Claim-Evidence Approach for the Opportunity of Scientific Argumentation

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Abstract: The purpose of this study was to analyze one science teacher's understanding of student argumentation and his explicit teaching strategies for implementing it in the classroom. One middle school science teacher, Mr. Field, and his students of 54 participated in this study. Data were collected through three semi-structured interviews, 60 hours of classroom observations, and two times of students' lab reports for eight weeks. Coding categories were developed describing the teacher's understanding of scientific argumentation and a description of the main teaching strategy, the *Claim-Evidence Approach*, was introduced. Toulmin's approach was employed to analyze student discourse as responses to see how much of this discourse was argumentative. The results indicated that Mr. Field defined scientific inquiry as the abilities of procedural skills through experimentation and of reasoning skills through argumentation. The Claim -Evidence Approach provided students with opportunities to develop their own claims based on their readings, design the investigation for evidence, and differentiate pieces of evidence from data to support their claims and refute others. During this approach, the teacher's role of scaffolding was critical to shift students' less extensive argumentation to more extensive argumentation through his prompts and questions. The different level of teacher's involvement, his explicit teaching strategy, and the students' scientific knowledge influenced the students' ability to develop and improve argumentation.

Key words: Claim-Evidence Approach, Scientific argumentation, Procedural skill, Reasoning skill, Scientific inquiry, Scientific literacy, Toulmin's approach

I. Introduction

Scientific inquiry in K-12 classrooms tends to lack procedural opportunities for understanding how scientific knowledge is constructed through reflection, debate, and argument (Gallagher & Tobin, 1987). Furthermore, limited opportunity to develop scientific argumentation skills prevents students from practicing scientific thinking skills needed to understand the nature of scientific knowledge and the role of scientific inquiry. Science education reformers argue that scientific literacy has become a necessity for everyone and this view holds that everyone needs to use scientific information to make choices that arise every day. For this purpose, the National Science Education Standards (National Research Council [NRC], 1996; 2000) presents a vision of a scientifically literate populace by outlining what students need to know, understand, and be able to do by understanding what scientists do to construct new knowledge through scientific inquiry. To solve this problem, recent research has focused on how to support student opportunities to learn scientific argumentation in the context of scientific inquiry.

The most important finding from current studies concerning student argumentation is the lack of opportunities for students to employ argumentation in the classroom when learning science. That is, there is a general lack of pedagogical expertise among science teachers in organizing activities in which students are given a voice. Therefore, it is important to improve teachers' knowledge, awareness, and competence in managing student participation in discussion and argumentation as well as to enhance the argument skills of young people. For this purpose, it is necessary to know what kinds of teaching strategies are effective

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or ineffective at enhancing students' argumentation or not in the classroom. The research questions that guided the investigation are as follows:

1. What is the teacher's knowledge of scientific argumentation?
2. What kinds of instructional strategies emerge when the teacher scaffolds to develop student argumentation?
3. How do students respond to these strategies?

II. Theoretical Background

1. Scientific Inquiry

Scientific inquiry is one way that scientists use to build new scientific knowledge. Reformers recommend that students need to have opportunities to experience scientific inquiry in order to understand how scientists construct new knowledge. Instruction in this process involves students' making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results as scientists do to investigate natural phenomena (NRC, 1996, p. 23). During the inquiry process, students develop an understanding of how they know what they know and what evidence supports what they know.

2. Teaching Scientific Inquiry in the Classroom

Many studies in science education have found that many scientific inquiry practices implemented in the classroom require only low cognitive thinking processes or are just cookbook type activities without opportunities for students to truly understand and explore the nature and limitations of scientific knowledge building (Gallagher & Tobin, 1987; Krajcik *et al.*, 1998). Gallagher and Tobin (1987) reported that the inquiry process was presented as a recipe, asking students to follow steps without applying reasoning skills. Krajcik *et al.* (1998) also reported that students did not use opportunities to draw conclusions by reflecting on their data and questions. Some students in groups drew conclusions based on their experience rather than their data.

The *Standards* is clear when it advises educators that scientific inquiry is not a hands-on activity. Getting students to understand science as inquiry requires minds-on activities such as argumentation, explanation, and communication of results as well as hands-on activities of experimentation and exploration. What is minds-on activity during scientific inquiry? Crawford (2000) described how one biology teacher implemented scientific inquiry with opportunities for student communication, which emphasized the students' reasoning skills as well as their hands-on activities. Crawford, Kelly, and Brown (2000) also described how students were offered opportunities to use their knowledge of inquiry processes, such as posing questions, observing, and offering alternative interpretations. Students also used their social practices, such as group norms for speaking and listening and particular ways of formulating an explanation. Students were encouraged to determine what would constitute evidence, to explore each explanation, and to gather evidence that either supports or refutes each explanation in turn, working critically and logically by using argumentation.

3. Argumentation in Science

What does student argumentation in the classroom mean? Driver, Newton, and Osborne (2000) stated that argumentation is important within the social practice of science because students need to develop knowledge and understand the evaluative criteria used to establish scientific theories, which will further enhance the public understanding of science and therefore improve scientific literacy. Kuhn stated that we should experience science as argumentation as well as science as exploration in order to understand the scientific thinking of scientists; students' scientific thinking can be developed best when they practice describing and justifying theories, presenting alternative theories, presenting counter-arguments, and providing rebuttals through argumentation with peers and teachers (Kuhn, 1986, 1993).

