Jour. Korean Earth Science Society, v. 31, no. 1, p. 106−117, February 2010

# Exploring Scientific Argumentation from Teacher-Student Interaction with Epistemological and Psychological Perspectives

**Young-Shin Park***

Department of Earth Science Education, Chosun University, Gwangju 501-759, Korea

# 교사-학생 상호작용간의 과학논증 탐색: 인식론 및 심리학적 관점으로

**박 영 신***

조선대학교 지구과학교육과, 501-759, 광주광역시 동구 서석동 375

**Abstract:** The purpose of this study was to explore students' argumentation in perspectives of epistemology and psychology and to find out how teacher can promote students' abilities of developing argumentation. The 60 hours of lessons from the interaction between one science teacher (Mr. Physics, who had 35 years of teaching experience) and his 26 students were observed, transcribed, and analyzed using two different analyzing tools; one is from the perspective of epistemology and the other from the perspective of psychology, which can portray how argumentation is constructed. Mr. Physics created the environment where students could promote the quality of scientific argumentation through explicit teaching strategy, *Claim-Evidence Approach.* The low level of argumentation was portrayed through examples from students' prior knowledge or experience in the form of an *Appeal to the instance* operation and the *Elaboration* reasoning skill. Students' own claims were developed through application of knowledge in a different context in the form of an *Induction* operation and *Generativity* reasoning skill. Higher level of argumentation was portrayed through *Consistency* operation with other knowledge or experience and *Explanation* reasoning skills based on students' ideas with more active teacher's inputs. The teacher in this study played a role as a *helper* for students to enact identities as competent "sense makers," as an *elaborator* rather than evaluator to extend students' ideas, and as a *mentor* to foster and monitor the students' development of ideas of a higher quality. It is critical for teachers to understand the nature of argumentation, which in turn is connected to their explicit teaching strategy with the aim of providing opportunities where students can understand the science enterprise.

Keywords: argumentation, epistemic perspective, psychological perspective, claim-evidence approach

**요 약**: 이 연구의 목적은 학생들의 논증을 인식론적 (사고과정) 및 심리학적 (사고유형) 관점에서 탐색하여 어떠한 사고과정 및 유형으로 교사가 학생들의 논증 형성 능력을 향상시키는지 알아보는 것이다. 35년의 교사경력을 지니고 있는 교사 및 그의 26명 학생의 과학수업 60시간을 관찰하고, 전사하였으며, 전사한 학생들의 논증이 어떻게 표현되는지를 두 개의 도구, 즉 인식론적 및 심리학적 관점으로 분석하였다. 이 연구 참여자인 교사는 학생들의 논증의 질을 향상시키기 위하여 특별한 목적으로 개발한 명시적인 교수법 "주장-근거 교수법"을 수업 시간에 활용하였다. 논증을 두 개의 다른 관점으로 분석해 본 결과, "보기" 또는 "예"를 이용한 사고과정에서는 "정교성" 사고유형이 가장 빈번하게 사용되었다. 모든 탐구의 시작인 가설을 세우기 위해 학생들은 "귀납" 사고과정으로 "일반화" 사고유형을 통해 탐구의 시작단계인 본인들의 "주장"을 형성하였다. 좀 더 높은 수준의 논증은 다른 지식이나 경험을 통한 개념의 "일관성" 사고과정을 통해 교사의 도움에 힘입어 학생들이 "설명"을 형성하였다. 이러한 높은 수준의 논증 기회에서 확인된 교사의 역할은 학생들이 스스로 논증을 형성할 수 잇도록 도와주는 조력자, 그리고 학생들의 논증을 평가하는 것이 아닌 좀 더 학생들의 사고과정을 확장시켜 주는 정교자 (elaborator), 그리고 학생들의 논증 수준이 높아질 수 있도록 논증을 추적하여 발전시켜주는 멘토로 확인되었다. 논증 본성에 대한 이해를 바탕으로 교사들은 학생들이 과학의 참 의미를 이해할 수 있도록, 논증 기회를 제공하는 명시적인 교수전략을 개발하는 것이 필수적이라 할 수 있겠다.

주요어: 논증, 인식론적 관점, 심리학적 관점, 주장-근거 교수법

*Corresponding author: parkys@chosun.ac.kr
Tel: 82-62-230-7379
Fax: 82-2-3460-0148

