argumentation on students' conceptual understanding call for further investigations with young students and their ability to construct scientific arguments.

Theoretical Framework

The theoretical framework guiding this inquiry is Learning Progressions (Berland & McNeill, 2010; Duschl, Maeng & Sezen, 2011;Stevens, Shin, Delgado, Krajcik, & Pellegrino, 2007). While learning progressions have been discussed in mathematics education for quite a while, science educators have only recently adopted and used the language of learning progressions (Duschl et al, 2011). Taking Science to School (Duschl et al., 2007), a reform document, defines learning progressions as “descriptions of the successively more sophisticated ways of thinking about a topic that can follow one another as children learn about and investigate a topic over a broad span of time” (pp. 8-2). This position maintains that the complexity of the disciplinary knowledge and practices acquired by students increases as students receive exposure, experience and scaffolding (Berland & McNeill, 2010). From this perspective, learning is conceived as a continuum of increasing expertise in a specific domain or practice (Duschl et al, 2011). If indeed learning takes place through subsequent progressions, through adequate support and sufficient experience students should be able to make transition from less sophisticated ways of thinking to more complex and sophisticated ways of thinking. Similarly, students should be able to develop more sophisticated scientific arguments as a result of their experience with argumentation. Building on the work of (Berland & McNeill, 2010) we tested this assumption with a class of 6th graders in this study.

Method

This study took place at an urban elementary school located in major city in Turkey. The school primarily serves students coming from economically disadvantaged families**.** The school is a public school implementing the national science curriculum. Participants consisted of 37 students; 22 males and 15 females enrolled in a 6th grade middle school science classroom. Most had parents with no or low education (no college education). The teacher who implemented the intervention is a female with five years of teaching experience. She had both her bachelor degree and master degree in science teaching and currently in the early stages of her PhD in science education.

Intervention

The intervention teacher followed the national curriculum over the course of six weeks. The teacher mostly taught classes by using traditional instruction; power point lectures and worksheet completion. During the intervention students learned 5 core concepts through argumentation (see Table 1). All argumentation tasks were developed collaboratively with the researchers. During each week, researchers had online meetings on the concept of the week with the teacher, discussed the argumentation task and gave feedback to the teacher about her progress on the task design. Additionally, she was provided with extra resources and support if she needed during her preparation of the tasks. Each implementation was observed by one of the researchers.

The argumentation tasks consisted of competing claims around core curricular concepts. They were first asked to pick a claim from three claims provided, that appealed to them intellectually, then to develop written arguments, by identifying and using relevant evidence and constructing a warrant. Students were given 20 minutes to complete each task. After the students developed their written arguments individually, they were asked to engage in collective argumentation in groups of 4. The instructor walked around each group during these argumentation sessions and guided student discussions when deemed necessary. Students were given 15 minutes for group argumentations. This intervention was practiced for five argumentation tasks over 6 weeks in the spring semester of 2014. Table1 presents the time flow of each task conducted through intervention.

Table1.Timeline and argumentation tasks

Task #	Week I: Task 1	Week II: Task 2	WEEK III: Task 3	WEEK IV: Task 4
Activity	Classification of penguins as mammals or birds.	Lunar Eclipse	Simple Electric Circuits	Extinction of Dinosaurs

Data Collection and Analyses

The participants engaged in six argumentation tasks but four of them were used as data source. As the first two tasks were used to get the students familiar with the language and structure of written arguments, they were not used as data sources. Consistent with our research questions we used the Claim, Evidence and Reasoning

Framework (CER) (McNeill & Krajcik, 2012) to evaluate the quality of students' written arguments. We used the CER framework because we take a pragmatic perspective as suggested by (Braaten & Windschitl, 2011) in that instruction in Turkish elementary science classrooms is geared towards students' acquisition of factual knowledge that can be tested through standardized assessments. As a result, curriculum affords limited opportunities for students to engage in inquiry-based activities whereby students can design investigations, collect and analyze data. Consequently, the aim of instruction (i.e. argumentation) became using argumentation to help students develop a causal account of the scientific phenomena covered by curriculum using evidence conveyed through textbook, experience and the teacher instruction. As a result, we adopted a view that defines argumentation "as a knowledge building and validating practice, which individuals attempt to establish or validate a conclusion, explanation, conjecture" (Sampson & Blanchard, 2012, p. 1123). This focus on how and why of the scientific phenomena under study, made the use of CER framework appropriate for our data analyses.