Vellom and Anderson (1999) investigated sixth graders' argumentation through small and whole class group work, using the concept of density as the content of the instruction. The study's findings indicated that (a) through argumentation with peers and teachers, students reached one agreed-upon theory by sharing their supporting or refuting evidence from their investigation, and (b) students had opportunities to discuss experimental techniques and replication and to assess whether a particular scientific claim or fact fits into a larger pattern of data and theory. By developing argumentation with peers and teachers, students were shown to learn science concepts in the context of scientific inquiry through argumentation based on their observations and experimentation.

4. Group Work as Social Practice for Scientific Argumentation

Then what kind of teaching strategies are effective in enhancing students'understanding of how scientific knowledge is constructed through scientific inquiry activities? A pivotal teaching strategy for teachers that provides students with the opportunity for argumentation is using small group activities with peers or teachers. Studies (Richmond & Striley, 1996) of student argumentation during scientific inquiry in the classroom have found that different types of small groups influenced students' achievement in gaining science concepts and the skills of scientific inquiry. Richmond & Striley (1996) showed that the specific social roles and leadership styles that developed within the groups greatly influenced the ease with which students developed scientific understanding. Three varying styles of group leadership influenced students' understanding of scientific content within a larger intellectual picture: (a) the inclusive leader who constructed knowledge through argumentation with other students, (b) the persuasive leader who mainly led argumentation in constructing knowledge, and (c) the alienating leader who constructed knowledge weakly. Overall, this study put emphasis on what kind of small group leader was most effective in motivating students to think scientifically and in helping students understand how scientific knowledge is constructed. The results concluded that the inclusive leader was the most effective. The study of Richmond and Striley (1996) showed how effective students' specified roles in small groups were in developing their abilities to think "scientifically" and to construct scientific knowledge through argumentation with peers or teachers. It is relevant then, at this point, to define "scientific thinking".

5. Scientific Thinking

Kuhn (1989) claimed that the heart of scientific thinking is the ability to differentiate between evidence and theory and to coordinate these two appropriately to construct new knowledge. She describes a scientific thinker as someone who (a) is able to consciously articulate a theory that scientists accept, (b) knows what evidence could support the theory and what evidence could contradict it, and (c) is able to justify why the coordination of theories and evidence has led scientists to accept a theory or reject others regarding the same phenomenon (p 674). On the basis of this definition of scientific thinking, Kuhn and other researchers (Klahr & Kotovsky, 1989) investigated the process of scientific thinking and obtained results that suggest that there are significantly different thinking processes among children, lay adults, and scientists.

Kuhn, Amsel, and O'Loughlin (1988) selected third, sixth, and ninth graders, average adults, and graduate students as experts to see how those subjects used a variety of devices to bring evidence and theory into alignment when their theory and evidence were inconsistent. It was found that younger subjects were less likely than older ones to distinguish firmly between theory and evidence and less likely to be able to resolve the conflict between the two.

Dunbar and Klahr (1989) selected third to sixth graders and undergraduate students with competent computer backgrounds to find out the function of a key from a keypad based on their trial-and-error practices with a BigTrak robot, observing their abilities to coordinate the two problem spaces of hypothesis and experiment. Hypothesis space is guided both by prior knowledge and by experimental results. Experiment space is guided by the current hypothesis, and it may be used to generate information to formulate new hypotheses. Dunbar and Klahr (1989) found that there were profound differences in the consequences of how this general orientation toward discovery was implemented. Adults had a 95% success rate, whereas 90% of the children failed. This difference was not from their procedural ability to generate informative experiments but from their reasoning and inducting ability using the results of those experiments. Children were observed to generate data to patch a faulty hypothesis or to produce an expected effect, whereas adults generated a data pattern with which they could induce a new hypothesis. Children were observed to induce new hypotheses from experiments, but none of them were able to use an experimental result to induce a new theory. Adults were largely successful in completing their job assigned, whereas children showed limited ability to coordinate the two problem spaces of hypothesis and experiment and to design informative experiments that led to successful problem solutions.

Students need to develop those scientific thinking skills, such as the ability to differentiate evidence from data, during their scientific inquiry lessons at school. Scientific thinking skills are achieved through argumentation practices regarding a certain scientific concept in the context of scientific inquiry (Duschl & Osborne, 2002). For this purpose, teachers need to provide students with opportunities to develop conceptual understanding, to develop investigative competence, and to understand the epistemology of science.

6. Developing Scientific Argumentation in the Classroom

Hogan, Nastasi, and Pressley (2000) investigated eighth-grade student groups' argumentation with and without a teacher's help in developing a model to explain a phenomenon. Students' accomplishments differed somewhat depending on the presence or absence of a teacher in the discussion. Teacher-guided discussions were a more efficient means of attaining higher levels of reasoning and higher quality explanations, but peer discussion tended to be more generative and exploratory. Yerrick (2000), acting as teacher and researcher, examined the effects of open inquiry instruction with low achieving high school students with physics as the lesson content. To develop a discourse community without a teacher's authority to determine the correct answers, Yerrick promoted the notion that students' questions and experiences were to be valued first, and critique of those ideas was promoted as a subsequent necessity for communal understanding of any problem.

These two studies, Hogan, Nastasi, and Pressley (2000) and Yerrick (2000), showed how teachers' roles in scaffolding could promote students' argumentation in order to develop their scientific thinking skills during scientific inquiry activities. In the scaffolding process, teachers pose questions, not to evaluate but to discover what students already know and what ideas students are struggling with. Teachers' prompts intend to help students gain understanding rather than simply evaluate what they are learning (Pressley, Hogan, Wharton-McDonald, Mistretta, & Ettenberger, 1996).

