To What Extent Does Classroom Discourse Synergistically Support Electronic Discourse? A Study of the Kids as Global Scientists Message Board

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Introduction

The purpose of this study is to understand the extent to which electronic discourse can be supported by classroom discourse. When 6th grade students participated in an Internet – enhanced science curriculum called *Kids as Global Scientists* (KGS), they studied weather phenomena using real-time data and a web-based discussion tool called Message Board with peers and scientists from all over the world. Yet, the structure of their science class was still similar to a traditional science class where the teacher's instruction played a significant part of the classroom activities. In this learning environment, we were interested in the characteristics of scientific understanding students exhibited on the KGS Message Board (as a form of electronic discourse) which was constructed in a classroom through teacher–student and student–student interactions. Although the product (electronic messages) and process (interaction with people in distant locations) of electronic discourse might be beyond classroom walls, it seemed critical to understand what role classroom discourse plays in the process as well as the product of electronic discourse because electronic discourse is still a part of classroom activity. To answer the research question ***To what extent does classroom discourse synergistically support electronic discourse on the Message Board?*** the following three sub-questions were examined:

1. To what extent could students exhibit their scientific understanding through electronic discourse?
2. What kinds of classroom discourse occurred relative to electronic discourse, and are there any patterns observed over time or between student groups?
3. In what ways does classroom discourse promote or inhibit productive electronic discourse on the Message Board? In other words, what factors might affect the synergistic relationship between classroom and electronic discourse?

A previous study of the KGS Message Board (S-Y. Lee & Songer, 1998a; 1998b) showed that students experienced new learning opportunities through electronic discourse including greater appreciation of first hand experiences, more comprehensive scientific content support from experts, and personalized scaffolding by the experts. At the same time, from our observations in local schools and from messages on the Message Board, we could recognize wide variation in both Message Board use in terms of frequency of use, quality of messages, and teachers' beliefs about use of Message Board in student learning. Whereas some teachers believed students could develop scientific understanding through communication with other members of KGS, the other teachers believed that the Message Board was just a place for socialization and did not have value for science learning per se. This led us to consider the role of the teacher in the use of the Message Board and opportunities of student learning on the Message Board. Unlike many other electronic conference forums utilized by college students in many distance education settings (e.g., Eastmond, 1994; Harasim, 1990; 1993; Hiltz, 1986), the KGS Message Board is used in a classroom with a teacher serving as the guide. This study looked at one classroom closely to document how the Message Board was incorporated with other classroom activities and how and what kinds of classroom activities and discourse influenced the electronic message writing activity and understandings.

In this study, by examining how a web-based discussion tool was used as a part of an Internet-enhanced program, we argue that technology under certain circumstances can provide new opportunities to work with the problems of traditional classroom discussion (e.g., teacher dominated I-R-E discourse pattern), and new learning environments for productive discourse which can help students construct scientific knowledge. We will begin by examining the development of students' understanding exhibited on the Message Board and classroom dialogues that occurred around the Message Board writing activities. Then, we will discuss how classroom discourse can support electronic discourse and how two forms of discourse together foster student scientific understanding.

Literature Review

Scientific Discourse and Scientific Inquiry

Science educators have emphasized the importance of scientific inquiry teaching and learning over text-based acquisition of scientific facts. Despite many variations in the definition of scientific inquiry by different researchers, there is a common belief that students should engage in the process of science activities as real scientists do in their field. Rather than being a single prescribed way of doing science, scientific inquiry is a multifaceted activity as described in the National Science Education Standards (NRC, 1996).

> Inquiry is a multifaceted activity that involves making observations; posing question; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, an prediction; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (NRC, 1996, p. 23)

Many scientific inquiry activities can be practiced by engaging in scientific discourse. Describing observations, generating questions, and formulating explanations using logical evidence all involve scientific discourse. Therefore, students' understanding of scientific inquiry can be manifested in their scientific discourse.

In this study, students were exposed to three specific scientific discourse forms: *description, question,* and *prediction*. Scientists often observe phenomena and *describe* the phenomena to keep a record or analyze their observation and to communicate their observation with others. Scientific inquiry practices often involve generating *questions* and attempts for answering questions. Many of the questions may not have a definitive answer. Rather questions guide scientists to learn what to study or where to look for more information. Thus, asking a good question is a crucial step in scientific inquiry. In addition, scientists often make a *prediction* about their experiments or natural phenomena such as hurricanes or volcanoes. Scientific prediction is however different from guessing because the prediction is made based on evidence (e.g., scientific laws or previously known factors). Thus, school science also should address the key elements of scientific discourse, such as *describing, critiquing,* and *predicting,* in the science classroom. Furthermore, as Lemke (1990) argued students should have opportunities to practice scientific discourse in a meaningful context.

Socio-cultural perspectives on learning theory informs us about the importance of shared knowledge among community members and its shared nature requires communication among participants via various representation systems including verbal or nonverbal dialogue (Hick, 1996; Lave, 1988; 1991; Rogoff, 1990; Vygotsky, 1978).

Based on this epistemological understanding, research has examined conversation and dialogue patterns in the classroom between teacher and students or student-student conversation and recognized crucial problems in the classroom (Cazden, 1988; Edwards & Mercer, 1987; Green, 1983; Heath, 1983; Hicks, 1996; Lemke, 1990; Mehan, 1979). Other studies have proposed innovative discourse practice in classroom and showed promising results (Hogan, Nastasi, & Pressley, 2000; Inagaki, 1981; Palincsar & Brown, 1984; 1989; Palincsar & Herrenkohl, 1999; Roseberry, Warren, & Conant, 1992; Roth, 1996; van Zee & Minstrell, 1997).

In inquiry-oriented learning environments, scientific discourse is a key resource for fostering students' scientific understanding (Hogan & Pressley, 1997). Compared to traditional, text-based learning environments, inquiry-oriented learning environments provide teachers and students with more opportunities to engage in conversational interaction. Hence, scientific discourse can play a more important role in students' learning in inquiry-oriented learning environments than in more traditional classroom where students' talking science is rarely encouraged.

If science learning is not a transmission of facts but the practice of talking and doing science, student understanding of their participation in (classroom) scientific communities should be evaluated through the practice of doing and talking science as well as by traditional assessments such as standard tests of scientific concepts. Teachers should, in consequence, need to become more sensitive to their students' dialogues. Undoubtedly, teachers will need opportunities to better understand how they can better support and investigate students' conversation. By facilitating productive discourse in classroom, perhaps teachers can better foster students' understanding in science and promote equity of gender, language and sociocultural minorities (Ballenger, 1997; Cazden, 1988; Gee, 1990; Heather, 1983; Hsi & Hoadley, 1997). The emphasis on scientific discourse can also foster the development of student understanding of scientific inquiry as well as scientific concepts. Multifaceted scientific inquiry activities can be carried out through scientific discourse including generating descriptions or predictions using logical evidence. Along with the instructional interventions and strategies, new technologies hold promise as vehicles to promote student understanding in science by providing a new medium for discourse (Edelson, Pea, & Gomez, 1996; Guzdial & Turns, 2001; His & Hoadley, 1997; Scardamalia & Bereiter, 1991; 1994; Tabak & Reiser, 1999).