First, we evaluated students' claims based on correctness. Second, we evaluated students' arguments based on the quality and quantity of evidence used by the students. Third, we evaluated students' reasoning skills based on their ability to link evidence and claim to develop a warrant to justify their claims. Students were given scores for each component of an argument based on their performance for each task, and an overall score for each argument they constructed. Then, we compared their scores across the tasks to evaluate the progress of quality of students' written arguments across claim, evidence and reasoning.

Results

Findings reveal several patterns regarding students' use of claim, evidence, and reasoning across 4 tasks. First, the results show that participants did not successfully use the scientifically accurate claim to justify. While they increasingly got better at picking the right claim to defend from task 1 to task 4 (as shown in Figure 1), this improvement was not significant in that students failed to score at level 2 in tasks 2, 3 and 4. The percent of students who scored 1 increased from %75 to % 93.75 from task 1 to task 4, but no student was able to receive a score of 2 on their claims.

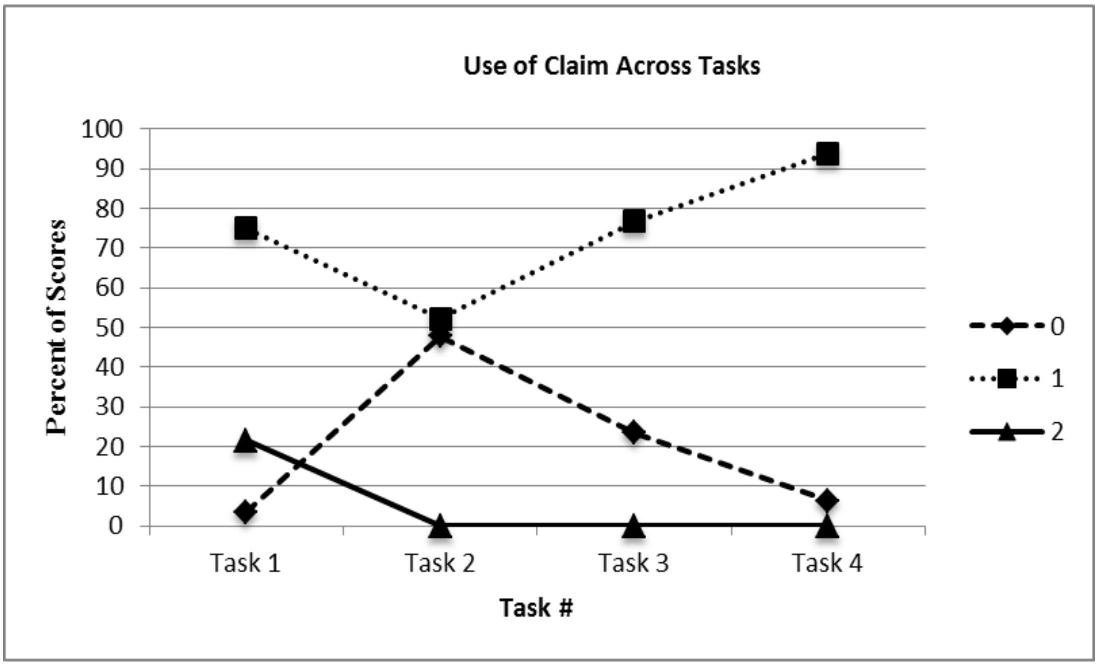

Figure 1. Performance on use of claim across tasks

Second, the results show that there was not a consistent pattern in students' use of evidence across four tasks as shown in Figure 2. While the majority of students (more than 60%) received a score of 1 and 2 combined on tasks 1, 2, and 3, only 46.7 received a score of 1 and 2 combined on task 3. We must note however that a greater number of students (31.25%) received a score of 2 on task 4 than any other tasks. Students performed very poorly on the use of evidence on task 3 compared to any other tasks including the first task.

