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Promoting Scientific Understanding Through Electronic Discourse

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Abstract

In this article we explore electronic discourse on a web-based discussion tool. We argue that despite many of the limitations expressed by others for web-based tools to promote learning, when these tools are enacted in classrooms as a part of a comprehensive, systemic reform program they can work effectively to address some of the challenges of traditional classroom discourse and discussions. We begin by examining the discourse patterns among electronic learners who participated in the collaborative, Internet-enhanced, middle-school weather project called Kids as Global Scientists. Specifically, we aim to identify 1) characteristics of electronic discourse in K-12 educational settings, and 2) how electronic discourse is similar to or different from traditional classroom discourse. Our findings support the premise that in systemic programs, electronic discourse can provide multiple avenues for establishing and sustaining productive collaborations for learning including greater opportunities for students' customization and ownership of knowledge than often found in traditional classroom dialogue.

Introduction

Can the World-Wide-Web be a productive learning tool for distributed learners? If so, what features of the tool need to be capitalized on, and how? These are some of the questions which guided our exploration into the role of a World-Wide-Web message board system, as a part of a comprehensive inquiry-focused middle school science program, in fostering students' understandings in science and in developing productive learning relationships with others. Current research by Roschelle and Pea (1999) and Wallace and Kupperman (1998?) states that despite the current enthusiasm for using the World-Wide-Web as a learning tool in classrooms, most current uses of web-based tools do not allow learners to find information effectively, form collaborative teams or to share work products towards the social construction of knowledge. Our work suggests that one reason why many previous web-based tools were not utilized effectively was because they were implemented as an individual resource, such as using the web as an enhanced super library system. In contrast, careful implementation of web tools as a part of a systemic curricular reform project where software, curricula, and the roles of teachers, students and information are synergistically modified allows each component to be best adapted to work with and off of each other. In a systemic change approach the role of each contributor, including the web-based message board, is crafted to best take advantage of the unique learning opportunities afforded with that component. Focusing our research on the role of the message board within our larger learning environment system allows us to ask, along with Roschelle and Pea (1999), What are some of the emergent properties of web-based message boards and the distributed learning communities that are fostered with such tools, and how can we capture the value of these?

From a sociocultural perspective, learning is the result of participation in communities. Participation involves practicing the community's norms and is mediated by symbolic systems such as discourse (i.e. Lave and Wenger, 1991; Rogoff, 1990; Vygotsky, 1978; Wertsch and Toma, 1995). The study of discourse as a mediating symbolic system is one mechanism for understanding learning related to participation and practice.

Many researchers have conceptualized scientific literacy as the appropriation of scientific discourse (Anderson and Palincsar, 1997; Gee, 1988; Latour and Woolgar 1986; Rosebery, Warren, and Conant, 1992). Some researchers regard learning science as, in part, communicating with others using socially shared language, in other words learning how to "talk science" (Lemke, 1990). Rosebery et al. (1992) state

> [this] view of science as a discourse helps us to see scientific literacy not as the acquisition of specific facts and procedures or even as the refinement of a mental model, but as a socially and culturally produced way of thinking and knowing, with its own ways of talking, reasoning, and acting; its own norms, beliefs, and values; its own institutions; its shared history; and even its shared mythologies. (Rosebery et al. 1992, p 65).

Examples of discourse norms common in traditional science include arguing, questioning, describing, and critiquing.

A contrasting view to this social view of scientific literacy is canonical scientific literacy which puts emphases on content knowledge and skill acquisition and is supported in science education reform documents (i. e. AAAS, 1993; National Research Council, 1996). Recognizing science learning as socially constructed and mediated by systems such as discourse allows researchers to 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, and metacognition and beliefs, among others.

The Study of Discourse

Traditionally, researchers such as Mehan(1979) have 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. Several recent studies have identified problems with traditional classroom patterns, such as the silencing of certain populations of students, and have proposed alternative discourse structures to solve these problems (Green, 1983; Hicks, 1996; Lemke, 1990; Mehan, 1979).

In this paper, we present a study that examines electronic discourse on a web-based discussion tool which is part of a comprehensive, inquiry-focused curricular program. We argue that despite many of the limitations expressed by Roschelle and Pea (1999) for many existing web-based tools' ability to promote learning, when a part of a systematic reform program, web-based discussion tools may provide new opportunities to work with some of the problems of traditional classroom discussions in fostering students' knowledge development. We begin by examining the discourse patterns among the electronic community of learners who participated in the collaborative, Internet-enhanced, middle-school inquiry science project called Kids as Global Scientists. Specifically, we aim to identify 1) characteristics of electronic discourse in 4-9th grade settings, and 2) how electronic discourse is similar to or different from traditional classroom discourse. Then, we provide data and analysis to support how electronic discourse can support and sustain productive dialogue towards the development of scientific knowledge as well as students' customization and ownership of learning.

Methods

The Kids as Global Scientists Program

The Kids as Global Scientists (KGS) project is an inquiry-focused Internet-enhanced atmospheric science program for middle school students. Based on the learning approaches of distributed expertise (Brown, Ash, Rutherford, Nakagawa, Gordon & Campione, 1993) and socially mediated cognition (i.e. Lave & Wenger, 1991; Pea, 1993; 1994; Vygotsky, 1978), the program is a Internet-rich curricular program which works to best take advantage of the technological tools' ability to foster social cognition and rich knowledge development in science. The KGS program was first developed in 1992. Since that time, our curricular activities, software tools and professional development supports have gone through many cycles of research-focused trial and refinement leading to our current program which is utilized by thousands of students, teachers and scientists with each iteration (see Songer, 1996; 1998; 1999 for previous research).

In the KGS program, student and teacher participants engage in scientific investigations and take advantage of one powerful feature of Internet tools: current data.