This study will examine electronic discourse as manifested in its textual products. At the same time, classroom discourse will be examined to understand social interaction process situated in a specific learning context, classroom use of the KGS Message Board. However, this study is not intended to compare electronic and classroom discourse directly; rather in focused on intertextual elements in the electronically written texts on the computer and on the oral discourse constructed around the texts. Such intertextuality has been studied in literacy (Kamberelis & Scott, 1992), history (Floriani, 1993), and mathematics (Brilliant-Mills, 1993).

This study thus examines electronic and classroom discourse in an effort to understand how two forms of discourse serve as symbolic mediators of students' learning. Student understanding can be traced via their written text, electronic discourse. However, the written text on the computer is a snapshot product of a student's understanding. Analysis of classroom discourse will provide a complementary picture of process of how the product was constructed. Analysis of classroom discourse will further help us to better understand the situation where the understanding was developed.

Program Overview

Kids as Global Scientists (KGS) is an Internet-enhanced atmospheric science curriculum for middle school students (Songer, 1996; 1998). During the coordinated eight-week period (from February to April), students, teachers, and scientists from all over the world participate in the KGS program to study weather phenomena in a collaborative learning environment.

The original KGS learning approaches were largely influenced by (1) contructivist inquiry learning, including greater student control and ownership of knowledge development (Bransford, Brown, & Cocking, 1999; White & Frederiksen, 1998); (2) socially mediated cognition (e.g., Collins, Brown, & Newman, 1989; Lave, 1988; Pea, 1993; 1994; Vygotsky, 1978) where knowledge would be constructed by social collaboration among members of a community; and (3) models of distributed-expertise (Brown, Ash, Rutherford, Nakagawa, Gordon, & Campione, 1993) in which all individuals can contribute and share their own expertise in a social construction of the knowledge process. By taking advantage of unique features of current Internet technology for learning, including access to real-time data (i.e., KGS CD-ROM) and communication among participants (i.e., KGS Message Board), the project utilizes first-hand experiences and learning artifacts from each participant and local weather experts towards the social construction of knowledge development (Songer, 1998).

The program begins with introductions from each participant. Throughout the program participants build on initial introductions through several collaborative exchange activities including the sharing of two weeks of data and information, sharing and critique of others' explanations and summaries of weather phenomena, making predictions about the others' weather for the following day, and sending and responding to weather questions posed by the Weather Specialists, and by peers or teachers in other locations who are simultaneously enacting the same set of KGS activities. In this way the program promotes opportunities for students in many distributed locations to use each other as resources for weather information and interpretation.

KGS CD-ROM

The KGS CD-ROM is a customized web-browser that can retrieve professional real-time weather data and display them in appropriate forms (Samson, Masters, Lacy, Cole, Lee, & Songer, 1999). The real-time weather data are updated hourly. An Internet-smart KGS CD-ROM allows users to view real-time weather data in various forms; from numerical data to text description to basic and overlay weather maps (see Figure 1). As a customized Internet browser, the KGS CD-ROM provides the advantages of Internet use to classrooms and alleviates problems of current Internet technology at the same time (Samson et al., 1999; Songer & Samson, 2000).

KGS Message Board

KGS provides a web-based, threaded discussion tool as a means of communication among participants (students, teachers, and on-line scientists). On the Message Board, participants can post, read, and respond to other messages as well. This allows users to engage in threaded (interconnected and focused) discussions. Messages can be displayed by thread, topic, date, or author (Wu, Lee, Samson, & Songer, 1999; see Figure 2). To facilitate productive collaboration among participants from diverse backgrounds, we grouped similar age students in the same clusters while maintaining a diverse geographical distribution in each cluster. In 1999, participants were divided into 10 clusters each containing 42-79 classes[1]. Two undergraduate students were assigned a cluster to monitor Message Board activities for inappropriate content of messages and to offer support to participants. In addition, four to five on-line scientists (e.g., graduate students in atmospheric science programs, professors, and professional meteorologists) were assigned to each cluster to serve as mentors and help students and teachers develop more accurate scientific understanding.

The KGS Message Board was designed to work within the KGS learning environment to support knowledge development among a socially-constructed, geographically-dispersed group where interactions are mediated via electronic dialogue among students, teachers and scientists (Songer, 1996). In the design of Message Board-related activities, we looked first at how we could define and understand the role of the Message Board toward fostering inquiry. The Message Board learning environment was designed to use both the communication features and the real-time data 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, communication with peers or scientists, 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 by applying their understanding to real world situations. Students sent messages

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[1] The number of students in each class varies from 1 student in a homeschool to 35 students in some urban public schools.

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.

Research Context: Setting

This study took place in a 6th grade science class in a middle school located in a small college town in the Midwest. In general, the students in the school come from diverse ethnic backgrounds (24% African Americans, 28% Asians, and 48% Whites) and socio-economic status.

At the time of the study, the teacher, Ms. Lewis, had been teaching science for five years, and for the past four years she had taught 6th grade earth science and mathematics. This was her second year participating in KGS. In general, we observed the teacher to be very organized and enthusiastic about trying new things. Besides the KGS program, she participated in several other Internet-enhanced science programs including GLOBE project (Global Learning and Observations to Benefit the Environment, http://www.globe.gov/) and MYDL project (Middle Years Digital Library, http://www.hi-ce.org/digitallibrary). She has personally used e-mail extensively for both personal and school-related matters. She was especially interested in earth science and was part of a team who revised a weather unit in her school district curriculum.

The classroom was composed of 9 girls and 16 boys. Ms. Lewis grouped the students based on her continuing observation of who had been working together well for the past four months. Six groups (3-6 students in each group) were established during the KGS study. Partly because Ms. Lewis felt that same gender groups had worked better in previous science units, and partly due to the unbalanced ratio of boys and girls in this class, she grouped boys and girls separately with an exception of Group 2 (two boys plus two girls). Groups 1 and 3 were composed of all girls while Groups 4, 5, and 6 were composed of all boys.

The computer lab was located just across the hall from the science classroom. Fifteen computers were available to students, and an additional computer was connected to a projector for teacher demonstration. Usually, two students worked together on one computer facing the walls. Each pair of students from the same group sat next to each other. All sixteen Macintosh computers (PowerPC 5260/120) were equipped with 14 inch monitors and connected to the Internet using a T1 line. The KGS CD-ROM was installed in all the sixteen computers, and the KGS homepage and Message Board were book-marked (http://www.onesky.umich.edu/) on a web browser, the Netscape.

Since the purpose of the study was to understand what was happening in the classroom while the program was implemented, the first author tried to keep naturalistic approaches while she was observing the class. However, on some occasions, the author discussed future lesson plans with the teacher. For example, at two points, the author recommended a classroom discussion of Message Board messages posted by the students on previous days.

Data Sources and Collection

The school had two-hour block scheduling between science and mathematics. The science class met every Tuesday and Thursday for two class periods[2] each and one class period on Fridays. In total, 29 KGS class periods were observed. The data set for this study includes the followings.