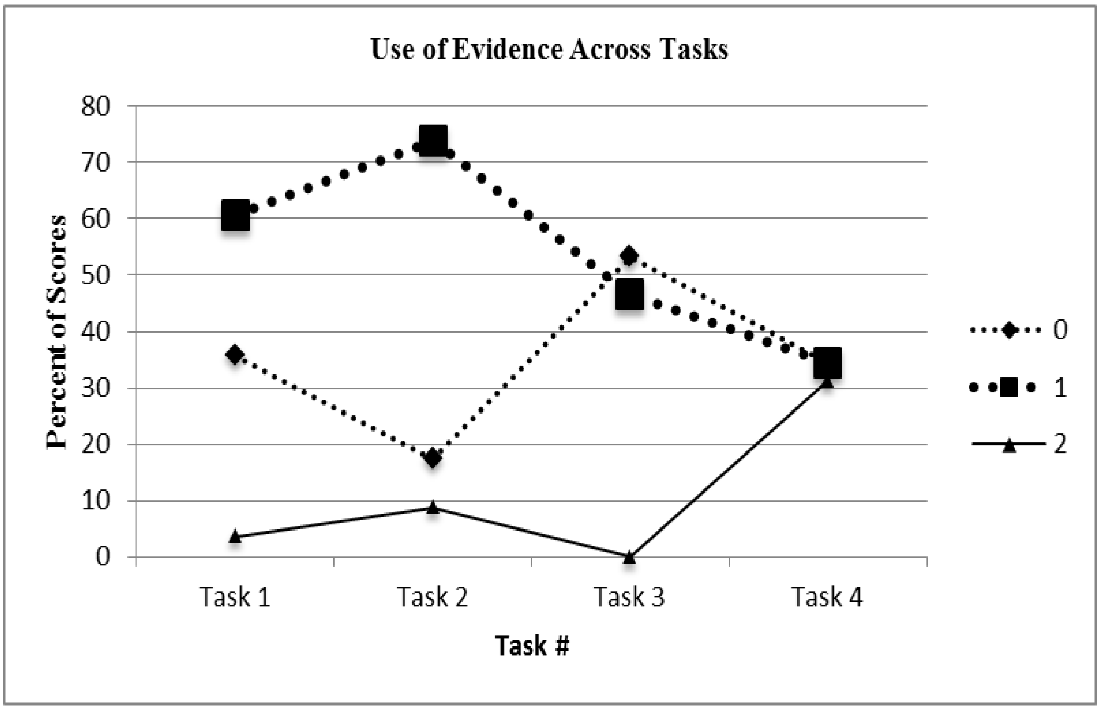

Figure 2. Performance on use of evidence across tasks

Finally, results show that students' performance on reasoning aspect of argumentation also did not lead to any consistent improvement patterns as shown in Figure 3. Students consistently scored low (at level 0 or 1) on most tasks except task 4. A greater number of students received a score of 2 (31.25%) on task 4. No one received a score of 2 on tasks 1 and 3, and only 4.35% received a score of 2 on ask 2. Overall, most students received either a score of 0 or a score of 1 on the remaining tasks.