Recent research has investigated few opportunities for students' developing scientific argumentation or opportunities of demanding low cognition to understand the nature of scientific knowledge. The research has also investigated teaching strategies that provide students with opportunities to develop argumentation skills. The research also implies that teachers can encourage students to demonstrate scientific thinking skills by providing them with opportunities for developing argumentation through instructional curriculum. However, there is little research on what kind of function or models of explicit teaching strategies teachers employ for student argumentation and how students respond to those teaching strategies. It can be assumed that the quality of student argumentation differs in response to teachers' different explicit teaching strategies.

III. Methodology

1. Educational Setting

The researcher worked with a science teacher, referred to here as Mr. Field, who teaches seventh grade science at a public middle school in a coastal Northwestern city. That city has a population of 9960 and its major industries include fishing, wood products, and tourism. The middle school where Mr. Field works has 446 enrolled students from grades six to eight. The socioeconomic status (SES) based on the number of students receiving free or reduced-price lunch is 44% compared to the state average of 39%. Student ethnicity is 85% White and 15% other races, including Asian (2%), Hispanic (7%), American Indian (6%), and African American (1%). In the State Assessment, this middle school ranked above the state average in reading (73% to the state average of 64%) and writing (70% to the state average of 66%), but below average in math (52% to the state average of 57%).

The researcher observed two units of instruction that were taught to two different periods of seventh -grade students in the same classroom. There were 27 students in each classroom and 50% of them received free or reduced-price lunch, which is higher than the school's average of 44%. The two classes had similar average academic levels. The students sat at seven different tables in groups of four and there was a separate table for the researcher to observe from. Three groups consisted of students whose parents gave permission for their child to participate in this study.

2. Participants

One science teacher, Mr. Field, and his students, 54 in two classrooms, at the middle school level (7th grade) participated in this study for two months. Mr. Field has taught science content for 30 years at upper elementary and middle school levels. Mr. Field also attends professional development programs regularly two or three times per year with the aims of (a) completing his school district's 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. Students included three ESL (English Second Language), two IEP (Individualized Educational Program) who had emotional disabilities, and one TAG (Talented And Gifted) students in two classrooms.

3. Data Collection

Three interviews employing semi-structured interview protocols were used to examine Mr. Field's understanding of scientific argumentation. There were first interview (entering: Appendix 1) protocols, asking his general understanding about scientific argumentation in the classroom, second interview triangulating his teaching strategies observed during class observations, and third interview (exiting) validating the results of this study based on the researcher's data analysis. Observational protocols (OTOP: Appendix 2) with field notes were employed to observe and investigate Mr. Field's teaching strategies that led students to demonstrate scientific thinking skills for 60 hours of lessons. 60 hours of class observations were all video-audio-taped for transcription later.

4. Data Analysis

Transcriptions of Mr. Field's interviews were used to generalize his understanding of scientific argumentation based on interview protocols through coding categories. 23 hours of class observations were analyzed by Toulmin's approach (1958) to see how much students' discourse was argumentative. Two different units of students' lab reports were also collected to analyze by Toulmin's approach to decide the quality of students' abilities of developing scientific argumentation.

Ⅳ. Results

1. Mr. Field's Understandings about Scientific Argumentation

Mr. Field defined scientific inquiry as the combination of developing procedural skills through hands-on activities and reasoning skills through argumentation. He also differentiated scientific inquiry from hands-on activity in that scientific inquiry is the combination of hands-on activity and the opportunity of using reasoning skills.

> Originally scientific inquiry was designed to be an open-ended experience that kids could use their creativity to explore open-ended questions or even come up with an investigation on

their own that they could investigate either in the classroom or at home and then bring in the work that they have done (**Definition of scientific inquiry**; 1st interview).

Here, Mr. Field stated that students need to use their creativity to design the experiment to find evidence for their own questions. When he was furthered to define scientific inquiry by differentiating it from hands-on activity, Mr. Field elaborated its definition in terms of the opportunity of discovering pieces of evidence to be used to support students' own developed claims or hypotheses in the following interview.

Then they have to, in their design, tell me whether they agree or disagree with that claim and why. They have to state their evidence right there based on their background and information. Then I require, in their analysis, for them to go back and read the claim, read their evidence and then state whether or not if they have learned anything from the beginning of the investigation to the end. Do they still think that evidence is valid? Do they still think that claim is valid, and why? The "and why" part is where they will pull in their collection of data to prove or disprove what is going on (**Differentiation between Scientific Inquiry and Hands-on Activity**; 1st Interview).

Mr. Field believed that the limited students' scientific knowledge is the barrier preventing students from demonstrating their reasoning skills in constructing their knowledge during the lesson. However, Mr. Field believed that students at the seventh-grade level can develop the reasoning skills needed to perform and understand scientific inquiry by practicing using reasoning with a teacher's guidance and discipline. To meet this goal, Mr. Field used some explicit teaching strategies to provide students with opportunities to demonstrate and promote their reasoning skills based on scientific investigation. Mr. Field believed that it is possible for students to develop reasoning as well as procedural skills through the practice of doing scientific inquiry activities.

Mr. Field added that students at this age (12 or 13 years old) are developmentally beginning to understand the mechanism of cause-and-effect thinking. Mr. Field responded that it is his role to scaffold lessons at this point to allow students to practice scientific thinking and argumentation, in order to understand how scientific knowledge is constructed.

2. Claim-Evidence Approach

The Claim-Evidence Approach (CLEA) is the main teaching strategy that Mr. Field employed for students' learning. This approach has two features. First, this approach is a deductive method for students to establish scientific claims based on their readings in the textbook or other sources. Second, this approach provides students with opportunities to develop evidence-based arguments that support or refute claims.

