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# A Preliminary Analysis of Observing Classroom Inquiry on a Web-based Discussion Board System

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The purpose of the study was to identify the characteristics of classroom inquiry features exhibited on a web-based discussion board, which is called the Message Board. Approximately 4,000 students from 80 schools with 60 on-line scientists were participated in the study. During the study, a total of 639 messages in the selected cluster and several patterns were identified and analyzed. Three main features of the classroom inquiry were analyzed in terms of: 1) learner gives priority to evidence in responding to questions; 2) learner formulates explanations from evidence; 3) learner communicates and justifies explanations. The results are as follow. First, once learners identified and understood the questions posed by the curriculum, they needed to collect evidence or information in responding to the questions. Depending on the question that students were given, types of evidence/data students needed to collect and how to collect the data could vary. Second, students' formulated descriptions, explanations, and predictions after summarizing evidence were observed on the Message Board. However, the extent to which students summarized evidence for descriptions, explanations, and predictions varied. In addition, students were able to make a better use of evidence over time when they formulate descriptions and explanations. Third, the Message Board was designed to allow the great amount of learner self-direction. Classroom teachers and on-line scientists played an important role in providing guidance in developing inquiry. At the same time, development of content understanding also contributed to inquiry development.

*Keywords: Classroom inquiry, Web-based discussion, Scientific discourse*

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## Introduction

Over the past decade, science education research and reforms have addressed the importance of inquiry in science learning and teaching more than ever (AAAS, 1993; Minstrell & van Zee, 2000; Oliver, 2008). One of most influential documents that discuss inquiry in a science classroom, *Inquiry and the National Science Education Standards* listed the five essential features of classroom inquiry; 1) Learners engage in scientifically oriented questions; 2) Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions; 3) Learners formulate explanations from evidence to address scientifically oriented questions; 4) Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding; and 5) Learners communicate and justify their proposed explanations (NRC, 2000). Along with the list of five major features of classroom inquiry, the document added another dimension; a degree of guidance from teacher-support to learner-centered.

Science educators and practitioners have advocated inquiry-based science learning and increasing numbers of studies have been contributed to expand our knowledge base on this topic. Many experimental and pilot studies have shown successful examples where even young children could develop complex inquiry skills with help of carefully designed scaffolding. Nevertheless, it has been argued that the general level of students' understanding and practice of scientific inquiry is still less than desirable in current science classrooms. In a search for a better way to foster inquiry, many saw a promise in technology as a tool to support learning and teaching inquiry-based science (Lim, 2004).

More recently the emphasis on inquiry has been accompanied by high expectations for how technology can transform the science classroom (Clark & Sampson, 2007; Osbourne & Henessey, 2003; Tan & Seah, 2011). Technology provides new learning opportunities which were not possible with traditional resources alone. Studies have explored such unique learning opportunities that technology can offer such as the value of online resources available on the web (Ikpeze, & Boyd, 2007), micro-computer-based laboratories using probes (Tinker, 1996), visualization tools (Beckett & Boohan, 1996; Escalada & Zollman, 1997; Zacharia, 2003), dynamic modeling tools (Quintana, Norris, Krajcik, & Soloway, 2002), , real-time data accessing & analysis tools (Songer, 1998), and meta-cognitive scaffolding tools (White & Frederiksen, 1998).

Nevertheless, the field is still its infancy and questions such as what roles technology can play to promote inquiry, how to support inquiry in technology-rich learning environments including roles of teachers, advantages and barriers that technology may bring into science classroom for inquiry, how different technological tools advance or inhibit the development of particular features of inquiry in science class, call for further investigations(Sriarunrasmee, Suwannatthacho, & Dechakupt, 2011). Simply bringing a computer into the science classroom does not guarantee inquiry learning. A complex interaction of accompanying support materials, a teacher, peer students, curriculum, and school context needs to be studied in order to understand whether or not and in what ways technology can promote inquiry.

Moreover, different natures and functionalities of technological learning tools – whether being visualization, animation, or communication – will contribute different aspects of inquiry development. For example, while visualization of real-time weather data can promote students' inquiry of data gathering, analysis, and interpretation skills, modeling tools will be better at the development of students' inquiry in formulating an explanation or a theory building. To this end, this study focuses on one specific technological tool, i.e., online communication with scientists and peers in different locations, which is part of larger technology-enhanced inquiry science curriculum, and its value in supporting students' inquiry in science class.