During the eight-week period, students and teachers follow a series of flexible, inquiry-focused curricular activities (Songer et al, 1997 Kids as Global Scientists: Weather!: An Eight-Week Inquiry Curriculum for Middle School Atmospheric Science) to study several national science standards including standard A: scientific inquiry, standard D: earth systems, and standard G: science as a human endeavor (National Research Council, 1996). Their study occurs through such activities as collecting and analyzing weather data, conducting hands-on experiments, and making predictions using the same real-time weather data that meteorologists use. Weather data is presented to students in real-time and in a variety of representations using Directorä -created Internet-smart CD-ROM software of our own design (Samson et al., 1999). is Following a modified distributed-expertise approach, students 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.

The project activities were also designed to encourage participants to take advantage of a second 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 exchange activities including sharing of two weeks of data and information, sharing and critique of others' explanations and summaries of weather phenomena, making predictions about others' weather tomorrow, and sending and responding to weather questions posed by our Weather Specialists, peers or teachers in other locations who are simultaneously enacting the same set of KGS activities. In this approach the program works to guide teachers and students in distributed locations as they learn to use each other as resources for weather information, interpretations, first-hand accounts, and professional development tips.

KGS Message Board

The KGS Message Board was designed to work within the KGS learning environment to support knowledge development among a socially-constructed, geographically-dispersed group. Like the overall design of the KGS program itself, in designing the Message Board we aimed to support inquiry, draw on distributed-expertise approaches (i.e. Brown et al, 1993) and social construction of knowledge theories (i.e. Lave & Wenger, 1991; Pea, 1993; 1994). We strove to build a learning environment where individual experience and understanding was recognized and shared by other members (Songer, 1996; 1999).

In our design, we looked first at how we could define and understand the role of the Message Board towards fostering "inquiry". We designed our learning environment so that it would use both the real-time data and communication features of the technology tools to support inquiry. For example, in the KGS program students processed various weather data by comparing, contrasting, and classifying the data. Students could use data tables and graphs to compare and contrast different sets of data. With the addition of the KGS Message Board, students could send messages to a comparison school and discuss their interpretations of the weather at the remote location with the target school. In this way, the KGS Message Board provided an additional medium besides tables or graphs to support the interpretation of scientific data as a part of scientific inquiry. Finally, students synthesized the data by generating patterns, predicting tomorrow's weather conditions, and applying their understanding to real world situations. Students sent messages containing their prediction for the next day's weather for a certain school, and the corresponding school responded with the actual weather on the following day.

A second goal of the message board was to provide a resource for dynamic scaffolding among student and teacher participants. By dynamic scaffolding we meant the ability to post and respond individually to questions on current topics. We recognized early on that generating authentic discussions on current atmospheric science phenomena was one possible outcome that could be facilitated by the KGS Message Board. "Authentic" questions in our program can be described as questions dealing with both real and near-time data and information, as well as questions relevant to the first-hand experiences of other participants (Songer, 1998). Dynamic scaffolding has not been well supported by other electronic tools such as email or group conferencing software (i.e. Harasim, 1990; Riel & Levin, 1990; Scardamalia & Bereiter, 1991). We hoped to investigate whether the features of the message board tool, combined with the accompanying supports, could lead to productive use of information resources such as individuals and real-time information.

The result of our designs was the current version of our KGS message board which allows users to post and read messages, and respond to other messages. As shown in Figure 1, the messages are displayed by threads on each topic, so it help users to see the flow of discussion (see Figure 1).

Participants and Learning Environments

The KGS program has recently grown significantly in numbers and currently includes approximately 80 schools from five continents involving over 4,000 students. Participants were from diverse settings including homeschools, rural schools, large urban schools, special needs classrooms, and private schools. Although the target audience was middle school students, our enrollment included 4^{th}-9^{th}grades. On the message board, participants were divided into seven message board sub-groups by age, with each sub-group containing 8-10 schools. A graduate student was assigned to each sub-group to screen for inappropriate messages and to offer support to participants. During the eight weeks of this program approximately 5,000 messages were exchanged. Participants in KGS never met each other, although photos of participants were distributed through a photo essay CD-ROM. KGS participants' social interactions were entirely created and sustained via electronic discourse.

Data Analysis

This section outlines analysis decisions made concerning the unit of analysis, the levels of analysis performed on various messages, the protocols utilized, and the types and numbers of electronic messages coded by each protocol.

Determining unit of analysis. The primary unit of analysis was a message containing from one to several sentences. Each message in a thread of discussion was considered as a turn at talk as in traditional classroom discourse (Cazden, 1988; Mehan, 1978). We chose to consider each message rather than each sentence or each thread as one unit of analysis so that we could most easily characterize discourse structures in classrooms relative to discourse structures within electronic dialogues.

Levels of analysis and protocols utilized. In analyzing electronic messages we looked for protocols which were well suited to our data source. In reviewing electronic messages, we noticed that electronic messages had some features similar to traditional text-based data such as essays or journals, and some features similar to traditional verbal conversations such as interviews, classroom presentations or classroom interactions. Because our data did not fit either type cleanly we found that we could not directly apply previous qualitative data analysis techniques such as the Ethnographic Interview Analysis (Spradley, 1979) or Written Document Analysis for essays or journals (Hodder, 1994). As we shared some theoretical assumptions of several different qualitative analyses approaches, however, we chose to work with two different protocols leading to two levels of analyses which we called Level One and Level Two. Table 1 displays a summary of level one analysis and coding categories utilized (see Table 1). Each of these will be explained more fully in the subsequent sections.