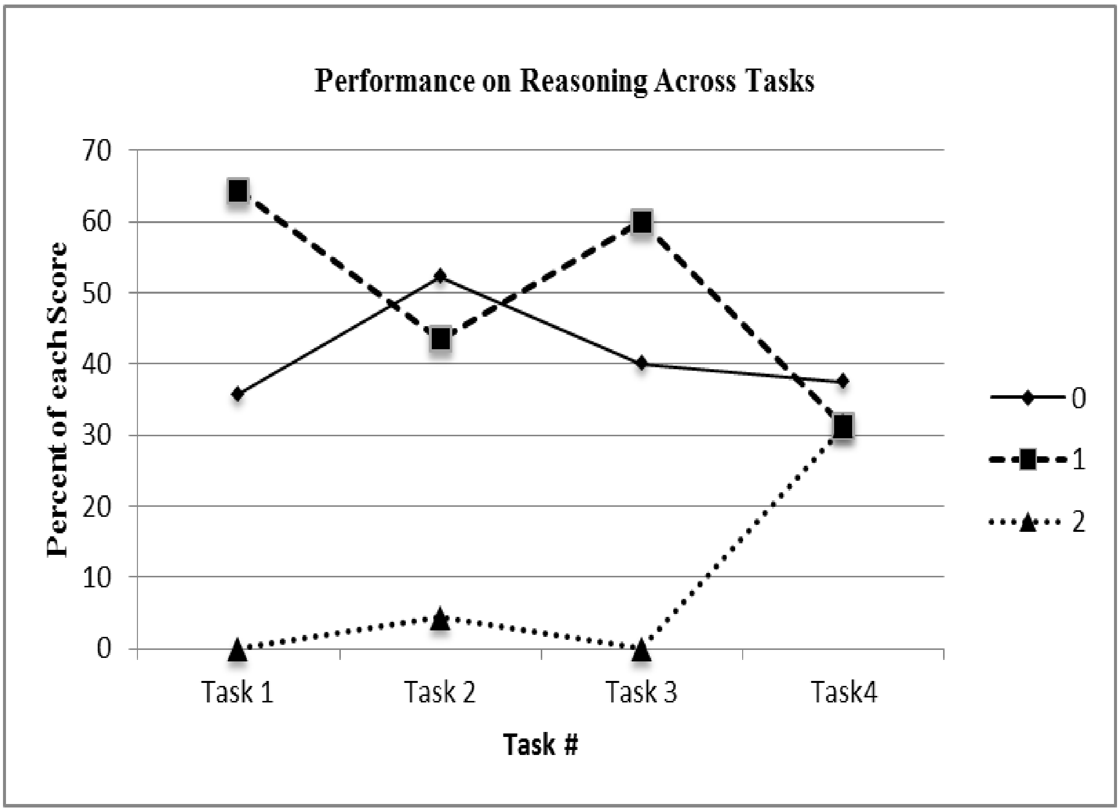

Figure 3. Performance on reasoning across tasks

Discussion and Conclusion

There is a large body of research demonstrating that teachers of science often teach science through lectures, exclusively focus on scientific facts and memorization (Driver, Newton, & Osborne, 2000; Jimenez-Aleixandre & Erduran, 2008; Larrain, 2014; Osborne et al., 2013). Similarly there is a consistent and growing concern among science educators about this trend in science classrooms. Science education researchers argue that science includes more than just facts discovered through observations and investigations, but also includes scientific ways of thinking and reasoning, and engagement in such practices as modeling and argumentation (Duschl & Osborne, 2002; Kuhn, 1993; McNeill, 2011). Consequently, they argue that in addition to developing an understanding about scientific facts, students should also be able to effectively engage in scientific practices such as argumentation during their formal education.

As Osborne (2010) states the production of new knowledge about the natural world through objective argument and critique is one of the hallmarks of science (Driver et al., 2000; Osborne, 2010). Moreover, argumentation scholars argue that activities where students assess alternatives, weigh evidence, interpret texts, and evaluate the viability of scientific claims are essential components of constructing scientific knowledge (Driver et al., 2000; Sampson et al., 2013; Simon, Erduran & Osborne, 2005). However, as the results of this case study indicate young students have difficulty in developing quality scientific arguments.

Consistent with the results of previous research related to student learning in the context of argumentation, our results suggest that students especially struggle with the reasoning component of the argument (Bell & Linn, 2000; McNeill, Lizotte, Krajcik, & Marx, 2006). The reasoning component measures the ways in which students justify how and why their evidence supports their claims (Berland & McNeill, 2010; Sandoval & Millwood, 2005). In other words, it deals with how successfully students use evidence to justify their claims to knowledge. Students struggle with this component of argument construction for two reasons: 1) lack of adequate disciplinary knowledge (Cross, Taasoobshirazi, Hendricks, & Hickey, 2008) and 2) perception of task goal that has been shaped by their prior experiences with assessments (Berland, 2011; Mila, Gilabert, Erduran & Felton, 2013). When students lack adequate disciplinary knowledge they cannot identify and use evidence to justify their claims. Because they are not directly involved in forming and pursuing their own questions, designing and collecting evidence through systematic investigations, their only source of evidence is what they can remember from the lecture, the textbook or homework assignments.