*Kids as Global Scientists* is an inquiry-based technology-rich weather science program for middle school students (Songer, 1996). The program provides several technological learning tools that share the same characteristics that Bransford, Brown, & Cocking (1999) described including: a) bring real-world problems through display and analysis of real-time weather imagery data, b) giving students and teachers more opportunities for feedback, reflection and science learning through a web-based discussion board called Message Board, and c) building learning communities through connecting students, teachers and scientists from all over the country via the Message Board.

In this paper, we examined which features of classroom inquiry were observed in middle school students' on-line communication with scientists and peers, to what extent the classroom inquiry we observed reflect NRC's five essential inquiry features, and what we can add to the five features from our understanding of the particular learning environment we studied.

## Related Researches

Our research draws from foundational literature in the learning sciences and instructional design for learning environment including work on the learning approaches of inquiry (Anderson & Palincsar, 1997; Bransford et al, 1999; Minstrell & van Zee, 2000; White & Frederiksen, 1998) and the social construction of knowledge (Brown, Ash, Rutherford, Nakagawa, Gordon, & Campione, 1993; Lave & Wenger, 1991; Vygotsky, 1978 among others). The learning environment called *Kids as Global Scientists* was developed as a context for students' exploration of their own queries and predictions in science through both the sharing and critiquing of others' work on threaded web-based discussions.

The inquiry-focused curriculum progressively guides students towards the organization of data and information on weather events including rich definitions of traditional weather concepts such as wind, pressure, temperature, and fronts. In the culminating activity, students can apply their more general understandings of these scientific terms towards the predictions and forecasting of current events. In this program the threaded web discussion boards, called Message Board, serve as essential sources of feedback for students' evolving content understandings, predictions and explanations. Previous research helps us understand that many conceptualize the appropriation of scientific discourse as an essential demonstration and means towards rich scientific understandings (Anderson & Palincsar, 1997; Gee, 1989; Lemke, 1990; Latour & Woolgar, 1986; Rosebery, Warren, & Conant, 1992). Lemke (1990) regarded "talking science" as an essential component of the process of developing complex understandings such as that involved in inquiry science, and in fact many of the examples of discourse norms discussed in science are identical to norms involved in inquiry: arguing, questioning, describing, and critiquing.

Adopting a social constructivist view encourages researchers to emphasize processes and products of social dialogue, such as small group or classroom conversations or web discussions as a compliment to more traditional evaluations, such as written pre or post tests for student learning. Mehan (1979) discovered that traditional classroom discourse often follows predictable patterns of Initiation-Reply-Evaluation (IRE). In this pattern, teachers initiate and control questioning and correct answers are emphasized. Other studies also have identified problems with the traditional classroom discourse patterns, such as the silencing of certain populations of students or convey certain teacher belief of science and society (Carlsen, 1997; ChanLin & Chan, 2007; Cunningham, 1997) and have proposed alternative discourse structures to solve these problems (Brown & Palincsar, 1989; Green, 1983; Hicks, 1996; van Zee & Minstrell, 1997). Computer-mediated communications between students and students and students and scientists bring innovative ways to overcome problems of the traditional discourse patterns (Guzdial & Turns, 2000; Hsi & Hoadley, 1997; Scardamalia & Bereiter, 1991). The study of scientific dialogue encourages researchers to look for measures of understanding of student concept and inquiry that go beyond a purely concept-focused view of science learning towards a view of learning as a process mediated by many influences including culture, learning environment, metacognition, and beliefs about science, among others.

# Methods

## Participants

The *Kids as Global Scientists* program involved several thousand learners for the eight-week program. Participants were from diverse settings including several public school categories (large urban schools, rural schools, special needs classrooms) as well as classrooms within private schools and an increasing number of home school classrooms. During the time of this study, approximately 4,000 students from 80 schools with 60 on-line scientists were participated. In order to facilitate more productive discussion, participants were divided into seven groups by age or grade-level, with each sub-group called a cluster containing 8-10 schools with 7-8 on-line scientists. A graduate student was assigned to each cluster to screen for inappropriate messages and to offer support to participants. Communication was only allowed within a cluster. In other word, each cluster operated independently. Participants in the program never met each other in person, although photos of participants were distributed through a web-based photo essay. Thus, the participants' social interactions were entirely created and sustained via electronic discourse.