Level One Analysis: Interaction Patterns

Our first consideration was the analysis of the interaction patterns of electronic discourse. Our methodological assumptions resonated with the underlying assumption of Interaction Analysis (Jordan and Henderson, 1995):

> Interaction Analysis finds its basic data for theorizing about knowledge and practice not in traces of cranial activity (e.g. protocol or survey interview data), but in the details of social interactions in time and space and, particularly, in the naturally occurring, everyday interactions among members of communicates of practices (p. 41).

Because we were interested in whether there is any difference in terms of patterns of message exchanges throughout the program and certain activities and because of the congruencies of Interaction Analysis to our needs, we developed the following Interaction Analysis foci for our Level One analysis:

a. Time: When a message was posted relation to the whole period of the program was considered as one focus of the Level One analysis. In particular, we were interested in patterns of the message exchanges in A) Weeks 1-2, when they were asked to introduce themselves, B) Weeks 3-5 when they were collecting local weather data and studying various weather concepts, and C) Weeks 6-8 when students were forecasting their next day's weather by synthesizing their experiences and ideas developed during previous weeks of the program.

b. Type of Activity: In the written curriculum, we suggested activities related to the Message Board specifying an approximate time-line. This coding category provided us insight to how participants used the Message Board. Examples of this coding category called Type of Activity are included in the Appendix.

c. Sender: Participants of the Message Board dialogue included students, teachers, on-line scientists, and graduate students as sub-group moderators. Since the participant rate of teachers and graduate students were relatively small (less than 5 percents), we categorized a sender of each message into 1) Students and 2) Adults.

d. Level of Thread: The Message Board allowed participants to read and respond to other's messages. The patterns of this threaded discussion such as turn-taking became our fourth focus of Level One analysis. Each message was coded regarding the level of thread within a given discussion (i.e. original message, first follow-up message, second follow-up message etc.).

In summary, all of the messages posted during this program run (N= 4,464) were analyzed via Level One analyses. Descriptive statistics provided general patterns of Message Board use during the program including the number of messages posted each phase and the level of discussion threads posted by adults vs. students.

Level Two Analysis: Learning Patterns

After initial categorization of messages by Level One analysis, we searched for a qualitative methodology that would facilitate a look at the characterization of electronic messages leading to results focusing on learning. We hoped to find a general protocol that would allow us to systematically distill large amounts of qualitative data into recognizable and reproducible patterns so that we could most easily characterize the kinds of resources and information which were contributing to students' developing understandings. We also wished to look for similarities and differences in interactions between electronic dialogue with classroom dialogue. Because of the match between analyzing verbal protocols for patterns in Chi's (1997) Verbal Analysis methodology and our goals we adapted Chi's multiple levels methodology for our Level Two analysis. Table 2 shows Level Two coding categories we utilized (see Table 2).

We modified the Verbal Analysis protocol (Chi, 1997) into the following steps. First, in order to organize the data and seek patterns among data, frequency bar graphs and taxonomies of categories were created. Numerically quantified data were easily transformed to a graph that helped us to see certain patterns over time or across categories. With a help of current technology[1], messages could be grouped together, categories could be fused or dissociated, or other modifications could be made based on different criteria. For example, we could select messages coded as Type of Question: Situated, then further broke these into groups of questions authored by students and

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[1] Any commercial qualitative analysis packages (e.g. Atlas/ti or NUD*IST) or database applications (e.g. Claris FileMaker Pro or Microsoft Excel) can be used.

questions authored by weather specialists (scientists). As such characterizations were made, we recognized that it was important to keep the context of conversation for this question available. The process between selecting certain messages and seeking themes, then coming back to the original context to confirm the themes was an iterative and cyclic part of our analysis.

After patterns were identified and categorized, we looked to understand the patterns in a broader context, particularly how individual messages contributed to a larger set of interactions and conversation. In this step we looked at the whole context where the interaction occurred to fully understand and confirm the pattern and the possible sequence or relations between patterns.

Because of the in-depth nature of coding, Level Two analysis was performed on all the messages from one sub-group of schools (Subgroup 3) for a total of 687 messages. We chose Subgroup 3 as their messages appeared representative of the larger group of schools and participants. In the following sections, we will discuss why we chose the three categories explored in the Level Two analysis: Socialization, General vs. Customized Weather Information, and Type of Question.

Socialization. The presence and influence of socialization as one component of the development of meaningful understandings in science is a topic of continued exploration in our project (Songer, 1998). In these data we wished to analyze the presence of social talk as one means of tracking this aspect of the social construction of knowledge and possible connections to knowledge development over the eight-week program. We also questioned whether the use of the Message Board as a means of "socialization" seemed to be an apparent difference of electronic discourse versus classroom discourse. The socialization coding categories and examples are found in Appendix.

General vs. Customized Weather Information. The KGS program provides students with current weather imagery in age-appropriate, interactive forms (Samson et al., 1999). In this study we were interested in how students utilized and discussed the current information resources provided by the Internet-smart CD-ROM. The opportunity to discuss current weather events such as tornadoes or severe storms as they are occurring can be a great conduit for productive dialogue and the questioning of simplistic understandings of science concepts (Songer, 1998, 1999). In addition, Internet-smart CD-ROMS can provide students with relevant information and first hand knowledge. In contrast current research states that middle school textbooks do not provide information on real-time or regionally-occurring weather phenomena and don't meet the AAAS criteria necessary to be categorized as a satisfactory resource, including providing students with relevant phenomena, first-hand experiences with phenomena, and a meaningful introduction to concepts (AAAS study, 1999). The coding categories focusing on patterns in dialogue related to general vs. customized weather information is presented in Appendix.

Type of Question. Preliminary Level One analysis, particularly the level of thread category, suggested that the lack of IRE turn taking patterns in electronic discourse seemed to be related to the type of questions asked on the Message Board. This hypothesis was tested through the addition of an analysis focusing on the type of question posed by participants (see Appendix for coding categories and examples). We were also interested to see if the types of questions asked varied with either activity type or experience with the inquiry-focused activities. (see Theme 1 under Discussion section for more details).