Mr. Field learned this approach at the Scientific Inquiry Summer Institute 2003, a professional development program. He had implemented this inquiry-based approach to science learning for one year at the time of this study. According to Mr. Field, the biggest benefit of using this approach is the connection between the content and lab activities. Here is how Mr. Field implemented *the Claim-Evidence* Approach in his first teaching unit on Newton's first law in this study.

First, Mr. Field used the textbook to develop background information about Newton's laws. The students learned new terms related to Newton's laws by reading the textbook. Then, students develop their own claims using their own words based on the background information from the textbook (Kahan, 2000) about Newton's first law: Newton's first law of motion states that an object at rest will remain at rest. And an object that is moving at constant speed will continue moving at constant speed unless acted upon by an unbalanced force (p. 48). Along with having students develop their own claims, Mr. Field encouraged students to develop their own research questions or hypotheses and to design and carry out the experiments to find the answer to those questions. The following excerpt shows Mr. Field's understanding of how important it is for students to use their own voices and subjectivities in designing the investigation.

The first thing you are going to do, remember, you have to tell me what is going to happen. That means which one of these you are choosing. Why do you think it is going to happen? This is extremely important and the why you use these words. What and the why need to use those words. I want you to get busy now writing up your framing the investigation. It is going to tell me what you think is going to happen, which one of these is going to fly the longest, and why you think it is going to happen, using as many of these words as you can (Mr. Field's 2nd interview).

During the lesson, Mr. Field explained what CLEA is and how students develop a claim generally by saying, "*Inquiry means thinking creatively,*" or "*You start with an idea.*" Mr. Field also displayed his holistic understanding of the nature of scientific inquiry and the nature of science in terms of the subjectivity and creativity needed to develop claims by saying, "*[Claims] must be true... What if it is not true?*" and "*You put it in your own words that make sense to you.*"

Mr. Field scaffolded students to develop their own claims by repeating definitions, giving concrete examples, and extending the knowledge needed for students to use in developing their own claims for the purpose of providing students with opportunities of developing argumentation. Mr. Field contextualized and demonstrated one simple activity so that students were motivated to think of the variables and knowledge needed to develop their own claims by saying, "If I put my rocket balloon here..." and "there is some energy added to it." This step of CLEA is called *Framing the Investigation.*

Second, Mr. Field introduced the Rocket Balloon Activity lab and demonstrated a simple activity with concrete materials. After his demonstration for students' observation, Mr. Field worked on helping students understand which variables would be dependent or independent in carrying out the rocket balloon activity. For example, some of Mr. Field's scaffolding to develop students' argumentation during the phase of data collection and transformation was included. In this example, Mr. Field scaffolded students to construct their knowledge based on the prior activity through redefining, repeating, and extending the content from another source. This step of the CLEA instruction is *Design the Investigation* and is when students design the lab activity, also including smaller steps such as demonstrations for class observation, discovering dependent and independent variables needed to design the experiment, and collecting and transforming the data.

Third, Mr. Field encouraged students to analyze the data and find evidence to support their claims based on their patterns of data. If students could not find any pattern or any evidence that could refute their claims, they had another opportunity to developing an argument about why this happened and how this limitation could be overcome to make this experiment better. This last phase of CLEA, *Analyzing and Interpreting Results*, occurred at the end of the inquiry activity and was performed through students' writing rather than whole class discussion. During this phase, Mr. Field had chances to discuss what students should discuss and write in their lab report under *Inquiry Guideline* developed by him. Mr. Field explained what students should report in their results, and implied that students need to use their own evidence (data) that they collected from their experiments to describe what happened in the results section of the lab report. Mr. Field emphasized the importance of using evidence that students collected themselves through experimentation in order to support their claims and hypotheses. Mr. Field also encouraged students to understand in what ways that evidence (data) supported their claims or did not, thereby developing students' argumentation. Mr. Field expected his students to understand what evidence they could use to support their own claims, how they could explain what happened using evidence, and how students could connect those results or conclusions to their own hypotheses or questions that were derived from their claims. Furthermore, Mr. Field provided opportunities for students to extend their thinking skills by describing the patterns of data to generally explain the mechanism of what happened as well as reporting their exact evidence to be used to justify what happened. During this process, Mr. Field encouraged students to think of any factor limiting their experiment in terms of obtaining evidence (data) refuting their claims. This step of CLEA is considered to be the most important stage in which students develop their reasoning skills by sharing ideas with peers in groups or with the teacher as a whole class.

3. Student Discourse as Response to Claim-Evidence Approach

This section examines student argumentation as response to Mr. Field's teaching with the use of Toulmin's approach. The transcripts of the 23 sample lessons out of 60 consisted of students' argumentation between Mr. Field and his students, not among students in groups. The definitions of each component and its uses in Toulmin's approach are as follows.

Toulmin's logical approach (1958, Fig. 1) was used to examine the students' abilities to think scientifically. Toulmin's approach (Fig. 2) for analyzing argumentation includes six components: Data, Claim, Warrant, Qualifier, Rebuttal, and Backing.