Participation in the program was totally voluntary. Thus, in some cases a total of 12 classes from grade level 6 through 8 in one schools were participated, while in other cases, only one teacher participated from one school. During the program, the jigsaw collaboration learning model was recommended. Four students comprised a group. Each group member specialized in one of four weather topics; temperature, pressure, winds, and humidity. When students communicate on the

Message Board, they compose, send and reply messages as a group not as an individual. In other words, each student group with four students was assigned one Message Board ID.

## Program

The *Kids as Global Scientists* learning environment is an inquiry-focused Internet-enhanced atmospheric science program for middle school students (Songer, 1996). The learning environment consists of a suite of eight weeks of curricular activities, software, and individuals coordinated across the United States towards the study of weather concepts such as temperature, wind, pressure, and precipitation in live contexts and with the guided support of on-line scientists and peers (Songer, 1996; 1998). Following a set of activities coordinated with others across the United States, students in each site work in small groups of two or three students, and each group specializes in one of four weather topics: Clouds & Humidity, Precipitation, Temperature & Pressure, or Winds.

Designed to build towards students' abilities to make live forecasts about current storms and justify their explanations for their predictions, the program has worked over several years to incorporate several key tenets in learning sciences research such as distributed expertise (Brown, Ash, Rutherford, Nakagawa, Gordon & Campione, 1993), socially mediated cognition (e.g., Lave & Wenger, 1991; Pea, 1993; 1994; Vygotsky, 1978), and the understanding that young children are capable of complex reasoning and higher-order thinking provided they are supported and guided by activities, tools and individuals who organize complex material for them, regulate the complexity of their questions and information, and provide resources for reflection and evaluation of information (Bransford et al, 1999; Nussbaum & Edwards, 2011).

In addition, the program is organized in three phases focusing on questioning, exploring and predicting current weather events as one approach to students' development of both a deep understanding of science concepts such as wind, precipitation, temperature and pressure, and as a means of applying their developing understandings through the prediction and examination of current weather events. This approach emphasizes both deep foundation of factual knowledge and a strong conceptual framework as advocated by Bransford and others (1999).

## Procedures

The project activities were designed to encourage participants to take advantage of a unique feature of Internet tools: the power of communication with many distributed first-hand resources, whether local or across the globe (Songer, 1996). Students begin the program by making self-introductions via the web-based Message Board to other students around the world. Throughout the program participants build on these initial introductions through several collaborative Message Board activities including 1) sharing and comparing two weeks of local weather data they personally collected, 2) sharing and critiquing others' explanations and summaries of weather phenomena, 3) making predictions about others' weather, and 4) sending and responding to weather questions posed by scientists called Weather Specialists, peers or teachers in other locations.

The main design consideration of the Message Board included the utilization of web-based discussions towards fostering inquiry, particularly the five essential features of classroom inquiry described in Inquiry in the National Science Education Standards. For example, during the program students were asked to process their own and others' weather data through the use of data tables and overlaid weather imagery to compare and contrast different sets of data. The Message Board allowed critical discussions about these comparisons and predictions. In this way, the Message Board as a compliment to the live and current weather data provides a forum for the development of descriptions, the interpretation of data, and the fostering of critical and logical conversations with others about current scientific information. In the final weeks of the program, students synthesized both their developing understandings of scientific concepts and their developing understanding of critical interpretation of data towards the prediction of tomorrow's weather conditions.

A second goal of the Message Board was to provide a resource for responsive scaffolding among student and teacher participants. By responsive scaffolding we refer to the ability for knowledgeable learners to post and respond to individual student questions on current topics (Nussbaum & Edwards, 2011). We recognized that generating authentic discussions on current atmospheric science phenomena was one possible outcome that could be facilitated by the Message Board. "Authentic" questions in the program can be described as questions dealing with both real-time and near-time weather data and information, as well as questions relevant to the first-hand experiences of other participants (Songer, 1998). Responsive scaffolding has not been well supported by other electronic tools such as email or group conferencing software. We hoped to investigate whether the features of the Message Board tool, combined with the accompanying supports, could lead to a clear understanding of the productive use of information resources such as individuals and real-time information.