In summary we worked with a data set which contained some similarities to verbal data and some similarities to text. As a result, we chose and modified analysis protocols which were suited to our data and analysis goals. Our data were coded on two levels of analysis appropriate to these protocols and goals.

Results

Level One: Interaction Patterns

Temporal organization of activity and participation structure. In the Kids as Global Scientists program, students generated messages throughout all three phases of the eight week program, but the highest percentage of messages occurred in the earlier weeks (50.38 % in weeks 1-2, 30.60% in weeks 3-5, and 19.02% on weeks 6-8). The primary uses of the Message Board were the Introductory activity (weeks 1 and 2) and the Real-Time Data activity (weeks 3-5). The introductory activity was designed to help participants know each other prior to exchanging and critiquing each others' scientific artifacts.

As predicted, several messages were original postings, and many others were messages posted in response to another note (i.e. follow-up 1, 2 or 3 messages). Figure 2 shows the percent of messages by level of thread (see Figure 2). Figure 3 illustrates the percentage of messages posted by student and adult authors including teachers and scientists (see Figure 3). Note that while 44% of the total student messages were original messages on a topic thread, only 24% of the total adult-participant messages were original. Building understandings from Level One analysis: Discourse Structures. In traditional classrooms, the prevalent structure of discourse follows the I-R-E sequence (Mehan, 1979). In this sequence, most initiations are generated by teachers who know the answers and students' replies are followed by teacher evaluation (see figure 4). After Level One analysis revealed that students initiated more messages than adults on the message board, we looked to map the discourse structures developing on the message board for a comparison of discourse structures in electronic dialogue to the IRE traditional classroom discourse structures mentioned above (see Figure 4).

Figures 4 illustrates the discourse structure and patterns observed in the mapping of KGS Message Board messages (see Figure 4). Note in Figure 4 that unlike traditional discourse, KGS Message Board discourse most often replaced the evaluation component of IRE with a second reply or new initiations rather than evaluations of earlier messages. This occurred, in part, because much of the material being discussed was current weather data or patterns that did not have definitive right answers (see Figure 4). As a result many of the participants, including the scientists at times, did not know the answers to students' questions about real-time phenomena. In observing our Level One analysis we believe that electronic discourse can more easily be characterized as a two-part sequential structure like an everyday conversation between two or more parties.

In summary, Level One analysis illustrates that a majority of messages occurred during the earlier phases of the program and, unlike traditional classroom discourse, were initiated by students. Analysis of discourse structures reveals patterns more similar to conversations than traditional classroom discourse.

Level Two: Learning Patterns

Social vs. non-social content. Socialization among participants through electronic communication was observed in all phases of the program. In general, about half of the total messages posted on the Message Board contained some social content as well as scientific information, such as students' descriptions of their school or hobbies. As shown in Figure 5, even though the percentage of messages that included social content decreased over the duration of the program, throughout the eight weeks participants often still included personal notes with their data and explanations and demonstrated interest in the lives of the individuals with whom they had developed electronic correspondences (see Figure 5).

Customized weather information. KGS provided real-time weather information through both KGS CD-ROM and the Message Board discussion. Content analysis of messages revealed that 62.4% of the messages that contained weather-related information discussed real-time, current weather information, whereas 30.1 % of those messages discussed more traditional weather information like that found in textbooks. This result illustrates that the majority of the content-focused dialogue on the Message Board discussed current and regionally specific weather information rather than general information. We speculate that discussing regionally and temporally customized information allows students' to expand their understandings beyond general textbook oriented definitions. We will discuss additional implications of the potential of customized weather information in student learning in the following section.

Type of question. We speculate that Message Board communication can illustrate aspects of students' inquiry processes during their participation in the KGS project. To explore this issue, questions on the Message Board were coded based on the question author and type of question. Table 3 illustrates the percentage of questions in each category by students and adults (see Table 3). Note that 91.1% of all questions (N=214) were generated by students.

In summary, Level Two analysis investigated students' learning patterns by analyzing the content and character of messages. The results of Level Two analysis illustrate that the KGS Message Board provided students with a forum for initiating more of their own discussions, applying general weather concepts to practical and meaningful first-hand contexts, and a range of questioning approaches.

Discussion

The Level One and Level Two analyses focused on identifying preliminary patterns in electronic discourse, the characteristics of electronic discourse which may contribute to students' knowledge development, and the similarities and differences between traditional and electronic discussion patterns. Combining the results from both Level One and Level Two led to three research-supported conjectures, each of which will be discussed and illustrated with characteristic message examples drawn from Level Two analysis.

Conjectures:

- On the KGS Message Board, more student-student communications occurred compared to a traditional teacher-dominant classroom conversation.
- Scaffolding by scientists on the message board provided learning opportunities that could be customized to individual learner's needs.
- Students' sharing of personal experiences and scientific knowledge on the KGS message board fostered an environment for sustained and productive collaboration for science learning.

Theme 1. On the KGS Message Board, more student-student communications occurred compared to a traditional teacher-dominant classroom conversation.

Students were active in Message Board discussions. In traditional classrooms, most whole-class discourse is led and dominated by a teacher or a small number of students. The teacher asks questions or explains ideas and a majority of students demonstrate only passive participation such as providing short, yes/no answers or even a nod. According to Bellack (1966), most talk was initiated by teachers and in Mehan (1979), 81.1% of total discourse was teacher initiated.

In contrast, on the KGS Message Board students initiated a strong majority (82.8%) of the total messages. In addition, 91.1 % of the original messages containing questions were authored by students. While students started threads of discussion and responded to other messages, the scientists and the other adults more often responded to students' messages rather than initiating a new thread of conversation.