Data	**Facts as evidence** from prior knowledge, observations or experimentation for the conclusions
Claim	**Conclusion** to be established
Warrant	**Rules that develop the relationship** between Claim and Data.
Qualifiers	Making Warrant **stronger** with merits
Rebuttal	Making Warrant **weaker** with not-merits
Backing	**General** conditions to the warrants

Fig. 1 *Components of Toulmin's Approach*

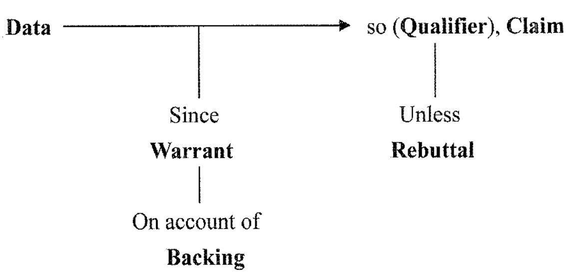

Fig. 2 *Toulmin's layout of arguments*

On the basis of this approach, the researcher investigated how Mr. Field's and his students' discourse fit into these six components. This analysis displayed which component of Toulmin's approach was most frequently used in the interactions between Mr. Field and his students as they developed scientific argumentation. Then, the argument developed by Mr. Field and by his students respectively was compared to see who was dominating the interaction and who developed which argument component defined by Toulmin. This analysis enabled the researcher to describe student argumentation as more extended one or less extended one, depending on phases of CLEA and science content. Student argumentation analyzed using the Toulmin method revealed two different patterns of argument; less extensive argument, which was the more frequent pattern at the beginning or middle phase of CLEA, and the more extended argument, which was the less frequent case at the last phase of CLEA in this study.

At the beginning phase of CLEA (Fig. 3), Mr. Field made questions so that students were able to answer with one-word answers about variables needed to design the investigation. Here, Mr. Field asked what variables need to be controlled to design this investigation. All of the responses by students at this point were Claims in the Toulmin system. Mr. Field asked his students to come up with factors that would make rocket balloon stay longest in the air. To this question, students responded, "*Acceleration*," "*Time*," "*Distance*," and "*Force*," as Data arguments. Mr. Field repeated students' answers and then kept asking for more factors. When one student responded with a factor, "*Motion*," Mr. Field asked the student to find a better word without giving the student more information. At this time, another student replaced "*Motion*" with "*Energy*," and then Mr. Field repeated it. This discourse between Mr. Field and his students during CLEA displayed the less extensive case of argumentation consisting of questions, answers, and evaluation. Overall, the discourse between Mr. Field and his students consisted of the teacher's question, students' answers providing a Claim, and then the teacher's evaluation without more explanation, which could be called the Warrant.

Students, however, later had more opportunities to develop extensive arguments during the last phase of CLEA. The following discussion (Fig. 4) shows how Mr. Field led students to discuss the factors that made it possible or impossible for the balloon to stay longest in the air. Mr. Field checked if students had collected evidence from their experiments in the *Rocket Balloon Activity* under the *Inquiry Guideline*. Mr. Field regarded the amount of tape students used as one of the factors influencing the balloon's flight, and he asked why the smallest amount of tape was needed to make the balloon stay in the air longer. This argument, a Qualifier (the smallest amount of tape makes the balloon stay in the air longer), strengthened the relationship between Data(the amount of tape) and Claim (the amount of tape used to hold

TEACHER	STUDENT	TOULMIN
Oh, very good. The last class didn't get reference point. You don't have to write these yet. Let's just generate them first. More words? Anything that you think is going to help you describe what you think is going to happen with this rocket balloon.		
	Acceleration	Data
Acceleration. Another one?		
	Time.	Data
Yes, you have to have time. Yes?		
	Distance.	Data
Distance. Yes.		
	Force.	Data
Force, oh, yeah, we better have that word in there somewhere.		
	Motion	Data
Motion. Any other words that you think might play a part.		
	Energy.	Data
Energy, okay. We said there were two kinds of energy. We haven't focused on them very much, but I'll write them down here – potential and . . .		
	Kinetic	Data
Kinetic. Potential and kinetic energy.		

Fig. 3 *Less Extensive Argument (October 12, 2004, 4th period)*

the nozzle to the balloon).

At this time, Mr. Field furthered the discussion by asking students more about the force involved in pulling the balloon downward. Mr. Field reminded students of the definition of the force of gravity, "*You are talking about some force here. What force are you talking about?*" Mr. Field confirmed students' understandings about the definition of the force of gravity, "*You are talking about the force of gravity and you seem to think that if something weighs more, the force of gravity pulls on it more. Is that right?*" Then, Mr. Field provided an example from the real world to help students understand the properties of gravity by prompting, "*OK, is that what you all think? If I went to the top of the school and I dropped a golf ball and I dropped a ping pong ball, the golf ball would hit the ground before the ping pong ball.*" Mr. Field stated the two conflicting theories about gravity, which prompted students to find more evidence based on their prior knowledge and experience to support one theory or to refute the opposing one. Mr. Field began the argument with one theory: "*OK, some of you believe that gravity pulls on everything with exactly the same amount of force.*" In response to his instruction, a few students confirmed their understanding about gravity with their opinions, "*It depends on what the mass is or It depends on how much [it weighs].*" These Qualifiers offered by students were possible because Mr. Field created the discussion about gravity. One student provided an opposing theory as a Rebuttal, saying "*In space you can drop a hammer and a feather and they will land on the ground at the same time.*" As response to these two opposing theories about gravity, either that it is constant or depends on mass, Mr. Field gave a demonstration to show how gravity is constant. The teacher's demonstration led students to reason based on their observations, and Mr. Field concluded that gravity is constant because the two balls landed at the same time. During this discussion, students used Qualifiers and Rebuttals, creating a more extended form of argument.