## Data analysis

A total of 4,464 messages were exchanged across the seven Message Boards. A total number of messages exchanged in each cluster varied from 175 to 1207. The rather large variance among the clusters was due to the different degree of participation by each school. The number of messages posted by each school varied depending on the number of participating students per school (clustering was based on school not class level), school's computer availability and Internet capacity, teacher's decision about time allocation for the Message Board communication compared to other activities (e.g., local data collection, hands-on experiments). We first examined a general use of the Message Board across several dimensions including time, type of activity, sender and level of thread. This level of quantitative analysis was applied to the total of 4,464 messages from the all seven clusters. Then, we chose one representative cluster to perform the more in-depth analyses on the content of messages. In order to explore the research questions, we developed coding categories which reflect the inquiry skills in the Inquiry in the National Science Education Standards. Chi's Verbal Analysis (1997) coding was applied to a total of 639 messages in the selected cluster and several patterns were emerged from the quantified data (see Table 1).

Table 1. Comparison between Verbal Analysis (Chi, 1997)

| Verbal Analysis (Chi, 1997) Procedures | Data Analysis Procedures of This Study |
|---|---|
| 1. Reducing or sampling the protocols | 1. Determining a unit of analysis and sampling messages |
| 2. Segmenting the reduced or sampled protocols (sometimes optional) | |
| 3. Developing or choosing a coding scheme or formalism | 2. Formulating coding categories |
| 4. Operationalizing evidence in the coded protocols that constitutes a mapping to some chosen formalism | 3. Applying, revising, and re-formulating coding categories |
| 5. Depicting the mapped formalism (optional) | 4. Organizing coded data in graphic forms & Seeking patterns |
| 6. Seeking pattern(s) in the mapped formalism | |
| 7. Interpreting the pattern(s) | 5. Interpreting the patterns in a broader context |
| 8. Repeating the whole process, perhaps coding a different grain size (optional) | |

For this study, a message was defined a unit of analysis since students' message was relatively short – i.e., 3~5 sentences. Coding categories were formulated to identify classroom inquiry features. Then, each message was coded using the classroom inquiry coding categories. Two researchers independently coded 100 randomly selected messages and checked for discrepancies. The researchers discussed the discrepancies and revised coding categories. Then, the researchers independently coded a total of 639 messages applying the revised coding categories. The final inter-rater reliability was 0.89.

## Results and Discussions

We examined to what characteristics of the classroom inquiry features in the Inquiry in the National Science Education Standards were observed on the Message Board. Due to the nature of activity structure of the Message Board, some features of the classroom inquiry were more visible than others. Those classroom inquiry features that were prominent in the design of the Message Board include;

- Learner gives priority to evidence in responding to questions
- Learner formulates explanations from evidence
- Learner communicates and justifies explanations

Table 2 was modified from the original essential features of classroom inquiry and their variations in NRC's standards to illustrate students' inquiry observed on the Message Board. The Message Board was not designed to support all features of classroom inquiry. Rather – as the results of this study confirmed – the Message Board was a better medium to support certain inquiry features than others. For example, some classroom inquiry features such as "Learner engages in scientifically oriented questions" were less visible on the Message Board due to the design of the program and the nature of the medium, on-line communication. In many cases, scientific inquiry begins with a question that can drive a scientific investigation including collecting evidence relevant to the question, formulating explanations and connect to the scientific knowledge (Nussbaum & Edwards, 2011).

The research questions in this context differ from concept-based questions that learners raise to understand a definition of concepts or principles or out of curiosity (e.g., what is freezing rain?) which do not necessarily lead to a scientific investigation (e.g., text-based questions, Scardamalia & Bereiter, 1991). Depending on the purpose of an activity and the level of student understanding of a given domain, scientifically oriented questions can be posed by learners themselves or provided by a teacher or materials such as curriculum. While having students pose their own research question can be a good start of inquiry learning, it is often difficult for young students to come up with a testable question to pursue inquiry in a science classroom. Researchers have found that students can benefit from guided inquiry – as opposed to open inquiry – where they engage in questions provided by teacher, materials or other sources (e.g., Rogoff, 1994).

In addition, the forth inquiry feature of NRC stating "Learner connects explanations to scientific knowledge" could be better supported by other combined features of the program such as other internet devices, student hands-on experiments and first-hand data collection, and curriculum questions on student worksheet. We will first discuss the characteristics of the students' inquiry shown on the Message Board and the discussion of Message Board system features which we believe supported the inquiry learning will follow.