## Introduction

Students are expected to develop their scientific thinking through argumentation in the context of scientific inquiry (NRC, 1996, 2000; Osborne et al., 2004; Reif and Larkin, 1991; Crawford, 2000, 2007; Park, 2006; Park et al., 2004, Park and Flick, 2004; Kim and Song, 2004; Oh et al., 2008; Jung et al., 2009). Then, what is scientific thinking? What kind of scientific thinking skills are developed through argumentation? Kuhn (1989) defined that scientific inquiry is the process of coordinating theories with evidence. Kuhn (1989) argued that scientists reconcile their ideas with the former competence with more evidences to justify them to the community. In this process, scientist is able to articulate a theory that he or she accepts, to know what evidence could support or contradict it, and to justify why the coordination of theories and evidences leads him or her to accept that theory or reject others to explain the same phenomenon, which is defined as the process of scientific thinking. Scientific thinking is also defined as the process of decision-making in choosing between different explanations and to reason that criteria lead to the choice (Jimenez-Aleixandre et al., 2000; Erduran et al., 2004). For this purpose, it can be added that decision-making through argumentation requires an adequate content domain and context of classroom, which influence students' abilities of thinking as knowledge-producers rather than knowledge-consumers. Kuhn (1986) also argued that students can develop the thinking abilities by practice them, such as how they adjust evidence to fit theory or adjust theory to fit evidence or how they coordinate them to evaluate their hypotheses. Then, how can teachers create this inquiry environment for students to develop their scientific thinking skills? Knowing the difference in thinking skills between students and scientists could help educators and teachers to design the curriculum or teaching strategies that facilitate students' practices of thinking process.

Reif and Larkin (1991) argued that students' difficulties in science leaning resulted from their unfamiliarity with knowledge domain of science, whereas experienced scientists cope successfully with the goals and cognitive *domain of scientific knowledge*. The authors analyzed and compared the domain goals and domain cognition of the everyday and scientific knowledge to show what kinds of students' learning difficulties were released from this unfamiliarity with the nature of scientific knowledge. Reif and Larkin (1991) also stated the difference in *methodology* to solve the problem from everyday and science domains. The need to solve problems is required to make decisions to choose among very many possible actions leading to the desired goals. Everyday problems can be solved by depending on large amount of accumulated knowledge to make short inferences in particular context locally, whereas scientists invented formal methods designed to implement long inference chains with great precisions, such as mathematical and structural formulas.

Klahr and Dunbar (1988) and Kuhn (1989) investigated the students' scientific thinking skills to see how they think scientifically in the context of experimentation. First, Klahr and Dunbar (1988) investigated how scientists and students react differently in a simulated scientific discovery context. To do this task, subjects had to formulate hypotheses based on their prior knowledge, conduct experiment, and evaluate the results of their experiments. Second, Kuhn (1989) stated that the metaphor of children as scientists is accepted in terms of scientific understanding, not in terms of the process of scientific thinking, concluding that the process of scientific thinking differs significantly in children and scientists. For the purpose of students' scientific thinking skills, it is suggested that teachers should provide chances for students to deal with theory and evidence. The empirical evidence on discovery suggested that students would fail to discover the alternative theories without the given sufficient guidance or hints by teachers. Students would come up with the accepted scientific theory in a guided discovery environment where a teacher provides hints or clues (Crawford, 2000). With different and alternative students' opinions, students need to learn how they adjust their evidence found from their experimentation to support their theories or refute others. Reciprocally, students need to learn how they apply their theories to fit their other evidences. Then, how can these students' opportunities occur? How can teachers create this inquiry environment for students to develop their scientific thinking skills through argumentation?

It is proposed that there are at least five intertwined dimensions or potential contributions from the introduction of argumentation in the science classrooms (Erduran and Jimenez-Aleixandre, 2008), which are situated cognition, sociocultural, linguistic, epistemological, and psychological perspectives. The first three are more intra-perspectives and the last two are more inter-perspectives, which mean that teachers' role of scaffolding are more related to the last two perspectives. That is, it is reported that the role of teachers' scaffolding can enhance and promote the quality of students' argumentation (Alexopoulou and Driver, 1996; Richmond and Striley, 1996; Lotter et al., 2007; Ash, 2007). From the epistemological perspectives of developing argumentation, learning science involves epistemic practices associated with producing, communicating, and evaluating knowledge, which in turn influence students' development of epistemological understandings. From the psychological perspectives, rationality of science is grounded in a commitment to evidence, which critical thinking is conceived as the educational cognate of rationality with the notion of reasoning aimed at interpretation, evaluation, or self-reflective presentation of arguments (Siegel, 1995; 2006; Erduran and Jimenez-Aleixandre, 2008). Overall, argumentation can portray the process of how science should be learned as the holistic way, so that students can experience the nature of how scientific knowledge can be constructed.

The purpose of this study was to explore the quality of students' argumentation in perspectives of epistemology and psychology, which can overcome the limitation of using the Toulmin's approach (Toulmin, 1958) only. There are only 6 different arguments in Toulmin's approach, but it does not indicate how the claim is justified and if a claim accounts for all available evidences and so forth, which can be portrayed through epistemological and psychological perspectives. Toulmin's approach can tell only the frequencies of arguments used during discourse and its relationship each other rather than illustrate the context how those arguments are formed and developed. The context where students can develop scientific argumentation can be created and promoted by teachers. In this study, scientific argumentation in the classroom was analyzed epistemologically and psychologically to illustrate how teachers can scaffold students to develop scientific thinking through argumentation.