<u>Students had high levels of interaction with real audiences.</u> Because KGS participants developed relationships with others through their electronic introductions and subsequent correspondence, students recognized the value of writing for real audiences and generated a majority of the follow-up messages produced. While 60% of the total messages were follow-up messages, 91% of these follow up responses were composed by students. Unlike typical classroom writing tasks that seldom involve an audience besides the teacher, Message Board messages were composed in response to dialogue from others within or outside their own classroom, and were composed for peers, scientists and other real audiences outside classroom walls. Research by Cohen and Riel among others (i.e. Cohen and Riel, 1989; Redd-Boyd and Slater, 1989) demonstrate that writing for real audiences increases the quality of writing products.

The threaded function of the Message Board also allowed participants to take advantage of some of the inquiry-related benefits of shared cognition. Because the messages were being read by other participants who then replied to the messages, authors had to be careful about the composition of their messages. Through the reading and commenting on others' suggestions, students were encouraged to rethink and revise their original messages. The group construction of ideas through a series of threaded messages helped students to realize that they did not need to know everything and that they could seek a greater range of ideas from more knowledgeable others.

Student-to-student scaffolding was observed. In the KGS message board dialogue, many questions were difficult for classroom teachers to address because they focused on more challenging and less predictable current events in which answers were often not determined. Perhaps as a result of the type of knowledge the Message Board dialogue focused on, the types of questions groups of learners asked varied from classroom norms.

While other studies show that the most prevalent type of questions asked in classrooms are "text-based questions" which ask for simple definitions from teachers (Scardamalia and Bereiter, 1992), the most frequently asked Message Board question type was the "data gathering/collecting questions (64.0%)" asked to fellow students. This difference illustrates the point that KGS students exploited each other's experience and knowledge more often than in most traditional classrooms where the teacher or textbooks can be the most common content resource. Also interesting was the type of questions asked by scientists. 47.4% of questions posed by scientists were real-time situated questions which are rarely found in a textbook.

Collectively, these results support the premise that traditional teacher-dominant discussion patterns were not observed on the Message Board. Rather, KGS students participated in the Message Board discussion more actively and interactively than students might in traditional classroom discussions. These results imply that KGS students, as higher-agents, are more active in their knowledge construction (Scardamalia & Bereiter, 1991). The students were not passive but took control over their own learning process through raising questions and pursuing their own inquiry.

Theme 2. Scaffolding by scientists on the message board provided learning opportunities that could be customized to individual learner's needs.

Regional customization. Many dramatic natural weather phenomena such as flooding, blizzards or unusual winds (such as Chinooks) happen in fairly contained local regions, caused by many factors including geography, microclimates, and the unusual combinations of natural events. Most middle school science textbooks provide little or no information about local weather patterns, rather they describe weather one more general level. In addition to these benefits, studying regionally-specific weather phenomena in real-time adds an additional layer of difficulty in that both these data and [2]their interpretations must be available in real or near time support students and teachers' abilities to track, predict, and explain the local event. The KGS Message Board was developed to serve as this customized resource through daily science updates each morning and continuous asynchronous dialogue with Weather Specialists. Example[2] 1 illustrates one instance of this.

[2] All participants' names used in this paper are pseudonyms. The underlines were added to illustrate each theme.o

Posted by SFE School, TX on March 06
Dear Weather Specialist, In the north we have been experiencing heavy rain. The Ohio River is Flooding and major rivers are flooding down here. We have had rain all week but the weather has finally changed! It is cold and windy. Should we expect more rain because of the rivers ?

*Posted by **Weather Specialist**, on March 10*
Glad to hear you are finally starting to dry out! As for getting more rain because of the rivers, I had always thought that if it rains here in Delaware, the water must have come from a nearby lake. But, as it turns out, most of the rain you get probably started out far away from you, possibly even as ocean water. One way to look at it is to look at a map of the U.S. Notice how small the Ohio river looks at that scale, then remember how big an area it was raining over. Anyway, hope you don't get that much rain again for a while!

Message example 1. Regional customization.

Temporal customization. During our fall program students studied live hurricanes and several tropical cyclones. El Niño was a weather phenomenon that was related to several unusual weather events in 1997-1998 including a very small number of hurricanes in the Atlantic Ocean. While El Niño was a commonly discussed topic in newspapers or on the news, almost no information was available in traditional school resources such as libraries or textbooks. Many students posted questions about El Niño on the Message Board allowing our Weather Specialists an opportunity to temporally customize their content information so that they could best respond to students' needs. Message 2 illustrates this temporal customization.

Posted by T School on October 09.
Q1: Do you think El Niño is really keeping hurricanes from forming in the Gulf of Mexico this fall? Q2: What makes El Nino reverse the direction of the flow of warm water across the Pacific? Q3: Does El Nino mean we may get more snow in Fort Worth this winter? We hope so! :-)

Posted by Hurricane Specialist on October 10.
A1: Definitely! Aug and Sep were the least active peak months of hurricane season since 1944.

A2: The winds pushing the currents reverse direction. The reason for the reversal of wind direction is not well understood, and is the topic of mush research.

A3: It means you will get more precipitation, more than likely--but whether it will be snow or rain, who knows!

Message example 2. Temporal customization.

"Reflective Toss" by Scientists. Van Zee and Minstrell (1997) coined the term "Reflective Toss" as an description of an alternative classroom discourse pattern where teachers give students increased responsibility for their own thinking (1997, p. 225). A reflective toss sequence consists of a student statement, a teacher question, and additional student statements. In contrast to the IRE sequence which concludes with a teacher's evaluation, the reflective toss sequence supports teachers' questioning as a means to foster students thinking rather than evaluate it. The "toss" in reflective toss refers to the teacher "catching" the meaning of a student' statement and "throwing" the responsibility of thinking back to students. (van Zee & Minstrell, 1997, p. 229).