## Do learners give priority to evidence in responding to questions?

In this program, various levels of questions were posed by Curriculum Questions on student worksheets that guided students' inquiry learning. Some of those questions were designed to be broad guiding questions so that students needed to engage in the questions as they conduct multiple activities. Other questions were more focused on a given specific activity.

Once learners identified/understood the questions posed by the curriculum, they needed to collect evidence or information in responding to the questions. Depending on the question that students were given (e.g., find out current weather condition in a participating school site where pressure is the lowest today and make a prediction of tomorrow's weather for that site), types of evidence/data students needed to collect and how to collect the data could vary. In the above example of "find out current weather condition", sometimes students were directed to collect certain data – for example, weather condition including temperature, precipitation, and wind direction in the area where pressure is the lowest – but other times students needed to determine what constitutes evidence or data and how to collect them (variation 1 & 2 in Table 2).

Table 2. Features of classroom inquiry observed on the Message Board and their variations highlighted (modified from Inquiry in the National Science Education Standards, NRC, 2000).

| Essential Feature | Variations | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 2. Learner gives priority to **evidence** in responding to questions | Learner determines what constitutes evidence and collects it | Learner directed to collect certain data | Learner given data and asked to analyze | Learner given data and told how to analyze |
| 3. Learner formulates **explanations** from evidence | Learner formulates explanation after summarizing evidence | Learner guided in process of formulating explanations from evidence | Learner given possible ways to use evidence to formulate explanation | Learner provided with evidence |
| 5. Learner communicates and justifies explanations | Learner forms reasonable and logical argument to communicate explanations | Learner coached in development of communication | Learner provided broad guidelines to sharpen communication | Learner given stops and procedures for communication |

More----------------------------------Amount of Learner Self-Direction-------------------------------------Less
Less--------------------------Amount of Direction from Teacher or Material----------------------------More

During the program, students collected various forms of evidences such as numerical weather data through the program specific web-browser (professional data) and weather instruments (local students' data). In addition, students communicated with other participants to gather descriptive weather information by asking weather condition of the other participants' area. The participating students often asked weather condition of other locations because they were interested in knowing how weather in other area is different from or similar to their own weather. By exchanging weather information, –even though students did not explicitly notice – they engaged in a scientifically oriented question such as "what might affect weather condition in a certain area at a certain time?" throughout the program. By asking for weather information and by reading geographical descriptions of participating school sites on the web-browser, students were able to develop factors which can affect weather condition in different areas in different times.

To understand why a certain area is having a current weather phenomenon, collecting specific evidence might be more helpful as opposed to general evidence. Of 465 science topic-related messages, 47.3% was requesting weather related information (evidence) in other participants' area. The level of elaboration of the questions that requested evidences varied. Some students requested weather information in a very general level such as "Tell us what's your weather like in winter", whereas other students requested more specific evidences such as "We heard about your bad weather on Friday, March 6. Did you get a chance to measure the speed of the wind on your anemometer? How about the wind direction? Tell us about it. Was it a blizzard? (Spruce Elementary Wind group 3/7)." In the latter example, a group of students were asking for specific evidences, i.e., wind speed and wind direction. In addition, content analysis of messages revealed that 62.4% of the messages that contained weather-related information discussed more specific real-time, current weather information, while 30.1% of those messages discussed rather general traditional weather information like that found in textbooks.

Combining the above findings together suggests that students were able to collect the appropriate evidences, i.e., regionally and temporally specific evidences by requesting information on the Message Board.

### Do learners formulate descriptions, explanations and predictions from evidence?

The next feature of classroom inquiry concerns to what extent learners formulate descriptions, explanations and predictions using evidence that either they collected or were provided by other sources. Once learners collected evidence or data, they need be able to analyze and summarize evidence to formulate descriptions, explanations, and predictions. Although Table 2 only shows explanations, depending on the research questions that learners are engaged in the summary of evidence can be used to support descriptions or predictions as well as explanations.