## Participants

One male science teacher, Mr. Physics, who had taught science for more than 30 years with his 26 students, participated in this study. Mr. Physics teaches $7^{th}$ grade in physical science content now and his highest degree is the master degree in curriculum and instruction. Mr. Physics also attends the professional development programs regularly two or three times per year with the aims for (a) completing his school district Science Curriculum Science Guide, (b) working with elementary and middle school teachers to implement inquiry based learning opportunities, and (c) developing opportunities for teachers to use the Standard Based Science Tests to assess strengths and weaknesses of science content. Basically, Mr. Physics believes that $7^{th}$ grade students need to start to develop their appropriate reasoning skills through experiencing scientific inquiry. Mr. Physics regards scientific inquiry as a holistic way, with the focus on framing the questions and analyzing and interpreting the data. Mr. Physics uses certain type of teaching strategies (Claim-Evidence Approach) during the lessons in his unit for the purpose of providing students with opportunities of developing argumentation. The research context, one middle school, where Mr. Physics worked as a teacher, is located in one of port cities in the western part of the State. Most residents had occupations as fishermen or service workers in the area of ocean resort.

## Instruments in Data collection

The researcher videotaped Mr. Physics' science classes (60 hours) to be transcribed and employed two different analyzing tools to analyze argumentation (12 hours out of 60 hours), which was deprived from interaction between Mr. Physics and his students during Claim-Evidence Approach. One analyzing tool is for epistemological perspective (Jimenez-Aleixandre et al., 1997; 1998; 2000) (Epistemic Operation; Table 1). Jimenez-Aleixandre et al. (2000) found that students used *Causality* more than other components of *Epistemic Operations* while they were developing their argumentation. However, their findings displayed students' discourse only without teacher's prompts or input that could support students' opportunities to demonstrate their argument skills. In this dimension of analysis, the researcher coded each discourse element developed by Mr. Physics and his students first, and then compared them to see who was developing more of which components of the *Epistemic Operations*.

The other analyzing tool is for psychological perspectives (Hogan et al., 2000) (Reasoning Complexity; Table 2). Hogan et al. (2000) stated that the sophistication of students' thinking about a given topic is judged with a reasoning complexity, which describes the essential components of scientific thinking. The first two categories (*generativity and elaboration*) specify the amount and type of ideas and elaborations of ideas within a topic unit. The second two categories (*justifications and explanations*) specify the structure of students' reasoning, meaning how their ideas are supported and explained. Finally, the *logical coherence and synthesis* categories specify the quality of the students' thinking. The *Reasoning Complexity* in Hogan et al. (2000) was derived from Resnick et al. (1993), who developed a descriptive and analytic account of reasoning as it occurred in social settings based on the work of philosophers, linguists, and psychologists. Resnick et al. (1993)

**Table 1.** Epistemic Operations

| Argument from | Category | Operational definition |
|---|---|---|
| Induction | | Looking for **patterns**, regularities |
| Deduction | | Identifying particular **instances of rules**, laws |
| Causality | | Relation **cause-effect**, looking for **mechanism**, **prediction** |
| Definition | | State the **meaning** of a concept |
| Classifying | | **Grouping** objects, organisms according to criteria |
| Appeal to | Analogy<br>Exemplar/instances<br>Attribute<br>Authority | Appealing to **analogies, instances or attributes** as a means of explanation |
| Consistency | With other knowledge<br>With experience<br>Commitment to consistency<br>Metaphysical (status object) | Factors of consistency, particular (with experience) or general (need for similar explanations) |
| Plausibility | | **Prediction or evaluation** of own/others' knowledge |

**Table 2.** Reasoning Complexity

| Criteria | Operational Definition |
|---|---|
| Generativity | **Subtopics** brought forth within the discussion. |
| Elaboration | **Details** to the subtopics that are brought up |
| Justification | **How to use evidences** from their own experienced experimentation or prior knowledge. |
| Explanations | The **presentation of mechanisms** that account for a phenomenon |
| Logical coherence | Logical coherence is **judged only when a justification or explanation is evoked** |
| Synthesis | **Disconfirming evidences,** which is a hallmark of dialectical and higher order thinking |

assumed that the structure of the discourse of reasoning depends significantly on the nature of the situation in which that reasoning is carried out and that some dimensions of the situation -such as social status of the participants (here, the teacher), the goals of the group, the goals of each participant, and the content- tend to affect the course of reasoning.

## Data Analysis

The researcher developed argumentation tables with cells of discourse released from interactions between teacher and students (Table 3). The numbers in the [Table 3] indicate "argumentation" defined by the researcher from students' or teacher's discourse and the researcher coded them with the frame of Epistemic Operation and Reasoning Complexity. Eight operations in epistemological perspective and another six thinking skills in psychological perspective were used to analyze argumentation developed by teacher and students' interaction. The researcher also developed profile of argumentation with these two perspectives from each block of lesson (Fig. 1). The researcher analyzed the first 30% of data by herself as a tool of