Mr. Field's purpose in using the CLEA was to provide students with the opportunity to develop their own claims to be tested and to find evidence from their experiments to support their claims. During this particular CLEA, Mr. Field followed his *Inquiry Guideline*, which gave students a chance to reflect on their own claims and whether they were testable or not, on their evidence to support their claims, and on the limitations of the experiment in order to improve it. When students discussed the limitations of the

TEACHER	STUDENT	Toulmin
I am going to use as small amount of tape as possible and still make that tight, so air can't escape. Why would I want to use the smallest amount of tape possible? Yes?		Qualifier
	So it doesn't weight it down	
So it doesn't weight it down. What do you mean by weigh it down?		Qualifier
	So that it doesn't go [down]. If its mass isn't too much. .	
You are talking about some force here. What force are you talking about?		
	gravity	Data
You are talking about gravity and you seem to think that if something weighs more, gravity pulls on it more. Is that right?		
	Yes	
OK, is that what you all think? If I went to the top of the school and I dropped a golf ball and I dropped a ping pong ball, the golf ball would hit the ground before the ping pong ball. Is that right?		Data
	No	
	[All talking at once]	
OK, some of you believe that force of gravity pulls on everything with exactly the same amount of force		Backing
	It depends on what the mass is	Qualifier
You are saying that the mass makes a difference		Qualifier
	If it is [different in mass].	Qualifier
Sebastian?		
	It depends on how much [it weighs]	Qualifier
	In space you can drop a hammer and a feather and they will land on the ground at the same time	Rebuttal
We have a difference of opinion here. Let's see if I can find two things that are different masses here. Let's make sure they are quite a bit different. I've got this book, and that is quite a bit of mass there, isn't it? A lot more mass there than say the top of my pen. Would everyone agree that these are quite different in mass?		Data
	[Unanimous yes]	
If I drop these, one should hit the ground before the other, right? [Noise] What did you see?		Data
	The same time	Data
	The book	Data
	The same time	Data
They hit the ground at the same time. That's because gravity is a constant. It pulls on all things with exactly the same amount of force. Even though you think that is not true, that is. Gravity doesn't care if you are big or small.		Data Rebuttal
	If a short person falls off a building and a heavy person falls off a building, they will both hit the ground at the same time?	Data
What about a feather? That is what most people say. If you drop a bowling ball and a feather at the same time, they are not going to hit the ground at the same time. Well, they said, that is because of air resistance. It is underneath the feather and makes it flutter down. Let's see what happens if we take all the air away. Have a bit huge column and they pump all the air out. They have a little thing that they pull so both things fall at the same time. The feather and the ball hit the ground at the same time.		Rebuttal Claim Rebuttal

Fig. 4 *More Extensive Argument (October 12, 2004, 4th period)*

experiment Rocket Balloon Activity at the last phase of CLEA, students could offer more extensive arguments such as Rebuttals and Qualifiers with the aid of Mr. Field. Mr. Field's prompting questions related to gravity and demonstration of a simple experiment made it possible for students to retrieve the knowledge needed to understand the phenomenon.

In terms of the Toulmin analysis in this study, total student argumentation as response to Mr. Field's teaching strategies consisted of Data (51% out of 1532 total argument elements, that is, 23 hours of transcription), Warrant (21%), and Claims (13%) as making up the more frequent case of argumentation relative to the other components: Qualifier (9%), Rebuttal (4%), and Backing (2%). These percentages display weak or less extensive argument forms. These results indicate that Mr. Field's CLEA focused on providing students with many brief but less developed opportunities to practice scientific discourse.

4. General Teaching Profiles

A structured observational protocol, OTOP, was employed for the purpose of describing the pattern of Mr. Field's instruction. There are ten OTOP items describing effective teaching strategies envisioned by the *Standards* (NRC, 1996, 2000). Mr. Field used many questions to assess students' prior knowledge or misconceptions—using OTOP #3 (Discourse and group work), #4 (Challenging ideas), and #5 (Misconception)—in each lesson where students developed their background information during the last phase of CLEA. He provided open-ended questions to solve during the first and middle phase of CLEA—using#1 (Habits of mind), #6 (Conceptual thinking), and #7 (Divergent thinking)—and encouraged students to express their ideas or demonstrate reasoning skills, using #2 (Metacognition). Mr. Field helped students develop their background knowledge through reading the textbook and transforming the data into other representations, such as bar graphs or drawings, using #8 (Interdisciplinary connection). In addition, he emphasized the use of appropriate information or knowledge in helping students understand the content and employed different discursive practices, appealing to #9 (Pedagogical Content Knowledge). Finally, Mr. Field used visual tools, such as videos or slides, in delivering the content and also used concrete materials for students' experiments, fulfilling #10 (Concrete material use).

V. Discussion and Implication

First of all, the students' abilities to develop scientific argumentation were related to their levels of scientific knowledge. The student writing argumentation, lab reports, was also analyzed and it proved that students' abilities of developing argumentation had the relationship with their learning achievements. Students completed the lab report under the *Inquiry Guideline* (Appendix 4) developed by Mr. Field, which gave students practice developing written arguments that included all six components of Toulmin's approach. The levels of students' written argumentation from lab reports, however, were divided into three levels, *Complete, Partial,* and *Limited,* based on a full score of five. Mr. Field validated this conclusion through his last interview. The higher achieving students proved to be qualified to demonstrate their reasoning skills through using appropriate evidences to support their claims to explain the phenomenon. The lower achievers proved to have limited scientific terms and knowledge to justify their phenomenon with their own collected evidences. The interaction among students can imply the development of students' cognitive abilities in social settings for future study.