Electronic Messages on the Message Board: A total of 67 messages were composed by the target classroom out of 475 messages in Cluster 3 Message Board. During the program, the first author closely monitored all electronic discussions on Cluster 3 Message Board to which the target class belonged. In addition, the author discussed the contents of messages that the target class composed with the classroom teacher. All electronic messages were stored in a database. Each message record included its own ID, sender's name, posted date and time, topic area, activity name, message types, level of thread, and message body.

Classroom Observation—Video Recording & Field Notes: In the science classroom, one Hi-8 video camera was located at the back of the classroom. A wireless microphone was used to capture the teacher's voice and her interaction with students. In the computer lab, a camera was located at the center of the room to capture the teacher's interaction with each student group. A total of 29 class periods (approximately 1,500 minutes) of the teacher's practice were video-taped. In addition to the audio and video

[2] One class period was 45 minutes.

recordings, field notes were taken every day of observation during the eight-week program. The field-notes were taken to record the name of the activity for the day, type of instructions and duration, type of resources, location where the activity was taken place, and a brief description of classroom activities. At the end of the day, more detailed field notes were developed.

Teacher Interviews: The teacher was interviewed three times throughout the program (before, during and after the program). The interview questions were designed to elicit the teacher's pedagogical beliefs regarding student learning and discussion via the Message Board and classroom communication. In addition to formal recorded interviews, the first author had brief discussions with Ms. Lewis before and/or after each instruction.

Students' Pre- and Post-Questionnaires: All students (n=25) in the Ms. Lewis' classroom were given pre- and post-program questionnaires focusing on (1) their background experience with technology (especially electronic communication-related experiences in the pre-questionnaire, and the Message Board-related experiences in the post-questionnaire); and (2) standardized scientific content knowledge assessment relevant to the KGS program (both multiple choice and open-ended items).

Three Key Event Cycles

Three cycles of Message Board-related activities were identified. Students were asked to 1) describe general weather patterns in their local area (Cycle 1. Introductory Messages); 2) ask questions to help their topic investigation such as which geographical factors influence their local wind (Cycle 2. Curriculum Questions Communication); and 3) make a prediction of weather condition based on their observation of a certain city (Cycle 3. Real-Time Data Activity) on the Message Board. In general, each cycle began in the classroom with teacher's overview and instruction for the activity. Then, the students moved to the computer lab and worked in pairs on the Message Board and the KGS CD-ROM. In addition, the class had whole classroom discussions about the messages they sent on the previous day in Cycle 2 and 3.

Figure 3 shows the main KGS activities for each day including the three cycles and illustrates the dates the class used the Message Board. Grid boxes indicate dates when students posted messages and diagonal boxes indicate classroom instructions and discussions relevant to the adjacent Message Board activities.

Analysis of Electronic Messages

Coding categories for electronic messages were developed to examine the degree of student scientific understanding of on the Message Board. Schwab (1964) addressed the importance of understanding of both the structures by which the scientific disciplines are organized (substantive) and processes in which scientists engage to conduct scientific inquiry (syntactic) in science teaching. National Science Education Standard (NRC, 1996) also presented standards for scientific inquiry and scientific content in teaching, learning, and research of science education. Taking this point of view, two coding categories were developed: Understanding of Scientific Concepts and Understanding of Scientific Inquiry.

Understanding of Scientific Concepts Coding Category

The Understanding of Scientific Concepts coding category concerned the degree of students' understanding of scientific concepts. Revised from Gagne's (1977) hierarchical taxonomy of conceptual learning, four levels of understanding of scientific concepts were identified. Due to there being a limited number of messages in this study, the four levels were re-categorized into a rather simple two-tier coding category, i.e., Minimal vs. Sophisticated Understanding of Scientific Concepts. Table 1 shows reasons for each coding category.

Minimal Understanding of Scientific Concepts referred to messages which showed that scientific understanding was limited to personal experiences or simple perception of facts only, even if concepts are scientifically correct. On the other hand, Sophisticated Understanding of Scientific Concepts referred to messages which showed more elaborated scientific understandings by comparing, contrasting, generalizing from or summarizing existing information, and making a prediction based on reasonable evidence. Table 2 shows examples of messages that include Minimal or Sophisticated understanding in each cycle and reasons for a corresponding code.

Understanding of Scientific Inquiry Coding Category

The Understanding of Scientific Inquiry coding category was developed to examine the extent to which students could exhibit their understanding of scientific inquiry. In this study two understandings of scientific inquiry presented in the National Science Education Standards (NRC, 1996) were particularly relevant:

- Develop descriptions, explanations, predictions, and models using evidence
- Think critically and logically to make the relationships between evidence and explanations

(From Content Standard for Science as Inquiry: Fundamental Abilities Necessary to do Scientific Inquiry for Grades 5-8, p 145)

Similar to the Understanding of Scientific Concepts coding category, a two-tier coding category was developed for Scientific Inquiry: Minimal vs. Sophisticated Understanding of Scientific Inquiry. Possible reasons for each coding category are presented in Table 3.

Minimal Understanding of Scientific Inquiry could mean that either students a) did not know what they were supposed to do (lack of understanding of the instructions for a given task; e.g., some students might not have known they were supposed to generate their own questions in Cycle 2); or b) did not understand how to do what they were asked to do (lack of understanding of a certain type of scientific inquiry; e.g., students might not have known what a prediction is or how to make one in Cycle 3). From the data available in this study, however, it was difficult to differentiate these two causes.

Sophisticated Understanding of Scientific Inquiry referred to messages which showed advanced understanding of scientific inquiry that each task asked for. Table 4 shows examples of messages that include Minimal or Sophisticated Understanding of Scientific Inquiry in each cycle and reasons for a corresponding code.

In contrast to the Understanding of Scientific Concepts coding category, scientific quality of the evidence was not counted here. In other words, we looked for how well students could use “evidence” to support their description, regardless of scientific accuracy of the evidence. For example, in the following example of prediction messages, the relationship between wind and humidity was not scientifically correct. Nevertheless, this message was coded as Sophisticated Understanding of Scientific Inquiry because students formulated a prediction using their own evidence and information.

> **Message posted on 3/26 by Group 3**
> The highest humidity was in Mexico so I would predict that you might have some wind, the lowest was in Canada so I would predict that it might be pretty warm and dry.

The coded messages were grouped by cycle, and differences between Understanding of Scientific Concepts and Scientific Inquiry within each cycle were examined. In addition, the coded messages were compared between student groups to explore patterns of group differences in their understanding on the Message Board.

Analysis of Classroom Discourse

Identifying three major discourse types was guided by previous research on instruction in the classroom (e.g., Bliss, Askew, & Macrae, 1996; Collins, Brown, & Holum, 1991; Davis, 1998; Fleer, 1992; Palincsar, 1986; Tharp & Gallimore, 1988). Based on the degree of cognitive engagement of subsequent students' actions, three levels of teacher scaffolding were coded (see Table 5). Contingency Management is "the means of assisting performance by which rewards and punishments are arranged to follow on behavior, depending on whether or not the behavior is desired" (Tharp & Gallimore, 1988, p. 51- 54). A big difference between Contingency Management and the other two levels of scaffolding (Procedural and Conceptual Scaffolding) is that Contingency Management does not initiate cognitively meaningful behaviors. A teacher's praise for students' progress (e.g., you are doing great) or a simple command to restart a computer (e.g., you need to restart your computer) does not advance students' cognitive understanding of scientific concepts nor help them to advance to the next step of a given task. Procedural Scaffolding helps students move to the next step of a given task. For example, upon receiving Procedural Scaffolding, students are able to proceed to the next question on the worksheet or post a message on the Message Board after they finish composing one. Conceptual Scaffolding is the most advanced means of verbal assistance, which possibly promotes students' understanding of both scientific concepts and inquiry. It often involves instructing, explaining, or modeling of the content and forms of messages. When multiple coding categories were applied the higher level of scaffolding was recorded.