**Table 3.** Examples of argumentation analyzed by Epistemic Operation and Reasoning Complexity

| **TOPIC**: Newton's third law (action and reaction: about friction) | | | |
|---|---|---|---|
| TEACHER | STUDENT | Epistemic | Reasoning |
| Have these wind suits that are also there to keep them warm. Does anybody see any frictions involved in this picture? Tyler? | | Deduction | Generativity |
| | The [people] leaning against. | definition | Elaboration |
| The snow there? OK, so he says the feet of the reindeer are specifically designed, and they are, to allow the reindeer to stand up against the loss of friction in the snow. They have sharp points to break into it. ① They also have, in the middle of their hoof, they have a special type of pad that not only keeps their feet warm, but it also grips the snow. ② That is a pretty amazing adaptation of the reindeer. ③ Does anybody see any other frictions involved there? ④ Yes? | ①<br>②<br>③<br>④ | Causality<br>Consist<br>Consist<br>Plausibility | Justification<br>Explanation<br>Logical<br>Generativity |
| | The skis. | Appeal | Elaboration |
| The skis, they are trying to reduce the friction as much as possible on the snow. ① The deer are trying to increase their friction. ② The men are trying to reduce the friction so that they have as little drag as possible. ③ This is a serious competition over there. ④ These guys are professional racers. ⑤ Their reindeer have been specifically bred to run long and fast. ⑥ There are lots of people that bet money on these races, just like horse racing or dog racing in the United States. ⑦ They are doing everything they can to try to reduce the friction. ⑧ What other friction do you see there that they are probably trying to reduce? ⑨ Victor? | ①<br>②<br>③<br>④<br>⑤<br>⑥<br>⑦<br>⑧<br>⑨ | Causality<br>Causality<br>Deduction<br>Consist<br>Consist<br>Appeal<br>Appeal<br>Causality<br>Causality | Justification<br>Justification<br>Explanation<br>Logical<br>Logical<br>Justification<br>Justification<br>Justification<br>Justification |
| | The wind with the suits? | Causality | Justification |
| Good the wind and that crouched position ① They are trying to reduce the wind drag as much as possible. ② They know from experience that if they can form a wing shape, the air goes over the top of them with the least amount of drag possible. ③ Yes? | ①<br>②<br>③ | Appeal<br>Causality<br>Consist | Elaboration<br>Justification<br>Logical |
| | Weight, ① because if they have a lot of weight, then they will go into the snow ② | Appeal<br>Causality | Elaboration<br>Explanation |
| That's another good one, because we know about mass affects acceleration, doesn't it? ① Very good. You came up with two very good ones there, Tyler. Probably these guys are very conscious about the weight that they carry, and they have a big strong match between their weight and their strength ratios, don't they? ② Alright, let's go on to page 57. | ①<br>② | Consist<br>Consist | Logical<br>Logical |

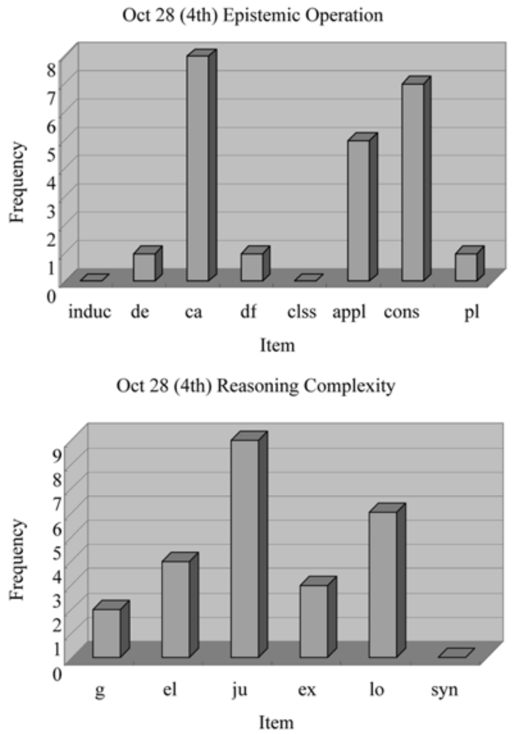


**Fig. 1.** The Profile of Epistemic Operation and Reasoning Complexity of Argumentation.

analyzing data. Then another science education expert and the researcher analyzed the second 30% of data, compared and discussed them until they had the agreement from different opinions, and the researcher analyzed the last 40% of data and repeated the first 30% of data to be confident in data analysis, through which the internal validity and reliability of data analysis were constructed.

## Results

The scientific argumentation developed by Mr. Physics and his students during Claim-Evidence Approach (CLEA) study was analyzed using two different perspectives: *Epistemic Operation* as an Epistemological perspective, and *Reasoning Complexity* as a psychological perspective. These two approaches in this study, *Epistemic Operation* and *Reasoning Complexity*, were employed to understand the context or process of developing arguments, rather than the specific content and validity of an argument as determined using *Toulmin's* approach (Toulmin, 1958), which enabled to portray what kind of epistemological and psychological perspectives were frequently used in forming or promoting students' argumentations.

### Mr. Physics' role of scaffolding to create authentic environment of argumentation

Mr. Physics created the environment where students could promote the quality of scientific argumentation. The example below of argumentation developed by Mr. Physics illustrated how he promoted students' chances of developing argumentation during Claim-Evidence Approach **(Highlight marked**: Mr. Physics' role of scaffolding for students' opportunities of argumentation).