Second, in spite of our sustained effort to help the students to provide more elaborate arguments, the quality of their arguments fell short of that expectation. One possible explanation for this failure is that the teacher had to strictly follow the standardized curriculum, moved from one topic to another every other day, which did not provide the students with enough time to comprehend and reflect on the topic. As a result, students did not develop sufficient disciplinary knowledge to reason with and elaborate on. This lack of disciplinary knowledge subsequently might have impacted both their ability to identify and use evidence as well as to understand the complex relationships between different components of the concepts under investigation.

Several implications can be drawn from these findings. First, while the idea of the assumption that the teacher can facilitate students' learning progression in argumentation (Berland & McNeill, 2010) may be possible, context plays an important role in the success and failure of such progression. For instance, if the teacher had ample time to elaborate on each topic beyond one lecture and one argumentation activity, students could have developed more sophisticated arguments. In fact, the success of progression has been reported in Ryu & Sandoval, 2012 and Sampson et al., 2013. Recent work by Katchevich, Hofstein and Namlok-Naaman (2013) points to the importance of context in the quality of arguments produced by high school students. Katchevich et al (2013) conducted a study with 116 11th and 12th grade advanced placement chemistry students in five different high schools in Israel. The purpose of the study was to explore the quality of students' arguments in two types of laboratories: confirmatory-type laboratories and inquiry-type laboratories. The results of their study showed that the number of arguments generated in inquiry-type laboratories were greater than the number of arguments generated in confirmatory-type laboratories. While the students in laboratories where confirmatory-type experiments took place were able to generate 1.9 arguments in 11 observations (21 in total), the students in laboratories where open-ended type experiments took place developed 6 arguments in 11 observations (66 in total). In addition to the greater number of arguments observed in inquiry type laboratories, students also generated arguments of higher quality in inquiry-type laboratories. For instance, the mean of quality of arguments developed by the students in laboratories where confirmatory-type experiments took place was 1.48. On the other hand, the mean of the quality of arguments developed by the students in classrooms where open-ended type experiments took place was 2.41. These results imply that contexts that allow students to conduct systematic inquiry where they collect evidence can make positive impacts on the quality of arguments produced by students.

Second, changing the culture of learning may not be as easy as it sounds in six weeks. In spite of all the scaffolding that we provided, students were not able to develop arguments of high quality. This may be, at least partly, related to students' expectations from assessments. The testing culture dominates Turkish schools, so the culture of assessment may have influenced students' expectations from the assignments and thus formed their answers accordingly. However, based on our analyses of students written arguments, we conclude that lack of disciplinary knowledge is the main limitation to students' progress in forming sophisticated arguments over time. In fact, Ryu and Sandoval's (2012) recent work may provide an explanation for our observations. Ryu and Sandoval's work showed that when students (mixed-age class of 8–10-year-old children) engaged in sustained argumentation around a core idea (i.e. electric circuits) for a long time, they do make progress in forming arguments of higher quality. We used a different and un-related topic each week in our argumentation tasks to keep up with the curriculum-pacing guide. This speedy change of topics may explain the limited progress achieved by our participants. Had they been exposed to argumentation around the same concepts over time; we might have observed a different pattern in students' progress on constructing scientific arguments. Finally, we want to emphasize the role of teacher in these reported results. While the teacher was knowledgeable about argumentation as an instructional approach, she did not successfully frame learning tasks when presenting the task, so the students would deliberately and persuasively engage in justification of their knowledge. As a result, students invested limited effort in elaborating on their justifications. The importance of teacher framing has been shown to greatly influence the quality of arguments produced by students (Berland & Hammer, 2012; Kelly & Chen, 1999; McNeill & Krajcik, 2008; Songer, & Wenk Gotwals, 2012). For instance, McNeill and Krajcik (2008) found that students construct high quality arguments when their teachers provide an explicit rationale for the importance of argumentation and provide the necessary guidance and scaffolding for them to construct scientific arguments. However, this claim needs to be further verified through systematic studies of teacher framing in the context of argumentation. Our future efforts will focus on exploring the effect of teacher framing on the quality of students' arguments.

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