Similar "tossing" of thinking responsibility through KGS were observed on the Message Board. On-line weather specialists often asked students real-time, real-life situated questions. In addition when students asked weather specialists questions, scientists often tossed another question back to students rather than providing the answer. The following message exchange example shows how a weather specialist used a real-time event, heavy fog, as an opportunity to present an authentic learning challenge to students. While the first group of students provided a correct response, they did not include any reasons behind their answer which encouraged the scientist to continue to prompt these students, and others, with additional questions and clues, rather than answers.

> *Posted by **Weather Specialist**, on February 04*
> While you all were sleeping soundly in Houston last night, I was having a tough time with your weather! [My flight] was inbound … and the fog moved in quickly and we couldn't land there! Question: <u>What direction do you think the wind was from when the fog "rolled" in?</u> … Now it's about 4:00 a. m. Central Standard Time and the fog has moved out of the Houston area entirely. The winds are now out of the southwest at about 12 miles per hour.
>
> > *Posted by SFE school, HOUSTON, TX. on February 05*
> > My answer is that <u>the winds came out of the south</u>. I have a question for you: What is the average wind speed in Houston? Would you please reply?
> >
> > > *Posted by **Weather Specialist**, on February 06*
> > > Good answer! Winds from the south and especially the southeast in Houston bring warm, moist air in off the Gulf of Mexico and can cause heavy fog conditions. To answer your question, I'm looking in a book of climatological data. Climatology is the study of weather history. The average wind speed in Houston, Texas is about 8 mph, with the average (or prevailing) direction out of the south-southeast..
> >
> > *Posted by SFE school HOUSTON, TX; on February 06*
> > Hello from the Winds group, sorry Jerry about our weather on flight 101. We don't usually have that much fog. We're guessing<u> the fog rolled in from the north</u>, but then again we're not that smart! How's the weather in central New York? See ya
> >
> > > *Posted by **Weather Specialist**, on February 10*
> > > Hello, the Winds group. Here's a clue to my fog question: <u>Where is the biggest body of water around Houston</u> (I know, too easy, huh?) That's where the fog rolled in from.

<u>Message example 3. "Reflective Toss" by KGS Scientists.</u>

In summary, the participation of scientists in on-going, asynchronous electronic discussion made this discourse different from the traditional classroom discussion in several ways. Scientists were content resources and they provided valuable information that a teacher might not have been able to provide. Furthermore, unlike other content resources such as textbooks or Internet websites, the scientists could provide <u>customized</u>

content resources and information based on each individual learner's need. Many weather phenomena are regionally and temporally specific and most textbooks do not provide enough information to help students or teachers understand these specific phenomena. Also, scientists' questioning and responses could be a model of scientific reasoning and scientific discoursing in its iterative and reflective manner. As students observed the way scientists talk about weather and explain phenomena, they could appropriate scientific reasoning and discoursing as well as gain understandings of scientific content.

Theme 3. Students' sharing of personal experiences and scientific knowledge on the KGS message board fostered an environment for sustained and productive collaborations for science learning.

Early socialization was essential in establishing collaboration. We believe that early social interaction among participants allows individuals who did not have face-to-face contact to establish credibility and identity between themselves so that they could experience productive scientific relationships with other participants. Understanding this need to establish social norms with others prior to knowledge development dialogue (i.e. Cohen and Riel, 1989; Riel and Levin, 1990), we designed our first Message Board activity to focus on establishing productive relationships through focused introductions. We also recognized that encouraging some personalization and social components in their introductions was an essential component in setting up a productive scientific relationship. Message example 4 illustrates one characteristic set of introductions. Through these, participants began to recognize differences among geography and weather as well as form social bonds through the recognition of common or diverse interests and profiles. Note that the questioning about temperatures in Guam was not a teacher-instructed task, but a demonstration of students' genuine interest.

Posted by MB School, Guam on February 17
Hello, My name is Don and my school is very small; it only has ten kids. We are trying to learn as much about the weather as possible. There are only two people in the temp. group. Andy is 12 years old and he enjoys scuba diving, soccer, and video games. Don is 13 years old and I like to play soccer, football, and video games. Usually the temperature is about 83 degrees F.

Posted by GM Middle School, VA on February 20
Hello from Virginia, USA. What is it like to live in Guam? It must be wonderful with the weather and all. Where do you live in Guam? What school do you go to? Got to go. Nice talking to you. Hope to talk to you again.

Posted by MB School, Guam on February 23
This is Don, I live in a small village and it is like a suburb for the island. The weather is not all that good when you live here for a long time, but the best time is right after a typhoon (that is like a hurricane). The weather is too much the same, I mean if you come in the dry season the weather is almost always going to be dry. See, we only have two seasons, the wet and the dry. I go to MB School, which is a very small school. It only has ten students but we are getting one more.

Posted by GM Middle School, VA on February 20:
Hello, my name is David. I go to GM Middle School in Virginia. I'm eleven years old. I like playing video games and playing sports. GM Middle School is a lot bigger than your school; the Middle School has about 400 people. It's colder here. <u>Today it's really warm- 53 degrees. Normally it's in the 30's in the winter. What season is it in Guam? How hot does it get all year? I'd really like to know.</u>

<u>Message example 4. Early socialization in establishing collaboration</u>

Early socialization by sharing diverse experiences was key factors in sustained collaboration. The large number and diversity among KGS participants provided a rich range of scientific resources, including personal experiences, than typically available in one homogenous classroom environment. Participants from various locations brought their personal experiences into the conversation. For example, students in Hawaii and Michigan were surprised by the differences in seasonal temperature fluctuations. For the Michigan student, weather was conceptualized with four seasons. After communicating with Hawaiian students, the Michigan students' conceptions of weather were expanded to include a range of other patterns.