[One of lessons in 7$^{th}$ grade during Claim-Evidence Approach]

Remember what we were talking about in **framing the investigation**. What did you think was going to happen in the rocket balloon lab? When we were doing the framing of the investigation, the first thing **we talked about what was the claim statement (A). Remember his law says anything at rest can stay at rest [forever]. If I put my binder on the table, I expect it to stay on the table and not move (B).** The second half of Newton's first law says something about anything in motion tends to stay in motion. **If I throw something, I expect it to fall back to earth because an equal and opposite force will slow it down and make it stop (C). Those forces would be gravity and friction, wouldn't they? (D)** Now **within the harder part was when we had to come up with the reasons why you thought that was going to happen (E). You began writing out an explanation of the reasons why you thought it would happen. First of all, remember what happened. Look at your "what" part that you wrote down – you cannot choose a couple of these (F).** Somebody, I think it might have been in here or 6$^{th}$ period said, "The best nozzle length is somewhere between 20 and 10 centimeters." You can't come up to fudge factor on your hypothesis. **You have to say specifically which length you think will be the right**

**one. You are going to say 10 or 20 or 30 (G).** You can just say, "The best nozzle length is [blank] centimeters." That is the one. Then we had all of these words that we brainstormed.

Mr. Physics stated to his students orally before the experiments what students were expected to do in the first stage of scientific inquiry activities, "*We talked about what was the claim statement*" (A). To help students to develop their claims, Mr. Physics gave the concrete and simple example describing Newton's 1st law; *"Objects at rest can stay at rest"* (B). Mr. Physics explained how an object thrown in the air would slow its speed to stop by gravity, which also describes the Newton's 1st law. This was the opportunity for students to develop the extended arguments to build the relationship between the conclusion, *"an object thrown in the air stopped to move,"* and the evidence, *"gravity force"* (C). Mr. Physics extended the knowledge with some merits to explain the mechanisms of how it happened (D). In other words, Mr. Physics added what kind of forces were related to make this happen, *"an object flying stopped to move,"* based on students' background information. Mr. Physics promoted so that students could use their knowledge or evidences to make the extended argumentation to explain the mechanism of the phenomenon (E). Mr. Physics encouraged students to think of "*what happened*" first as the conclusion or claims (F). Then, Mr. Physics instructed students to use their exact evidence to support their claims (G). Here, Mr. Physics emphasized the exact evidence to support students' claims.

In summary, this new approach, Claim-Evidence Approach (CLEA), made Mr. Physics feel confident that he was connecting the content from the textbook with the students' lab activities in the classroom. First, the CLEA initiated students to form their background knowledge with the teacher's input regarding the specific content from the textbook. Then, Mr. Physics interacted with students to help them develop their own claims to be tested within the content of unit. This early stage of CLEA is called *Framing the Investigation*. Second, Mr. Physics demonstrated simple experiments to motivate students to identify the variables for their experiments and to differentiate the independent from the dependent variables in designing their investigation. Then, Mr. Physics guided students in carrying out investigations wholly (*Rocket Balloon Activity:* appendix 1) or partially (*Marble Activity*). At this stage, students collected the data and transformed them into other representations under Mr. Physics' guidance. This middle stage is called *Designing the Investigation*. Third, Mr. Physics interacted with students to discuss how they would write the results, what evidence they would use, and how they would explain the mechanism of the phenomenon observed. At this point, Mr. Physics emphasized the appropriate level of scientific reasoning skills for the students to understand how their inquiry activities were carried out, such as describing what happened, how it happened, and why it happened, thereby connecting all the stages of the inquiry lab activity. Mr. Physics encouraged students to discuss the extended skills and content in describing the pattern of data and the limitation of the experimentation. This last stage is called *Analyzing and Interpreting Results.*

Overall, argumentation developed during CLEA had higher level of argument rather than the teacher's other regular strategies used in science teaching (Park, 2008). However, we cannot judge the quality of argumentation in terms of logics mainly; instead we need to understand the context and process of how argumentation occurred, which explained the nature of argumentation. The following result showed the process of how argumentation (here, epistemologically and psychologically) occurred rather than what kind of argumentation emerged.

### The argumentation from Epistemological Perspective

During the *Marble Activity* in the middle phase of CLEA, Mr. Physics asked students questions, and students responded to his questions with one-word answers. At this time, students' responses worked as "means" or "tools," which were used to explain the mechanism for the phenomenon (*Appeal* to the

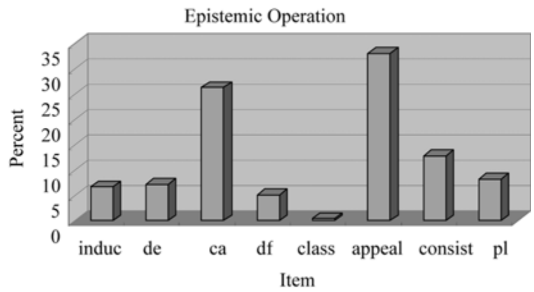


**Fig. 2.** Percent distribution of Students' Argumentation in the dimension of Epistemic Operation. induc (Induction), de (Deduction), ca (Causality), df (Definition), class (Classifying), appeal (Appeal to analogy or example), consist (Consistency with other knowledge or experience), pl (Plausibility).