Each visit of the teacher to a group was counted as a unit of the analysis. While some visits were simply to check the progress of students by browsing computer screens or student worksheets (Contingency Management), other visits involved discussions about content and forms of messages with students (Conceptual Scaffolding). In addition, the teacher often provided instructions and explanations regarding what students were supposed to do with a given task or software (Procedural Scaffolding).

Results

General Use of the Message Board in Ms. Lewis' Class

During the KGS '99 program, a total of 4,853 messages were posted. Table 6 summarizes the number of participants and the number of messages in all clusters, Cluster 3, and Ms. Lewis' class, respectively. Whereas the average number of messages posted by each class was on average 9.1 in Cluster 3 (i.e., 400 messages by 44 classes), Ms. Lewis' class contributed 67. This indicates that Ms. Lewis' class was one of the classes that used the Message Board more extensively, compared to other classes.

Out of 67 messages posted by this class, 32 messages (8 messages in Cycle 1, 10 messages in Cycle 2, and 14 messages in Cycle 3a & 3b) were directly related to the three cycles of the Message Board instruction. Besides the three cycles, the class also used the Message Board for two additional days to 1) respond to messages from other participants and 2) say good-bye to others. Because no explicit learning goal was presented for these two days, the messages that posted on these days were excluded from the analysis.

Verbal Analysis of the Message Board

Thirty two messages were each coded for the degree of understanding of scientific concepts and scientific inquiry for coding categories. Overall, about a third of the messages showed sophisticated understandings of scientific concepts (31.3%) and scientific inquiry (34.4%), respectively.

Levels of Understanding Shown on the Message Board by Cycle

This section compares levels of understanding of scientific concepts and scientific inquiry exhibited on the Message Board by cycle. This comparison within each cycle rather than across the cycles is important because each cycle had different instructional goals and those differences seemed to be reflected on the messages: Changes — especially in understanding of scientific inquiry — should not be expected over time, since each cycle focuses on a different type of scientific inquiry.

Cycle 1

Cycle 1 activity asked students to provide a description of local weather patterns, their school, and interests of individual students. However, the degrees to which the students described their local weather varied. Approximately 63% of Cycle 1 messages showed sophisticated understandings of scientific inquiry, i.e., *description*, whereas only 25% showed sophisticated understanding of scientific concepts (see Figure 4). In other words, 63% of messages successfully described their local weather patterns, but 75% of messages were based on more personal feelings or experiences rather than scientific information.

Since this was the beginning of the program, students' understanding of scientific concepts of weather was still limited. Students described local weather patterns mostly based on their personal experiences. Students had not yet developed sophisticated ideas about weather concepts such as relationship between the local geography and the amount of snow. This explains low percentage of messages coded as representing sophisticated understanding of scientific concepts (25%).

In contrast, about 63% of the Introductory messages contained sophisticated understanding of scientific inquiry, i.e., *description*. For example, the following example of Introductory messages showed minimal understanding of scientific concepts (i.e., personal experiences). Nevertheless, students' understanding of scientific inquiry — in this case, description of local weather patterns — was sufficient because the students were able to provide their own evidence (i.e., local weather information) and further organize the information by comparing winter and summer weather patterns.

> **Introductory message posted on 2/23 by Group 3 (Cycle 1)**
> We live in [this city]. In the winter our weather is very cold, and it snows a lot, but that is good because we get to do a lot of winter sports. In the summer, we usually get rain showers and it is always pretty warm. It can get also get humid sometimes after the rain.

The rather higher percentage of sophisticated understanding of scientific inquiry (63%) might be due to the fact that the class received more explicit instruction on writing Introductory Messages — one aspect of scientific inquiry, i.e., description — and spent more time composing the Introductory messages than other cycles. For example, Ms. Lewis encouraged students to think about how they could best describe local weather patterns to people who had not been to their city before using appropriate adjectives.

> **Ms. Lewis**: I want you to start thinking about what kinds of weather information do you think people in other parts of the country would want to know about [this city], in the month of February. And has our weather been usual this year, or has it been unusual this year? And then what kinds of questions do you want to ask other groups? What kind of information do you want to know?
> (from video transcripts on 2/16/99)
>
> **Ms. Lewis**: You're working with Mrs. Reed in Language Arts on using adjective, descriptive words to describe something to someone else. So when we think about our area, we should be able to come up with some adjectives to describe the geography of [this city] to let someone who hasn't traveled here get an idea of what [this city] is like.
> (from video transcripts on 2/18/99)

Ms. Lewis provided multiple examples of Introductory messages as well. Modeling of message writing also helped students to understand what they were expected to write. In addition, the students first composed messages on paper and Ms. Lewis gave feedback on their writing. This opportunity for drafting and revising messages might explain the higher percentage of sophisticated understanding of scientific inquiry in Introductory messages as compared to the other two types of messages (i.e., question messages in Cycle 2 and prediction messages in Cycle 3a).

Overall, the high percent of sophisticated understanding of scientific inquiry (description) and the low percent of sophisticated understanding of scientific concepts indicate that even though students had not developed sophisticated scientific knowledge early on the program they were able to write scientific descriptions successfully with the help of the teacher who modeled description-writing and gave feedback on drafts.

Cycle 2

The KGS curriculum proposed five to six Curriculum Questions in each topic area. Students were expected to investigate and gather information to answer these Curriculum Questions. In addition, students were encouraged to use the Message Board to send questions when they needed more information to answer the Curriculum Questions. Examples of the Curriculum Questions included "Give some local wind statistics for your area. What are the effects of wind in your area?" and "How does the local geography affect wind in your area? What other local characteristics affect wind near you?" The Curriculum Questions that were provided in the curriculum were rather general, but since KGS participants were from different locations, their answers would vary for each location. For example, to answer the first question above, students needed to understand the kinds of local wind statistics available (e.g., an average wind speed in each month or the maximum wind speed on record). In a like manner, to answer the second question, students needed to identify characteristics of local geography (e.g. our town is in a valley or near the Great Lakes). The students needed to narrow down the general questions and made them more specific to their particular area. However, some students posted the Curriculum Questions copied directly from the worksheet hoping the weather specialists could provide customized answers for each location.

Since the copied questions did not show sophisticated understanding of either scientific concepts nor scientific inquiry, only 20% of Cycle 2 messages showed both sophisticated understanding of scientific concepts and scientific inquiry, i.e., the discourse of *question* (see Figure 5). The majority of students seemed not to know that they were supposed to generate their own questions and/or why they needed to generate their own specific questions instead of asking the same general questions as in the student's worksheet. The students who copied the questions from the worksheet many have misunderstood the instructions. Prior to KGS students had not had opportunities to ask real scientists questions to help their investigations. They were more often asked questions by the teacher. Therefore, the students did not have clear ideas of appropriate questions.