On the Message Board we observed that students formulated descriptions of weather condition in local area, explanations of weather concepts, and predictions of future weather conditions. Of science topic-related messages (n = 465), 79.1% (n=368) included either description, explanation or prediction of weather phenomena. The rest of messages (20.9%) contained questions only. It is not surprising to see a high percentage of description messages (80.4%) compared to explanation (17.1%) or prediction (2.4%) messages because the program specifically asked students to describe their local weather condition as a part of an activity in the earlier stage (Introduce Yourself activity), which majority of the participants carried out(see Figure 1). Furthermore, while students authored 93.6% of the description messages (277 out of 296 description messages), scientists authored 66.7 % of the explanation messages (42 out of 63 explanation messages). This implies that students were more actively and frequently involved in formulating descriptions while they could observe how scientists formulated explanations.

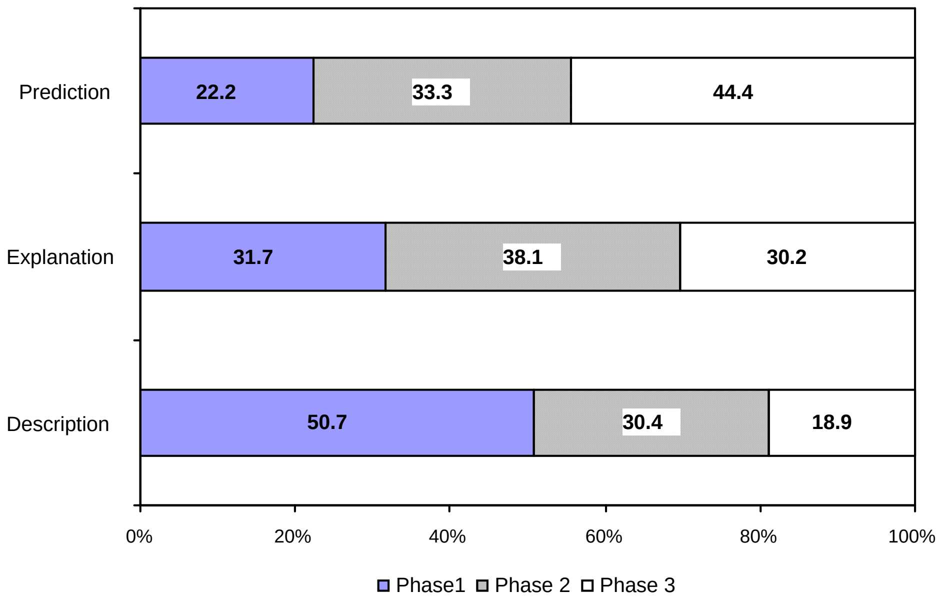


Figure 1. Percentages of messages posted in each Phase by Message Type (Description (n = 296), Explanation (n = 63), and Prediction (n = 9))

In addition, it is worthwhile to note that the percent of explanation and prediction messages increased over time. Whereas 50.7% of the total description messages (n = 296) were posted in the earlier phase, 68.3% and 77.7% of the explanation messages (n = 63) and the prediction messages (n = 9) were posted in the later phases (Phases 2 and 3). More detailed discussion on description, explanation, and prediction messages follows below.

First, the description messages contained a general description of weather condition in students' own local area. The level of sophistication of the descriptions varied among student groups. Some messages described weather in a general level such as "It is hot and humid in summer and cold and windy in winter" without providing any organized or summarized evidences; rather these evidences seemed to be implicitly based on their personal experiences only. On the other hand, some other messages provided more detailed description of local weather condition including several scientific evidences such as "Houston is usually extremely hot and very humid. But today we have a cold front nearing. Today we are also having a beautiful day. We have wispy cirrus clouds. This is a huge change because lately we have had stratus & altostratus clouds bringing us cold and rainy weather." This group of students used scientific evidence, i.e., having a cold front and cirrus cloud not stratus nor altostratus cloud, to describe pleasant summer-like weather in Houston area. It could be speculated that teacher's belief about science and technology, teacher's experience with the program, type and frequency of teacher scaffolding along with individual student's prior understanding of science and technology could be account for different levels of sophistication of student messages (Estrada & Grady, 2011).

Second, the explanation messages are addressed as follow. As described above, students were able to develop more sophisticated descriptions over time. Moreover, sophisticated descriptions could evolve to explanations which contained reasons for the description. For example, the following messages were all from the same classroom. The earlier messages merely described a weather pattern in their local area, but later of the program, students began to include evidence for specific conditions (i.e., wind from the north instead of the south, and temperature never drops below freezing in winter). Overall, the percentage of explanations for weather conditions increased over time (11.6% in Phase 1 to 20.5% in Phase 2 to 24.1% in Phase 3).