Second, the teacher's more involvement in interacting with students provided them with opportunities of demonstrating their reasoning skills. Students' argumentation opportunities were promoted when Mr. Field engaged in guiding students to extend their knowledge or skills by prompting, questioning, and giving clues. Two different types of argumentation emerged (a) fundamental argumentation, consisting of the teacher's initial questions, students' responses to them, and teacher's evaluation and (b) exploring argumentation, when Mr. Field provided extended knowledge and supported more complex skills.

In fundamental argumentation, there is a linear pattern of discourse consisting of a two-part question -answer structure or a three-part question-answer

-evaluation structure, called "Triadic Dialogue" (Lemke, 1990). Fundamental argumentation uses the linear flow as diagrammed in Fig. 5.

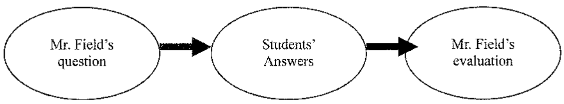

Fig. 5 *Fundamental Argumentation*

In exploring argumentation, there is a circular pattern of discourse rather than a linear one (Fig. 6). Mr. Field created a question, students answered it, Mr. Field evaluated their answers with more questions or prompts, and students developed extended argumentation as response to Mr. Field's instruction. Mr. Field then synthesized all content based on students' ideas. The students often developed a higher quality of argument by offering alternative or contrasting points of view. This mutual interaction between the teacher and students takes place as a circular argument, exploring argumentation, represented in Fig. 6.

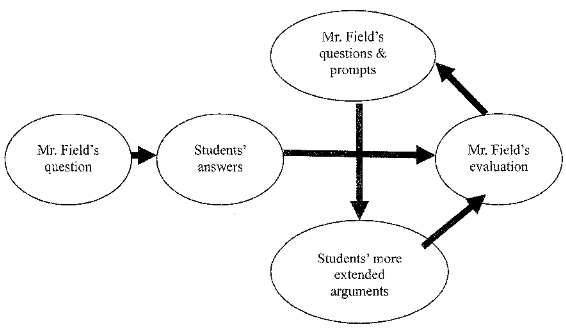

Fig. 6 *Exploring Argumentation*

It is implied that students could have more chances to develop a higher quality of argumentation with more teacher involvement and interaction with students. It is clear that teacher involvement in students' expression of scientific argumentation improved the quality of argumentation. That is, the teacher's active engagement guided students to a higher quality of argumentation by shifting the form of argument from fundamental argumentation to exploring argumentation. In this study, students were able to justify their claims with the use of evidence through Mr. Field's use of extended content and demonstrations in his role as a mentor and a facilitator.

Third, the explicit teaching strategy, *Claim-Evidence Approach* which was designed and implemented for the purpose of providing more opportunities of developing argumentation, was successful to meet its goal. The developed explicit teaching strategy can be used as a guide for teachers to learn through professional development program, including induction program for beginning teachers, preparation program for preservice teachers. In addition, the research methodology, Toulmin's approach for student discourse analysis, made it possible to view the interaction between teacher and students to see how the teacher helped students develop argumentation. Since there is mutual interaction between the teacher and students (or among students) that in turn influences consecutive arguments, it is necessary to analyze interpersonal discourse in the context of a social setting. This methodology can be also useful for teachers and educators to design curriculums providing the opportunities of argumentation. Further investigation of students' abilities to develop scientific argumentation in different contexts, such as group work and whole class discussion, is recommended with the use of the argument analysis tool employed in this study, in order to better understand the nature of learning and teaching scientific argumentation in the classroom.

VI. Significance of this study

Many teachers are not sure of how to use scaffolding to help students understand how scientific knowledge is constructed. If generalizable and exemplary instructional strategies that enhance students' argumentation are developed, these strategies should be documented and used as a guideline for other inservice teachers to employ to develop student argumentation. In addition, identifying exemplary instructional strategies for students' argumentation can also make a significant impact on teacher education for preservice teachers. Preservice teachers are trained to design scientific inquiry lessons with the emphasis on hands-on activities through experimentation rather than minds-on activities through argumentation. Therefore, this investigation through identifying models or functions of students' argumentation during scientific inquiry can lend support for science educators to provide preservice teachers with more practical knowledge of how to create scientific inquiry environments full of argumentation.

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APPENDIX 1

1. How do you define scientific inquiry in your classroom?
   [I expect that participating teachers can understand that scientific inquiry is NOT just to follow the procedures given by them, since these teachers have discussed with science educators what ideal scientific inquiry is in the classroom, through workshops, conferences, and projects.]

2. How does scientific inquiry differ from hands-on activities?
   [Responses from teachers must indicate that those teachers can differentiate hands-on activities from scientific inquiry, which requires reasoning skills as well as procedural skills.]

3. How do students develop their reasoning skills during scientific inquiry?
   [Participating teachers have certain knowledge of how students can develop their reasoning skills as well as procedural skills during scientific inquiry activities here I can expect that teachers might mention certain strategies in which students develop their reasoning skills, such as discussion time as a whole class or in group work.]

4. How do teachers support students to develop their scientific thinking? Do you have any specific or explicit teaching instruction or model that you designed for this purpose in the classroom?
   [This question is asking for teachers' certain designed model or function for students to develop their scientific thinking.]

5. Have you experienced a critical moment in which you felt that students were successful in developing their scientific thinking or reasoning skills during scientific argumentation?
   [This question is asking teachers to provide an example where they provided opportunities for students to develop their scientific thinking skills.]

6. What are the barriers preventing students from successful scientific argumentation?
   [This question is asking about the limitation of pedagogical skills for students' scientific argumentation.]