In Cycle 2, the instruction — especially on the kind of message the students were supposed to write — was short and examples of the Question message were vague.

> **Ms. Lewis**: Some of these questions you were able to answer very easily and some of these questions you needed more information, and that is what we're doing today. … So, in your group, you're going to share your ideas about the information you needed like "I need more information about *whatever it is* that you need more information about the winds." You're going to go onto the Message Board and you're going to post a message saying, "In our study of winds, we've learned this stuff, whatever it is that you're going to share with others that you've learned, but we still need more information to help us understand this." Or "We need [information] about *such and such*, could you help us. We need more information, what information do you have to share with us."
>
> (from video transcripts on 3/18/99)

As shown in the above excerpt, Ms. Lewis did not provide any specific examples of questions. Instead, she used vague pronouns such as "*whatever it is* that you need more information" or "we need about *such and such.*" This lack of specific examples of message writing in Cycle 2 compared to Cycle 1 might be responsible for the increased percentage of less satisfactory messages in Cycle 2 than in Cycle 1. In addition, the teacher's scaffolding on the content of messages was rarely observed in the computer lab. In consequence, more than half of the Question messages produced in Cycle 2 were exact copies of the Curriculum Questions.

On the following day, the class had a follow-up discussion about messages they sent out the previous day. When the teacher prompted the students about the audience for their question and more effective ways of using resources on the Message Board, the students were able to suggest ways to improve their questions (i.e., largely narrowed down their general questions). The class, however, did not have an opportunity to send revised messages due to time constraints. Nevertheless, the discussion with the help of the teacher in the classroom seemed to help students formulate more specific questions.

In the post-program questionnaire, the students were asked to come up with a question for the weather specialists. The same student who wrote a very general question message (i.e., how does local geography affect local wind pattern?) wrote a more specified question in her post-program questionnaire (i.e., Being located next to the Great Lakes, would [this state] would be colder than a state not close to bodies of water?). On the post-program questionnaire, students were also shown four sample questions their peers had created and were asked to criticize them. Of the students, 80% chose specific questions as good examples because those questions included specific information.

These results provide further evidence of a positive effect of the explicit discussion of scientific inquiry in the classroom.

Cycle 3

In Cycle 3, the Real-Time Data Activities asked students to make a prediction of weather conditions based on their observations from the KGS CD-ROM. First the students made a prediction of "Precipitation" for one of KGS cities (Cycle 3a). The following day the students made another prediction of "Humidity" (Cycle 3b). These two tasks were structurally the same but dealt with different concepts (i.e., precipitation *vs*. humidity). There was a dramatic improvement observed between Cycle 3a and Cycle 3b. In Cycle 3a, only 22.2 % showed sophisticated understanding of scientific concepts and 11.1% showed sophisticated understanding of scientific inquiry, i.e., the discourse of *prediction* (Figure 6). In contrast, 80.0% and 100.0% of Cycle 3b messages illustrated sophisticated understanding of scientific concepts and scientific inquiry (prediction), respectively (Figure 7).

The classroom discussion that occurred after the first prediction activity may explain the improved quality of Prediction messages on the second day. Ms. Lewis addressed the importance of "evidence" in prediction making and helped the students to distinguish a prediction from a question or a statement. She used examples of prediction messages the students posted on the previous day, and had the students discuss whether those were predictions or not. Use of real examples from the Message Board and other examples the students might be familiar with seemed to help the students to understand the difference between a prediction and a statement of a fact.

The students also often wrote "tell us if our prediction is right," without including a prediction in the message. The students used prediction without thinking much about what that means. After the class constructed the definition of a prediction, however, the students were able to distinguish between what is a prediction and what is not, and to further suggest ways to make a statement a better prediction. The following two prediction message examples show how students in Group 2 began to develop scientific reasoning and communication skills after the class discussion.

Prediction message1 posted on 3/25 by Group 2 (Cycle 3a)
We had to look on the KGS CD-ROM to find places with the most precipitation, and we found you! We are predicting that if KGS is right, you have some precipitation. We predict that it was light precipitation on Thursday. If we are correct or incorrect, please send us a message in reply.

Prediction message2 posted on 3/26 by Group 2 (Cycle 3b)
We think that your weather is really hot and uncomfortable because it looks like your humidity is high. Please tell us if our prediction is correct by writing back to us.

Although the students used the word *predict* in their Prediction message 1, they were reading off the weather map (KGS CD-ROM) rather than making a prediction. They stated what they saw on the weather map, “you have some precipitation … was in light precipitation on Thursday.” On the following day, the same group of students made a prediction of a weather condition (i.e., hot and uncomfortable) caused by high humidity. The hot and uncomfortable weather was not only due to high humidity but also due to high temperature of that location. Thus, their reasoning was not scientifically comprehensive. However, this example illustrates the potential of students’ development of scientific inquiry, i.e., use of logical evidence to formulate a prediction. Cycle 3a and 3b messages illustrate the importance of 1) conceptual scaffolding during the classroom discussion about scientific inquiry and 2) repeated opportunity for students to exercise their new understanding.

It is also worthwhile to note that even though the classroom discussion was about scientific inquiry (i.e., definition of a prediction and importance of evidence in prediction making), the discussion also seemed to help students to better understand scientific concepts. As students learned to include “evidence” in their prediction message, it prompted students to think about possible relationship between scientific concepts such as *high humidity* (evidence) and *hot and uncomfortable* (a prediction). The relationship which students proposed in their prediction message was not always scientifically correct, but it suggested that students began to synthesize isolated scientific concepts in their own words.

Level of Scientific Understanding by Student Group

This section presents differences in the level of scientific understanding exhibited on the messages by different student groups. Again, this analysis was conducted on 32 messages which were directly related to mandatory tasks in the three cycles.

Table 7 summarizes the number of messages containing different levels of understanding of scientific concepts and scientific inquiry by groups. The total number of messages posted by each group varied from one (Group 6) to nine (Group 5) although all groups spent the same amount of time in the computer lab. Groups 1 posted a fair number of messages but their understanding of both scientific concepts and scientific inquiry in the messages were very limited. On the other hand, about a half of messages posted by Groups 2, 4 and 5 showed sophisticated understanding of scientific concepts and scientific inquiry. It is worthwhile to note that the same groups (Groups 2, 4, & 5) posted larger number of additional messages (besides the mandatory messages in the three cycles) than the other groups.

Group differences in sophisticated understanding of scientific concepts appear to support trends generally in academic achievement and technology-fluency (based on pre and post-program questionnaire scores). Group profiles indicated that Groups 2 and 5 were two of the highest achieving groups and their technology-fluency was also higher than the other groups, and these groups produced the most sophisticated understandings. On the contrary, Groups 1 and 6 got the lower scores in both pre and post-program questionnaires and the degree of technology experience than the groups. These groups produced messages that displayed only minimal understandings of scientific concepts and scientific inquiry. While 40% of Group 3 messages showed sophisticated understanding of scientific inquiry, none of the messages shows sophisticated understanding of scientific concepts. This illustrates that this group of students was able to use evidence in their messages, but the evidence was not always correct like shown in the following example.