> Posted by Francesca Middle School posted on February 3
> Our weather in Houston is normally hot and humid, but lately it has been cold and dry
>
> Posted by Francesca Middle School posted on February 6
> Snow and cold weather sounds great because we are from Houston, Texas where it is usually very hot and humid. Yet lately it has been pretty cold.

> Posted by Francesca Middle School posted on March 5
> Today we have 28% humidity which is very unusual considering the humidity that Houston usually has. The cause of the low humidity is because today we received winds from the north instead of the south.
>
> Posted by Francesca Middle School posted on March 6
> Well we get some pretty rainy not snowy weather in Houston too, especially in the winter. This is because during the winter our temperature never drops below freezing.

More than a half of the explanations of science concepts were posted by on-line scientists (66.7%) as a response to students' questions about science concepts, principles or phenomena. On the other hand, students' explanations for a scientific concept (e.g., how clouds forms or why hurricanes can not be developed over the land) were less frequently observed on the Message Board. This is mainly because the Message Board and activity structure did not ask for students' explanations for a scientific concept or principle. The main purpose of the Message Board was to gather and share information. Rather, formulating an explanation of a scientific concept usually happened in a classroom while students were answering Curriculum Questions using their experiences through hands-on experiments, real-time data investigation on the program specific web-browser, library and the Internet research, and information exchanged on the Message Board. It implies that generating explanations beyond descriptions on the Message Board does not happen automatically; students need more scaffolding from teachers, scientists or curriculum to do so.

Third, the prediction messages were not observed as much as we hoped (2.5% of the scientifically oriented messages). The reason for a small percentage of prediction messages might be because 1) this was the one of the later activities in the program and many schools were not able to finish the program in time, and 2) prediction activity was not well structured at the time of this study. After this run, the prediction activity was revised to provide more scaffolding through activity itself and technological features. The result of this change showed that students were able to make more and better predictions under new condition.

In addition, it seemed that students in early middle school ages have not yet developed understanding of prediction. Many students used the word "prediction" in their message but their message was often a mere statement of observation rather than prediction, such as "Are you guys having a rain? We saw precipitation on the software. Write back and tell me if our prediction is right!" It illustrates that students first need to understand what the prediction is in a science community and how prediction is difference from description and observation from more examples of both good and bad predictions (Lee, S., 2000). Partly, due to a lack of understanding of what prediction is in science, even when students made a prediction, they rarely included evidence for their prediction nor made explicit relation between evidence and prediction.

Studying a real-time weather provides a unique learning opportunity including making a prediction of real weather condition, which does not have a known answer. A scientific prediction requires evidence to support the prediction. It demands a high level of inquiry skill which students have not had much chance to develop in a traditional classroom. In a traditional science classroom, students are often asked questions of which answer is already known. This case clearly illustrates that technology (such as real-time data access) presents a great promise to provide a new learning opportunity that was not possible before. However, often students (and teachers as well) have not had an experience of practicing this kinds of new inquiry so that this implies that students need more scaffolding such as modeling when they exposed unfamiliar inquiry.

Overall, students' formulated descriptions, explanations, and predictions after summarizing evidence were observed on the Message Board. However, the extent to which students summarized evidence for descriptions, explanations, and predictions varied. In addition, students were able to make a better use of evidence over time when they formulate descriptions and explanations (the total number of predictions was too small to illustrate a pattern overtime). This may partly attribute to guided-inquiry process from teachers and scientists, examples of other students' messages, repeated practice, and developed understanding of scientific concepts which often contributed as an evidence.

## Do learners communicate and justify explanations?

By its nature of the Message Board, all students' inquiry on the Message Board was mediated by written communication. However, the communication inquiry skill that featured in the Inquiry of the National Science Standards specifically concerns how well students communicate scientific procedures and findings, and justify their explanations. There were multiple occasions that students specifically discussed procedures of their observation and data collection.

Weather Specialists, on-line scientists on the Message Board, often guided scientific communication of procedures and explanations by prompting or requesting clarification.