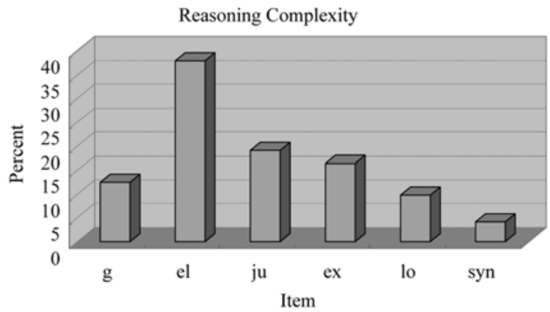


**Fig. 3.** Percent distribution of students' argumentation in the dimension of Reasoning Complexity. g (Generativity) el (Elaboration) ju (Justification) ex (Explanation) lo (Logical coherence) syn (Synthesis).

*instance* made up 26% of 119 total operations). In addition, students added description to justify how marbles on the top of the rail hit one another in the middle, or the others at the end of the rail, using the concept of energy transfer (*Causality*, 41% of total operations). These two operations, *Appeal* and *Causality*, were the most frequently used during the *Marble Activity*. At this time, Mr. Physics could only provide students with opportunities to develop arguments through factual or conceptual knowledge as one-word answers, and then he used students' ideas to explain the cause and effect mechanism of *Marble Activity*.

The general pattern of student argumentation analyzed by *Epistemic Operation,* based on the selected 12 hours of classroom observations, consisted of *Appeal* (33% of 1500 total operations) as the most frequent operation, and *Causality* (26% of total) as the second most frequent. This pattern means that students, in general, produced short answers (*Appeal* as instances) to Mr. Physics questions or prompts, and then Mr. Physics used students' ideas to explain the mechanism of certain phenomena (*Causality*) during the discussion. The relationship among three operations, *Causality* (by Mr. Physics) with *Appeal* (by students) and *Consistency* (by Mr. Physics), contributed significantly to the discussion in Mr. Physics classroom in terms of *Epistemic Operation* analysis (Fig. 2).

### The argumentation from Psychological Perspective

The argumentation analyzed by *Reasoning Complexity* consisted of *Elaboration* occurring most frequently (38% out of 1563 total reasoning skills), *Justification* second (19%), *Explanation* third (17%), and relatively little use of the other three, with *Generativity* (12%), *Logical Coherence* (10%), and *Synthesis* (4%).

The argumentation analyzed by *Reasoning Complexity* consisted of *Elaboration* as the most, *Justification* as the second, *Explanation* as the third, and a little percentage distribution of the rest of it (Fig. 3). The high percent distribution of the *Elaboration* reasoning is consistent with students' ideas, supporting some conclusions or claims (*Generativity*) about what would happen or what happened as responses to Mr. Physics' initial questions or prompts during the lesson. On the basis of students' ideas, other students or Mr. Physics provided a description of how it would happen and how it happened as the second highest operation, *Justification*. Then, Mr. Physics provided the description of how to apply *Justification* into new context with more extended knowledge or experience as the third most operation, *Explanation*. Other operations -*Logical Coherence* and *Synthesis* for the quality of argumentation-were developed mainly by Mr. Physics.

In summary, argumentation analyzed by *Reasoning Complexity* was provided by students mainly in two reasoning of declarative knowledge, *Generativity and Elaboration*. Mr. Physics, as well as students, provided two reasoning of procedural knowledge, *Justification and Explanation*. Finally, Mr. Physics mainly provided the last two reasoning for assessing the quality for argumentation, *Logical Coherence and Synthesis.*

Student argumentation during *Daily Science* (which is Mr. Physics' another teaching strategy for the opportunity of students' inquiry skills*)* consisted of Mr. Physics questions, students' one-word answers, and Mr. Physics' evaluation. Since the purpose of implementing *Daily Science* was to provide students with the opportunity to practice discussing science, the nature of the classroom discourse was simple and not highly structured. Student argumentation during *Daily Science* stayed within the 1 level of argumentation. On the other hand, the more complex student argumentation that occurred during CLEA consisted of Mr. Physics' questions, students' answers, and Mr. Physics' evaluation without closing the discussion; then it included Mr. Physics' additional questions or prompts, students' justification, Mr. Physics' explanation based on students' justification, and finally Mr. Physics' more extended argumentation. The nature of the classroom discourse during CLEA moved into more complex levels of argumentation depending on Mr. Physics' interaction with students.