Message posted on 3/26 by Group 3
The highest humidity was in Mexico so I would predict that you might have some wind, the lowest was in Canada so I would predict that it might be pretty warm and dry.

Patterns of Teacher Scaffolding in the Computer lab

In this section, different levels of teacher scaffolding in the computer lab were analyzed. Because the prevalent instructional mode in the science classroom was teacher-led whole classroom instruction, little group difference was found in the science classroom. Therefore, the group difference in teacher scaffolding was only explored in the computer lab.

Of teacher's scaffolding in the computer lab during the three cycles (N = 299 visits in total), 60.5% was Contingency Management, 34.4% was Procedural Scaffolding and 5.1% was Conceptual Scaffolding. Overall, Conceptual Scaffolding was rarely found in the computer lab.

Different Level of Teacher Scaffolding in Each Cycle

Figure 8 shows the percentages of different level of teacher scaffolding in each cycle. The overall patterns of teacher scaffolding were consistent throughout three cycles: Contingency Management was the most prevalent and Conceptual Scaffolding was rarely observed.

The Internet network problem can account for the higher percentage (71.3%) of Contingency Management in Cycle 3b compared to the other two cycles. During the first half hour of Cycle 3b in the computer lab, the teacher had to spend most of her time telling her students to restart computers rather than providing either Procedural or Conceptual Scaffolding. For example, one group had to restart their computer eight times during those 30 minutes. Once the teacher made a decision to move to a new task, the class was able to carry out the second task more smoothly. Figure 9 discounts the unproductive time period due to the network problem and includes only the later half of Cycle 3b in the analysis.

Overall, in the revised scheme, the percent of Conceptual Scaffolding increased, whereas the percent of Procedural Scaffolding decreased from Cycle 1 to Cycle 3 (see Figure 9). There might be two possible reasons for this change. First, the nature of a task in Cycle 1(describing local weather pattern) was conceptually less challenging than in Cycle 2 (relationship between geography and wind pattern) and Cycle 3 (predicting a weather condition based on observation). Thus, the teacher needed to provide less Conceptual Scaffolding in Cycle 1. Second, students became more familiar with the technology tools (e.g., Internet browser, Message Board, and KGS CD-ROM) over time, allowing more time on Conceptual Scaffolding in Cycles 2 and 3.

Different Level of Teacher Scaffolding to Each Group

In the computer lab, the teacher provided scaffolding to each group while she was rotating groups rather than checking the progress of the whole class. The next analysis concerned the level of teacher scaffolding in each group visit. Figure 10 shows frequency in percent of teacher visits to each group. If the teacher visited each group equally, the mean would be 16.6%. Given that, Groups 4 and 5 received more visits than others. The differences of frequency of teacher visit were statistically significant by group (χ^2 (5, N = 6) = 15.61, $p < 0.05$).

The physical setting of the computer lab might be one factor of difference in the number of teacher visits. The groups who received the more teacher scaffolding were all seated in the one side of the computer lab. It is also interesting to note that Groups 4, 5, and 6 were composed of all boys. Studies of gender difference in a classroom have reported that teachers usually called on boys more often than girls (AAUW, 1992; Baker, 1987; Becker, 1981). The same phenomena seemed to occur in the computer lab. Whereas girls' groups worked quietly and tried to solve problems among themselves, boys called teacher's attention whenever they encountered problems or to show off their progress.

Figure 11 illustrates the frequency of different levels of teacher scaffolding in each group. Overall, Groups 4 and 5 received more Conceptual Scaffolding than others. On the other hand, Group 3 received no Conceptual Scaffolding at all.

Groups who were having more problems with a given task due to their behavioral problems or a lack of technology experience (e.g., Groups 1 & 6) drew more teacher attention. These groups received a greater percentage of Procedural Scaffolding (45.9% in Group 1 and 39.6% in Group 6) than others. However, the percent of Conceptual Scaffolding that these groups received was limited. On the other hand, Groups 2, 4, and 5 who had more technology experience received less Procedural Scaffolding than others.

Group 3 was an all-girls group and received the least number of teacher visits. This group seemed to manage to follow procedures on their own. On balance, they did not get any Conceptual Scaffolding which might be necessary for them to advance their conceptual understanding. Group 3 sent a fair number of messages but their understanding on the Message Board was limited (see Table 7).

In conclusion, there was a strong trend towards similar patterns between the degree and the focus of teacher scaffolding and the degree of students' scientific understanding appearing on the Message Board. The trends include:

1. The teacher's explicit modeling of scientific discourse — which was a blend of conceptual and procedural scaffolding — was critical to help students to understand the tool and tasks

When explicit conceptual scaffolding was provided, students' messages tended to show more sophisticated understandings. For example, when the teacher provided multiple models of messages as a means of conceptual scaffolding, Cycle 1 messages showed sophisticated understanding of scientific inquiry. In a similar manner, classroom discussions about scientific inquiry such as a definition of a prediction — another means of conceptual scaffolding focusing on inquiry — seemed to help students to better understand scientific inquiry. Furthermore, students who received more conceptual scaffolding showed greater percentage of sophisticated scientific understanding on the Message Board than other groups. These suggest that explicit *conceptual scaffolding* can promote students' understanding on the Message Board.

2. As students became more familiar with procedures (curriculum as well as technological procedures), teacher's focus could shift to more conceptual scaffolding.

While conceptual scaffolding seemed to play an important role in promoting students' scientific understanding on the Message Board, a certain amount of procedural scaffolding was also necessary for some students. Students who did not have high prior understanding of science and technology often received more frequent procedural scaffolding than other students. However, procedural scaffolding decreased while conceptual scaffolding increased over time. This suggests that some students needed to have procedural scaffolding to carry out a task which involved technology. Once they had learned basic procedures, they were more receptive to conceptual scaffolding. For those students to take a full advantage of conceptual scaffolding, prior procedural scaffolding seemed to be necessary.

3. Different degree and focus of teacher's scaffolding was provided depending on students' prior understanding of science and technology.

The teacher played an important role in providing necessary procedural and conceptual scaffolding based on each group's prior understanding of scientific content and technology. Students who had higher prior understanding of science and technology received more conceptual scaffolding and showed more sophisticated understanding. In contrast, students who received less conceptual scaffolding showed less sophisticated understanding. Since the measurement of prior understanding of technology was not comprehensive and the number of messages were quite small in this study, it is difficult to generate any conclusive statement between the prior understanding and the development of scientific understanding on the Message Board. Nevertheless, these results suggest "Digital Divide" issues in the computer lab. Students who hold limited understandings of technology needed a great amount of procedural scaffolding, which most likely took away from teacher's time for conceptual scaffolding. Students who did not receive conceptual scaffolding tended to show less sophisticated understandings on the Message Board. In contrast, students who had more prior understanding of technology and therefore did not need as much procedural scaffolding allowed the teacher to provide more frequent conceptual scaffolding instead. These students tended to show more sophisticated understanding on the Message Board. Together these results suggest that use of technology-rich program such as this one could broaden a gap between students who have different levels of technology experience, as it influence the amount of conceptual scaffolding they receive. Besides the difference in students' prior understanding of technology, the group composition including gender and the number of students in each group might also have influenced the amount of procedural and conceptual scaffolding they received and the degree of their understanding on the Message Board. This study only suggests a possibility of "Digital Divide" gaps in the computer lab. Teachers should be more sensitive about students' different levels of prior understanding of technology as well as content in the computer lab.