7. What are your criteria for students successfully demonstrating reasoning skills?
   [This question is asking if teachers have certain criteria that make teachers feel they scaffold students to demonstrate scientific thinking skills.]

APPENDIX 2

OCEPT-Teacher Observation Protocol (O-TOP)
Outcomes Research Study-2005

This instrument is to be completed following observation of classroom instruction. Prior to instruction, the observer will review planning for the lesson with the instructor. During the lesson, the observer will write an anecdotal narrative describing the lesson and then complete this instrument. Each of the ten items should be rated 'globally' the descriptors are possible indicators, not a required 'check-off' list.

Item	Not Observed				Characterizes Lesson
1. This lesson encouraged students to seek and value various modes of investigation or problem solving (Focus: Habits of Mind)	**N/O**	1	2	3	4

Teacher/Instructor:
- Presented open-ended questions
- Encouraged discussion of alternative explanations
- Presented inquiry opportunities for students
- Provided alternative learning strategies

Students:
- Discussed problem-solving strategies
- Posed questions and relevant means for investigating
- Shared ideas about investigations

Item					
2. Teacher encouraged students to be reflective about their learning. (Focus: Metacognition - students' thinking about their own thinking)	**N/O**	1	2	3	4

Teacher/Instructor:
- Encouraged students to explain their understanding of concepts
- Encouraged students to explain in own words both what and how they learned
- Routinely asked for student input and questions

Students:
- Discussed what they understood from the class and how they learned it
- Identified anything unclear to them
- Reflected on and evaluated their own progress toward understanding

Item					
3. Interactions reflected collaborative working relationships and productive discourse among students and between teacher/instructor and students. (Focus: Student discourse and collaboration)	**N/O**	1	2	3	4

Teacher/Instructor:
- Organized students for group work
- Interacted with small groups
- Provided clear outcomes for group

Students:
- Worked collaboratively or cooperatively to accomplish work relevant to task
- Exchanged ideas related to lesson with peers and teacher

Item					
4. Intellectual rigor, constructive criticism, and the challenging of ideas were valued. (Focus: Rigorously challenged ideas)	**N/O**	1	2	3	4

Teacher/Instructor:
- Encouraged input and challenged students' ideas
- Was non-judgmental of student opinions
- Solicited alternative explanations

Students:
- Provided evidence-based arguments
- Listened critically to others' explanations
- Discussed/Challenged others' explanations

5. The instructional strategies and activities probed students' existing knowledge and preconceptions. (Focus: Student preconceptions and misconceptions)	N/O 1 2 3 4
Teacher/Instructor: Pre-assessed students for their thinking and knowledge Helped students confront and/or build on their ideas Refocused lesson based on student ideas to meet needs Students: Expressed ideas even when incorrect or different from the ideas of other students Responded to the ideas of other students	
6. The lesson promoted strongly coherent conceptual understanding in the context of clear learning goals. (Focus: Conceptual thinking)	N/O 1 2 3 4
Teacher/Instructor: Asked higher level questions Encouraged students to extend concepts and skills Related integral ideas to broader concepts Students: Asked and answered higher level questions Related subordinate ideas to broader concept	
7. Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence. (Focus: Divergent thinking)	N/O 1 2 3 4
Teacher/Instructor: Accepted multiple responses to problem-solving situations Provided example evidence for student interpretation Encouraged students to challenge the text as well as each other Students: Generated conjectures and alternate interpretations Critiqued alternate solution strategies of teacher and peers	
8. Appropriate connections were made between content and other curricular areas. (Focus: Interdisciplinary connections)	N/O 1 2 3 4
Teacher/Instructor: Integrated content with other curricular areas Applied content to real-world situations Students: Made connections with other content areas Made connections between content and personal life	
9. The teacher/instructor had a solid grasp of the subject matter content and how to teach it. (Focus: Pedagogical content knowledge)	N/O 1 2 3 4
Teacher/Instructor: Presented information that was accurate and appropriate to student cognitive level Selected strategies that made content understandable to students Was able to field student questions in a way that encouraged more questions Recognized students' ideas even when vaguely articulated Students: Responded to instruction with ideas relevant to target content Appeared to be engaged with lesson content	
10. The teacher/instructor used a variety of means to represent concepts. (Focus: Multiple representations of concepts)	N/O 1 2 3 4
Teacher/Instructor: Used multiple methods, strategies and teaching styles to explain a concept Used various materials to foster student understanding (models, drawings, graphs, concrete materials, manipulatives, etc.)	

APPENDIX 3

TOPIC: Newton's third law (action and reaction: about friction)
October 28, 2004 (4th Block)

TEACHER	STUDENT	Toulmin
have these wind suits that are also there to keep them warm. Does anybody see any frictions involved in this picture? Tyler?		Claim
	The [people] leaning against.	Data
The snow there? OK, so he says the feet ofthe 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) (2) (3) (4)	Warrant Qualifier Qualifier Warrant
	The skis.	Data
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) (2) (3) (4) (5) (6) (7) (8) (9)	Warrant Warrant Qualifier Qualifier Data Data Claim Claim Data
	The wind with the suits?	Data
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) (2) (3)	Data Warrant qualifier
	Weight, (1) because if they have a lot of weight, then they will go into the snow (2)	Data Warrant
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) (2)	Qualifier Qualifier

APPENDIX 4

Inquiry Guideline designed by the teacher

- Report the results.
- Identify patterns.
- Talk about what you think happened and why.
- Look over your design and tell of anything that caused a problem
- Write a conclusion that tells:
  - What was the question and the claim
  - If what you thought would happen and how you know.
  - How the problems could be solved.
  - What is another experiment you would do with this equipment?