### Portraying student's argumentation through the teacher's guide

Both opportunities and quality of student argumentation in the classroom were found to depend on various conditions. First, specifically designed teaching strategies, CLEA, promote students' abilities of developing argumentation. Second, student argumentation during CLEA consisted of more extended arguments as a result of the teacher active interacting more with the students. Third, students' low levels of arguments (simple arguments, such as evidence and claim) were developed through examples from students' prior knowledge or experience in the form of an *Appeal to the instance* operation (*Epistemic Operations*) and the *Elaboration* reasoning skill (*Reasoning Complexity*). Students' own claims were developed through application of knowledge in a different context in the form of an *Induction* operation and *Generativity* reasoning skill. Sometimes, *the process of connecting evidence and claim* was developed through the *Causality* operation and the *Justification* reasoning skill. Fourth, higher level of arguments was possible through *Consistency* operation with other knowledge or experience and *Explanation* reasoning skills based on students' ideas.

## Discussion and Implication

First, the teacher's involvement in students' development of argumentation skills was critical in shifting from low to higher level of argumentation. For example, Mr. Physics provided a concrete demonstration, such as dropping a golf ball and a ping-pong ball, to provide students a base from which to reason. Mr. Physics continued by reasoning out loud that gravity is constant. When students provided evidence refuting the claim that gravity is constant, Mr. Physics introduced a new concept of "resistance" to explain the mechanism of the phenomenon. Mr. Physics' demonstrations and prompts enabled students to apply their knowledge to achieve a higher quality of argumentation, making the argument shift from low to high level. This process of developing high level of argumentation is called "Reflective Discourse." The teacher in this study played a role as a *helper* for students to enact identities as competent "sense makers," as an *elaborator* rather than evaluator to extend students' ideas, and as a *mentor* to foster and monitor the students' development of ideas of a higher quality. These three roles occurred when Mr. Physics interacted with students in the context of high level of argumentation, helping students develop extended forms of argument.

Second, it is essential for teachers to understand the nature of argumentation, which in turn is connected to their explicit teaching strategies, such as CLEA, with the aim of providing opportunities where students can understand the science enterprise (AAAS, 1993).

Students need to understand how scientific knowledge is constructed instead what knowledge is constructed (Lee and Hewson, 2004; Kim and Song, 2004; Park, 2008) Teachers need to understand how argumentation can be promoted epistemologically and psychologically then scaffold students to develop argumentation with appropriate prompts, questions, and evaluations. Rather than providing environment where students look for patterns or instances through generativity or elaboration, it is more enhancing the quality of argumentation by making students relate cause with effect and look for mechanism through explanation or justification.

Third, the rationality of science reform address that students need to develop the abilities of solving the social and scientific issues arising at modern times, which is called "scientific literacy". For this goal of scientific literacy at schools, students need to have opportunities to develop the abilities of argumentation, such as how to support their stance or refute others using their own evidences. To make this happen, it is essential to understand the nature of teacher's teaching strategies and students' argumentation at natural setting in the classroom context, because we know that practicing of developing abilities of scientific argumentation is critical to understand how scientific knowledge is constructed. The understandings of scientific argumentation by teachers and students through their interactions make science education an education in reasoning and critical thinking in the domain of psychology.

Fourth, this study will provide profound views in understanding the nature of student scientific argumentation and the nature of the teacher's roles of scaffolding, for the goal of designing the curriculum and instruction for scientific argumentation in the classroom (Hogan et al., 2000). The identification of more complex argumentative structure reveals different interaction modes and argumentative styles in different context of social settings. Within this issue, it may be possible to verify the "change" or "evolution" of students' abilities in developing skills in scientific argumentation as an effect of the interaction with the teacher and peers in a guided/ scaffolded learning environment.

## References


Alexopoulou, E. and Driver, R., 1996, Small-group discussion in Physics: Peer interaction modes in pairs and fours. Journal of Research in Science Teaching, 33, 1099-1114.

American Association for the Advancement of Science, 1993, Benchmarks for science literacy. Oxford University Press, NY, USA, 418 p.

Ash, D., 2006, Thematic continuities: Talking and thinking about adaptation in a socially complex classroom. Journal of Research in Science Teaching, DOI 10.1002/tea.20199

Crawford, B.A., 2000, Embracing the essence of inquiry: New roles for science teachers. Journal of Research in Science Teaching, 37, 916-937.

Crawford, B.A., 2007, Learning to teach science as inquiry in the rough and tumble of practice. Journal of Research in Science Teaching, 44, 613-642.

Erduran, S., Simon, S., and Osborne, J., 2004, TAPing into argumentation: Developments in the application of Toulmin's Argument Pattern for studying science discourse. Science Education, 88, 915-933.

Erduran, S. and Jimenez-Aleixandre, M.P., 2008, Argumentation in science education: Perspectives from classroom-based research, Springer Press, Germany, 294 p.

Hogan, K., Nastasi, B.K., and Pressley, M., 2000, Discourse patterns and collaborative scientific reasoning in peer and teacher-guided discussion. Cognition and Instruction, 17, 379-432.

Jimenez-Aleixandre, M.P., Bugallo-Rodriguez, A., and Duschl, R.A., 2000, "Doing the lesson" or "Doing science": Argument in high school genetics. Science Education, 84, 757-792.