Discussion

In this study, it was surprising to find that only 5.1% of teacher scaffolding in the computer lab was counted as conceptual scaffolding. Throughout the program, there were instances that Ms. Lewis missed opportunities where she did not provide conceptual scaffolding to students as we had hoped or expected she might. For example, the following excerpts illustrate two missed opportunities for further conceptual scaffolding. In the first instance, students were looking for local wind statistics on a web site and current wind data on the KGS CD-ROM (Cycle 2). In Line 3, Ms. Lewis directed students' attention to a specific feature of a wind map and asked whether it gave any other information. Although the students could not provide a proper response in Line 4 (maybe because the students could not understand Ms. Lewis' question or they did not understand the map they were looking at), Ms. Lewis just moved away from the group without providing additional help. She could have given hints about what the students were supposed to look for (e.g., other statistical data such as typical local wind direction in January) or how the information they had found could be related to the <u>Curriculum Questions</u> activity.

1 **T**: What does that show us there? [pointing a web site of wind statistics]
2 **S**: Average wind speed in our area. It's 20 miles per hour.
3 **T**: Is that, right now, that's an interesting picture. Scan down, what do we see on that map, do they give us any other information?
4 **S**: Just umm…
[Ms. Lewis moved to the next group]

(from video transcripts on 3/18/99)

A similar situation happened in the following excerpts in Cycle 3. Students were doing <u>Real-Time Humidity</u> activity and tried to find out what relative humidity is.

1 **S**: Ms. Lewis, isn't relative humidity like about the same humidity in two different places?
2 **T**: Nope. No.
3 **S**: Do you want me to get science books?
4 **T**: Yes.
[Ms. Lewis moved to the next group]

(from video transcripts on 3/26/99)

A student asked Ms Lewis whether her definition of relative humidity was right (Line 1). Instead of providing any assistance to help the student to re-think about the concept of relative humidity the student came up with, Ms. Lewis simply answered "No" and asked the student to consult the science textbook. The class had not studied humidity before this activity. Thus, Ms. Lewis might have thought that there was no reference she could draw upon and the textbook might be the best resource to provide a scientific definition of unfamiliar concept, i.e., relative humidity. However, she could have explained the concept using a simple example or experience such as how people might feel under low or high relative humidity.

We can only speculate why she had missed opportunities for further conceptual scaffolding in the computer lab. Some of the reasons might be due to 1) Ms. Lewis' perception of two separate weather unit curricula in her class, 2) her pedagogical belief about students' role in the computer lab, and 3) limited understanding of the program.

First, Ms. Lewis used two curricula for the weather unit expecting that the two curricula could serve different purposes; while the KGS curriculum could be used to introduce technology and develop students' inquiry skills, the non-KGS local district curriculum could be used for scientific concept learning. Even though she did not explicitly state, she seemed to perceive scientific concepts separated from scientific inquiry. In her interview, Ms. Lewis said that even though KGS provided innovative ways of studying weather using real-time weather data, she still needed to teach basic concepts of weather in a traditional way using the non-KGS school-district curriculum because KGS does not directly deal with weather concepts as in science textbooks.

> I think one of the things that I really liked about it [KGS] was that you [KGS] did <u>have access to the real-time data so you could get in there and go take a look at things</u>…. My expectation from my experience with it [KGS] last year was like KGS is really good, but they've got some holes and so I can use it like I did last year to fill in with the new curriculum [the local school-district curriculum] since

> we've tightened up our curriculum, I can use this [KGS] as filler again since I feel really confident of ours. When I got it [KGS] and started going through it, it's like, this isn't laid out, it's not I could just pull it in. It's got it's own, and it was like, how am I going to work this in, it was something I struggle with, how am I going to incorporate, this, that I've worked on with the district and how can I take the best of both and what's going to have to get sacrificed?
>
> (Post-teacher interview on 4/15/99)

Hence, it seemed that Ms. Lewis saw the KGS CD-ROM and Message Board as means to access to real-time data and communicate with Weather Specialists, which are, at least in her mind, not the most efficient means of teaching scientific content as explaining scientific concepts on a blackboard and having students read paragraphs in the science textbook.

Second, Ms. Lewis believed that students should take control of their learning in the computer lab as illustrated in her interview. Upon reflecting on previous year's KGS program in her class, Ms. Lewis noticed different patterns in her interaction with students in the computer lab when using the KGS program.

> I did a lot of talking before [the KGS program], I still did a lot of talking with KGS but instead of whole class lecture kind of thing, it was more one on one working with the groups in the computer lab, answering their questions, so it kind of took away, took the emphasis off me and put the emphasis on the kids in terms of acquiring the knowledge.
>
> (From an interview with Ms. Lewis after KGS '98, 1998)

In 1999, Ms. Lewis spent a small amount of time on teacher-directed instruction (1.0%) or teacher-led discussion (2.1%) in the computer lab. Instead she spent more time on helping each group of students to understand the material while monitoring the individual pace of progress (96.9%).

Once students came into the computer lab, they rushed into their assigned seats and immediately started what they were supposed to do for the day. The teacher walked around the computer lab and checked the progress of each group. She rarely caught everybody's attention at once in the computer lab. In the computer lab students often worked at their own pace.

> As soon as the kids get in front of the computer, it's like "don't talk to me anymore, leave me alone. I'm on my own. If I have a question, I'll ask you, but don't you interrupt me!" And when you try to say, "ok, let's stop for a second, this group over here was working on this, and they found this, what do you guys think about that?" They're like "I don't care, don't want to be involved, doing my own thing, talk to me later." … So, in the lab, it's a lot harder. In the

> classroom you can say "put your pencils down" and in the computer lab, it's like, "ok, take your hands off the keyboards everybody put your hands in your lap, everybody turn your chairs this way." ... And so the discussion. <u>The students aren't focused on the discussion in the computer lab there are too many distractions for them in there</u>. … They [students] really want to get to work on the computers.
>
> (Post-teacher interview on 4/15/99)

Due to the belief that students should be able to solve their own problems in the computer lab, Ms. Lewis seemed to perceive her main role in the computer lab as a technology-related problem solver, rather a scaffolder for scientific concepts and inquiry. This seemed to hinder Ms. Lewis from providing more conceptual scaffolding.