The early social connection established in the first weeks were also a key factor that supported sustained collaborations throughout the program. A related example follows. During the Phase 3 Data Comparison activity, a group of students in Indiana noticed that Guam was the only school with a high temperature of 80 °F in March and inquired about cold weather in Guam. This probe led to a productive exchange of both personal and scientific data which added richness to these students' understanding of weather. This message exchange also shows an example of sustained communications between two groups of students. As they obtained new information, it led them to ask new questions.

Posted by S Elementary School, IN on March 11
HI! We just finished mapping out your temperature, for those 2 weeks in February, that you sent in weather data. While I was doing that I noticed that you were the only school with temperatures in the 80's. Almost all the other schools were in the 30's, including us. <u>What is the coldest it has ever been at your school?</u>

> *Posted by MB School, Guam on March 11*
> Hello, so you mapped our temperature. What do you think about the temperatures we're having? We're close to the equator; that is why we have the temperatures in the 80s all year around. <u>The coldest temperature we have is somewhere in the 60s.</u> Like to hear from you again, Don.

> > *Posted by S Elementary School, IN on March 12*

> Hello, we think your weather is pretty neat. Over the winter, it got to be -15, a few times [in our area]. I think you guys in Guam would really like snow. Do you have tornadoes where you live?
>
> > *Posted by MB School, Guam on March 12*
> > Hello, well if you live here for all your life you would not like the weather here. You asked if we get tornadoes here, well we don't because the island we live on is only 32 miles long but we do get water spouts. Do you know what a water spout is?

Message example 5. Early socialization and sustained collaboration.

The novelty of first-hand experience of dramatic science events. Severe weather such as hurricanes, tornadoes, and flooding were popular topics of discussion among participants. Whenever unusual weather phenomena happened, the participants who were experiencing the phenomena reported their first-hand experience on the Message Board, and these first-hand experiences drew other's attention to the phenomena for further discussion. During this run of our program, severe flash floods occurred in the Houston, Texas area. After students in Houston posted a message regarding their flood, other participants responded to that message showing concern for these students and their situation. In these ways, communications related to severe weather events often prompted in-depth study and conversation, particularly when events affected participants first-hand. We speculate that such conversations also help students understand a version of the nature of science which has science as a matter integrated with, rather than separated from, everyday life.

> *Posted by SFE School, TX on February 12*
> Today in Houston it is pouring rain and there is a flash flood. All of the windows are foggy..

Posted by GM Middle School, VA on February 20
Hi to people from Houston, How's the flood doing? How is everyone in Houston? ….Got to go! Hope to hear from you soon! I'll write back. Bye-Bye!

Posted by GM Middle School, VA on February 20
Hi, How bad is the flood? Is it still flooding there? Tell me about everything.

> *Posted by SFE School, TX on March 03*
> Hi, The flooding wasn't that bad w[h]ere we live. Pasedena got hit by a tornado a few weeks ago. We have had some rain and its been overcast... It was really cool and the weather was pretty good. At night you can see all the stars. Well, write back soon.

Message example 6. First hand experience of dramatic science events.

Through the personal exchange of simple everyday experiences that might be boring or obvious to the authors, individuals provided information which was valuable to others. In addition, through the exchange and appreciation of first-hand scientific experiences students came to appreciate new definitions of the nature of science, including that that science is not only performed by scientists, but involves many activities experienced by everyone everyday.

Participating in science practice through productive exchange of both personal and scientific information. The following incident illustrates that a personal question could lead to a scaffolded dialogue where the scientist prompted students to explore what they knew about types of clouds and associated weather condition in order to guess the scientists' hobby. This example illustrates how a personally-driven conversation can lead to a motivational means of learning content knowledge. The dialogue also served as an instance where scientists could use this electronic communication with students as an opportunity to connect science to the students' everyday life experiences, thereby providing authenticity for students' inquiry.

Posted by GV School, NH on January 29
What's your favorite cloud?

Posted by ***Weather Specialist****, on January 29*
My favorite cloud is the cumulonimbus. Do you know what type of weather is associated with a cumulonimbus cloud? If you do you might be able to figure out what one of my hobbies is. Let me know: 1) What weather is usually found with a cumulonimbus,2) Take a guess at what hobby would be related.

Posted by GV School, NH on February 06
Cumulonimbus clouds are associated with high wind speed and thunder storms. We were guessing that it would be hang gliding or ballooning. We were wondering if you do any of these sports?

Posted by ***Weather Specialist****, on February 07*
Hello Cumulus kids. You sure know your clouds! I have never hang glided or went ballooning, but I am a private pilot (but that isn't the hobby I am talking about :)) Cumulonimbus clouds are usually associated with bad weather, so I don't think to many people would want to hang glide or balloon near them. I'll give you another clue about the hobby I am talking about: Have you ever seen the movie Twister??

Message example 7. Learning content through personal experiences.

The Real-Time Data activity in week seven allowed students to analyze current weather data using our own visualization tool culminating in making inquiry-focused predictions of weather in another classrooms' city. Example 8 shows how electronic discourse encouraged participants to practice scientific inquiry through cycles of prediction-making and observation/evaluation with other community members. Through these communications, students had greater opportunities to go beyond the collection and analysis of scientific data; they had the opportunity to apply the data to their everyday life and to the lives and discussion of others. While the application of scientific data is advocated by the national standards (National Research Council, 1996) and other policy documents, students often have little chance to do this kind of inquiry in traditional classrooms (Songer & Linn, 1991).

Posted by S Elementary School, IN on March 04
Dear H School [in New York], We are the precipitation group at S Elementary. We have just looked at "Blue Skies" and we have predicted that today, <u>Tuesday, March 4, your weather will be cold with light snow.</u> Please let us know if we were right or wrong.