Jimenez-Aleixandre, M.P., Diaz de Bustamante, J., and Duschl, R.A., 1998, Scientific culture and school culture: Epistemic and procedural components. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Diego, CA.

Jimenez-Aleixandre, M.P. and Bugallo-Rodriguez, A., 1997, Argument in high school genetics. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Chicago, IL.

Jung, W-Y., Lee, J-Y., Park, E-J., Kim, C-J., and Lee, S-K., 2009, Interaction patterns in dialogic inquiry of middle school students in small group in the natural history gallery. Journal of Korean Earth Science Society, 30, 909-920.

Kim, H. and Song, J., 2004, The exploration of open scientific inquiry model emphasizing students' argumentation. Journal of Korean Association for Science Education, 24, 1216-1234.

Klahr, D. and Dunbar, K., 1988, Dual space search during scientific reasoning. Cognitive Science, 12, 1-48.

Kuhn, D., 1986, Education for thinking. Teachers College Record, 87, 495-511.

Kuhn, D., 1989, Children and adults as intuitive scientists. Psychological Review, 96, 674-689.

Lee, S.-K. and Hewson, P.W., 2004, Research Article: The Relationship between Argumentation and the Conceptual Change Model in a Science Teacher's Explanations. Journal of Korean Association for Science Education, 24, 709-721.

Lotter, C., Harwood, W.S. and Bonner, J.J., 2007, The influence of core teaching conceptions on teachers' use of inquiry teaching practices. Journal of Research in Science Teaching, DOI 10.1002/tea.20191.

National Research Council, 1996, National science education standards. National Academy Press, Washington, D.C., USA, 262 p.

National Research Council, 2000, Inquiry and the national science education standards. National Academy Press, Washington, D.C., USA, 410 p.

Oh, J-A., Lee, S-K., and Kim, C-J., 2008, A Case Study on Scientific Inquiry and Argumentative, Communication in Earth Science MBL Classes. Journal of Korean Earth Science Society, 29, 189-203.

Park, Y-S. and Flick, L., 2004, Students Opportunities to Develop Scientific Argumentation in the Context of Scientific Inquiry: A Review of Literature. Journal of Korean Earth Science Society, 25, 194-204.

Park, Y-S., Flick, L., Patricia, D.M., and Wainwright, C., 2004, Student Teachers and Beginning Teachers` Understandings of Scientific Inquiry. Journal of Korean Earth Science Society, 25, 160-175.

Park, Y-S., 2006, Theoretical Study on the Opportunity of Scientific Argumentation for Implementing Authentic Scientific Inquiry. Journal of Korean Earth Science Society, 27, 401-415.

Park, Y-S., 2008, Analyzing Science Teachers' Understandings about Scientific Argumentation in terms of Scientific Inquiry. Journal of Korean Association for Science Education, 28, 211-226.

Reif, F. and Larkin, J.H., 1991, Cognition in scientific and everyday domains: Comparison and learning implications, Journal of Research in Science Teaching, 28, 733-760.

Resnick, L.B., Salmon, M., Zeitz, C.M., Wathen, S.H., and Holowchak, M., 1993, Reasoning in Conversation. Cognition and Instruction, 11, 347-364.

Richmond, G. and Striley, J., 1996, Making meaning in classrooms: Social processes in small-group discourse and scientific knowledge building. Journal of Research in Science Teaching, 33, 839-858.

Siegel, H., 1995, Why should educators care about argumentation? Informal Logic, 17, 159-176.

Siegel, H., 2006, Epistemological diversity and education research: Much ado about nothing much? Educational Researcher, 35, 3-12.

Toulmin, S.E., 1958, The uses of argument. Cambridge University Press, NY, USA, 324 p.

2009년 7월 17일 접수
2010년 1월 8일 수정원고 접수
2010년 2월 17일 채택

# Appendix 1
# Rocket Balloon Lab

**I. Materials:**

2 straws, meter stick, sausage, balloon, making tape, stop watch, scissors

**II. Procedures**

1. Tape the two straws together, putting them, using a small amount of tape
2. Measure the straws to 35 cm. Put the remaining amount inside the balloon.
3. Tape around the straw and the balloon making a tight seal.
4. Blow up the balloon so that it is 30 cm in length. Be sure the balloon is 30 cm for all trails.
5. Make hole into the balloon as indicated in the illustration.
6. Release the balloon while you start the stop watch.
7. When the balloon touches the desk or passes below the desk top, then stop the watch.
8. Repeat one more time.
9. Cut off 5cm of straw.
10. Repeat #1 through 9. Record data and observations

**III. Data**

Length of Nozzle

| | 35 cm | 30 cm | 25 cm | 20 cm | 15 cm | 10 cm |
|---|---|---|---|---|---|---|
| Trial 1 | | | | | | |
| Trial 2 | | | | | | |
| Average | | | | | | |

Observations

35 cm

30 cm

25 cm

20 cm

15 cm

10 cm

**IV. Analysis and Conclusions**