> Posted by Ken from Magnolia School posted on January 29
> Dear Wind Group, I live in Guam. So far I have just started to measure wind speed. I measure in front of the Magnolia School every morning.
>
> Posted by Weather specialist posted on January 29
> Good job, Ken. Consistent weather observation is very important. Tell us about the equipment you use and what information you record when you make your wind observation.
>
> Posted by Ken from Magnolia school posted on February 2

> I use the Beaufort scale and winds are usually a light or gentle breeze. Right now it's the beginning of trade wind season.

As observed in the above example, instead of giving an answer, a Weather Specialist encouraged students to do their own thinking and research first. Lederman and his colleagues argue that students' inquiring or understanding about inquiry as a nature of science is as important as doing inquiry (Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001). Discussions on the Message Board were able to provide students with opportunities to understand the nature of science and scientific inquiry through communication. As students discussed current weather events, they encountered uncertainty and complexity of information and data they observed.

On the Message Board, students were not asked to "form reasonable and logical argument to communicate explanations" as in variation 1 of the fifth inquiry feature "Learner communicates and justifies explanations" in Table 2. Nevertheless, students were able to develop understanding of scientific communication that was guided by scientists in the importance and scientific procedures or understanding of nature of science and scientific inquiry.

## Conclusions and Recommendations

Our research extends the work began through the study of on-line communication tools by others. At the same time, Message Board has its own unique features which were designed to specifically support inquiry learning of real-time science using the Internet. As a result, some of our results confirm and share findings of previous studies in the field of online communications (e.g., Guzdial, & Turns, 2000; Hsi & Hoadley, 1997) while contributing unique understandings to the field of classroom inquiry. For example, we also found that students' active participation in the electronic discussion (Hsi & Hoadley, 1997) and benefits of having scientists in the electronic discussion (O'Neill & Gomez, 1998). However, our study was also able to add several new insights. Our study could show that students' active participation in the electronic discussion is still true with a large number of diverse participants beyond one classroom setting as found in Hsi and Hoadley (1997)'s study. O'Neill & Gomez (1998) reported that a lack of expectation and experience of telementoring made scientists' participation less productive. However, we found that certain program structures, such as initial training package for scientists, coordinated time-line for ensuring commitment, and specific tasks for on-line scientists could make scientists' participation productive.

Guzdial and Turns (2000) argued the importance of anchors in facilitating effective discussion. In our program, activity structures (such as specific Curriculum Questions on the worksheet) and special live events of weather condition (such as tornadoes or hurricanes) could be considered as an anchor for a discussion. We observed more sustained discussions occurred around structured activities or interesting events. Building upon our findings and Guzdial and Turn (2000)'s findings, future Message Board could be incorporated with other program features such as the program specific web-browser to facilitate more meaningful anchors. For example, when students observe an unusual weather condition on the web-browser, this incidence can serve as an anchor for a discussion and directly link to the Message Board. At the same time, the Message Board that could be enhanced by advancing technology will be able to support multimedia resources (e.g., graphics, animations, URLs), so that scientists can more effectively explain difficult weather concepts.

NRC (2000) presented the five features of inquiry and each feature's variations in terms of amount of learner self-direction or amount of direction from teacher or materials (Estrada & Grady, 2011). Full inquiry refers to follow all five features of inquiry. However, as Settlage (2003) argued full inquiry may not be an appropriate model of science teaching in a classroom because of many constraints of schools including lack of teacher's understanding of content as well as inquiry, short class periods to do any extended inquiry meaningfully (45 minute), students' limited understanding of content and inquiry.

Thus it is more realistic to design a classroom learning environment that support partial inquiry at a time and help students built on what they have learned previously by interacting with different resources and tools. The Message Board was not designed to promote all five inquiry features. Rather we focused three inquiry features that most suitable to be developed through the Message Board participation. Multiple iterations and revisits of different level in different content areas are needed to develop full inquiry over time.

In addition, we should not expect for students to do the most independent inquiry from the beginning. Students would need more amount of direction or scaffolding from teachers, curriculum materials, and most of all from on-line scientists and gradually gain more amount of learner self-direction over time. Students need guidance in appropriate level. Teachers' and scientist's modeling of inquiry is critical (MaKinster, Barab, Harwood, & Andersen, 2006). Technology such as Internet provide unique learning opportunities that when carefully designed can foster inquiry learning such as opportunities to study real-time natural phenomena, collaborate with scientists, and understand science as a way of communication. We hope this study can serve as a starting point of research into understanding classroom inquiry in a technology-rich learning environment.

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