> *Posted by H School, NY on March 12*
> Hi. You were about right in your prediction... <u>it was a bit colder Tuesday than it had been and we had a little bit of snow before school.</u> I wrote this to you before but we were disconnected as it was being sent in
>
> > *Posted by S Elementary School, IN. on March 13*
> > Hi. We received your letter, we're are glad to here from you. We've gotten pretty good at predicting the weather. <u>We think you will have rain within the next 48 hours</u>. Let us know if were right.
> >
> > > *Posted by H School, NY on March 19*
> > > <u>On March 14 we had an Ice Storm and we didn't have any school!!</u>

<u>Message example 8. Participating in science practice</u>.

In summary, building identity as members of an electronic community of science learners , and establishing social connections or “social glue” prior to the productive exchange of content information were key factors in making the KGS electronic discourse more scientifically productive. From the beginning, participants shared the common goals of studying weather phenomena and sharing their understanding and information about themselves with others. The awareness of a sense of community encouraged them to work together and share each other's experiences as valuable resources for developing understanding.

Students often perceive science as a subject that has nothing to do with their everyday lives. They rarely find connections between what they are learning in a science classroom and what they feel and see outside of school. On the KGS Message Board, however, there were many incidents where students’ first-hand experiences were valued by other participants, and scientific data and personal experiences were woven together rather than presented as separated issues. Sharing personal experiences also provided a more meaningful context for student learning. For example, temperature, one component of scientific data, can be understood as just a number on a table in a textbook. But when students talked about temperature in their area, it had meaning to them —e.g. how cold 17 °C really feels.

In addition, the electronic discourse illustrated that KGS participants practiced scientific inquiry which was, in several ways, similar to the way scientists practice inquiry. Students collected their local weather data and compared to other students' data in distant locations. They also used professional data provided by the interactive visualization tool as a resource for developing a broader understanding. Students analyzed the data and looked for patterns, then made weather forecasts based on their understanding. Their weather forecasts were checked with the students residents in that location. In addition, real-time weather phenomena provided students with opportunities to engage in inquiry through dynamic scaffolding with peers and scientists and by asking and researching situated questions.

Conclusions and Implications

Analyses of KGS Message Board communication between students and scientists helped us begin to understand the characteristics of electronic discourse as one example of the scaffolding and collaboration benefits possible when message board tools are utilized as part of a carefully implemented systemic reform program. Organizing our results led to patterns that supported three conjectures characterizing discourse media.

We found that a well-coordinated curriculum program (e.g. careful selection of content and related-resources, appropriate sequence of activities, and classroom-supportive technology) could support the building of a “social glue” and relevant social relationships between participants, even within an eight week program. Specific tasks such as the Introductory activity and the Real-Time prediction-making activities provided participants with opportunities to build and revise socially constructed knowledge.

Our research has also outlined areas where message board tools could better support scaffolded learning. Advanced sorting functions (e.g. sorting messages by date, by senders, or by topics) or automatic prompting systems could better support the organization of the social construction of knowledge by others. Furthermore, as the scale of the electronic community increases, management of the huge volume of messages became a challenge. More research is needed on issues associated with facilitating productive discussions among tens or hundreds of thousands of participants.

In spite of the increasing interest in the use of Internet-based technology in the classroom, research on the effects of these technologies on learning and teaching are still limited. We have just begun to systematically examine the effects of newly emerging technologies on student learning and teaching in middle school settings. This study of electronic discourse, which examined how electronic discourse could support the building of a community of learners and foster student learning, can serve as a starting point to expand understanding in this area.

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Appendix. Data Coding Categories and Examples

Level One Coding Category: Type of Activity

A1 Introductory Messages

- Hi, We're from Canada. This town is surrounded by mountains so therefore we have lots of animals such as: deer, bears, cougars, woodpeckers, ...

A2 Ask Questions to the Weather Specialists

- Could you please send us a list of GOOD web pages/sites having to do with clouds and/or humidity?

A3 Real - Time Data Analysis

- Our weather maps here showed very low barometric pressure in your area. How low was your barometric yesterday (3/6) during your bad weather?

A4 Weather Forecasting

- We think you will have rain within the next 48hours

Level Two Coding Category: Socialization

S0 No Social Content: only science related information

- When do you think your next severe storm will happen again?

S1 Some Social Content: individual interests, hobby or descriptions of a school, etc.

- Elisa's hobby is playing sports (field hockey, soccer, softball & water skiing) and doing things with friends.

Level Two Coding Category: General vs. Customized weather information

WI0 No weather information offered (or question only)

- How’s weather in your area?

WI1 General weather information: Climate or weather pattern

- Our usual weather here is rainy and wet

WI2 Current weather information: real-time,

- It snowed last night, then in the morning it rained so the snow turned into slush

WI3 Both current and general weather information

- We usually have very cold winter, but this year we haven’t had a snow day yet.

Level Two Coding Category: Type of Questions

Inquiry-based Question

Q1 Data gathering/collecting question: asking experience, observation, measurement, and recording data

- Does it snow where you live? What kind of precipitation do you get

Q2 Data processing question: comparing, contrasting, classifying data, and identifying anomalies

- Is it usual that there is no winds 2 weeks in a row at this time of year? or is there always no winds except for some? does the no winds have to do with where you are located on the globe?

Q3 Data synthesizing question: predicting, hypothesizing, generalizing, and applying to the real world

- When do you think your next severe storm will happen again?

Concept-based Question

Q4 Text-based question: asking definition, basic information

- What exactly is pressure?

Q5 Knowledge constructing question: requires explanation of scientific principles, theories

- Why are some clouds white and some are gray?

Q6 Situated Question Real-time/ real-world question

- I know that 3/4 of tornadoes occur in the u.s. Why is that? and why do most tornadoes occur in "Tornado Alley"?