Third, it is challenging to provide appropriate conceptual scaffolding while students are studying complex, real-time information. The KGS learning environment may require teachers to have more subject content knowledge than a traditional science classroom. Although this was her second year of KGS participation, her understanding of the KGS curriculum seemed to be limited because she did not fully implement KGS in her first year (i.e., 1998) and the KGS curriculum and technology had been changed. Therefore she was in the process of learning about KGS and she was not yet able to figure out what would be a balanced amount of conceptual and procedural scaffolding. Previous KGS research (Songer, 1998) indicated that when a teacher became more familiar with the program after at least three years of experience, s/he was able to utilize more of her or his time on conceptual scaffolding instead of procedural scaffolding. Whereas procedural scaffolding is still necessary to promote student understanding on the Message Board, teacher's experience and confidence can help the teacher to balance procedural scaffolding with more conceptual scaffolding more effectively.

Technology-rich learning environments do not mean that technology replaces classroom teachers. Technology must be viewed as complementary to the classroom teacher rather than a replacement. We want students to use technology not just for the sake of the technology but to help them think deeper and engage higher-order thinking, which might not be possible without the help of technology (e.g., real-time data interpretation or collaboration with scientists). Can using technology guarantee that students will think deeper as we hope? In order to make productive learning happen using technology, teachers should play a more active role in the computer lab as a cognitive scaffolding provider not just a problem solver.

Schofield (1995) reported that there were differences in computer use in a classroom and in a computer lab and students and teachers preferred using computers in the computer lab to the classroom. The use of computers in the lab often led to a high level of students' motivation, and the teachers functioned as a skilled collaborator rather than an authoritative expert. In addition students reported more positive experience with peers and teachers in the computer lab. The students worked more independently in the computer lab.

Furthermore, Means and Olson (1995) reported that they observed teacher's role in the computer lab shifted from the dispenser of information to acting as facilitator, setting project goals and providing suggestions and resources, moving form student to student, providing suggestions and support for student activities. Moreover, in many cases, students are given the chance to see their teachers also struggle with the acquisition of a new set of skills, i.e., using technology.

Despite these possible benefits of the computer lab as a productive learning environment, it is not so easy as it sounds to foster the productive learning environment in the computer lab. For many teachers including Ms. Lewis in our study, shifting their role from the information dispenser to facilitator does not come easily. In many cases, teachers move from group to group solving emerging technology problems and rarely involved in cognitive interaction with students. Teacher scaffolding tends to be more procedural than conceptual in the computer lab. In this study the physical settings and cultural norms of the computer lab, which was favorable to small group or individual work, encouraged the teacher to became a technical problem solver instead of a conceptual understanding guide. Out of 299 instances of teacher scaffolding in the computer lab only 5.1% was scientific scaffolding. In the computer lab, the teacher spent an average of 30 seconds in each group. Within this short amount of time it appeared to be easier for the teacher to detect problems with technology and solve those problems, because those were more evident than difficulties with conceptual understanding. In addition, if a group of students was having a problem with either technical or curriculum procedures they could not make further progress. Engaging in a dialogue with students regarding their progress in conceptual understanding required more careful and comprehensive monitoring of the progress.

This study argues the importance of conceptual scaffolding in a technology-rich learning environment for the development of students' understanding of scientific concept and inquiry. At the same time, a balance between conceptual and procedural scaffolding is equally important to keep in mind. Teachers' perception of their role in the computer lab should be changed as facilitator. Teachers should more actively involve in students' cognitive activities rather than passively act as a problem solver.

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Figure 1. A Screen Capture From the KGS '99 CD-ROM

Figure 2. A Screen Capture From the KGS '99 Message Board

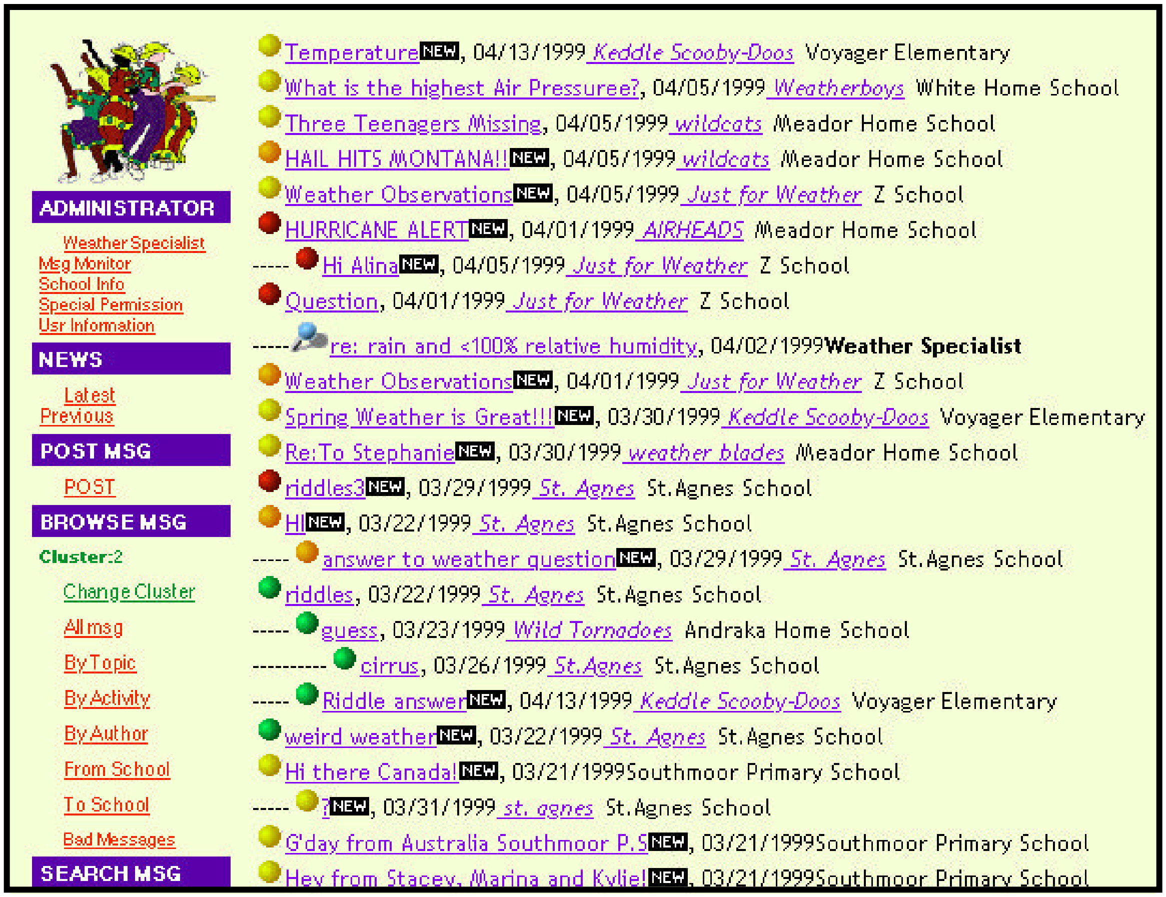


Figure 3. Activity Topics and Message Board Cycles

Phase	Date	KGS activities	Related Scientific Concepts	Message Board Use	Cycle
Phase I	2/16	Introduction to Weather	General weather		Cycle 1
	2/18	Introduction to Weather (Cont.) & Introductory Messages	General weather		
	2/19	Introductory Messages	Local weather		
	2/23	Introductory Messages	Local weather		
Phase II	3/2	N/A	Temperature & Hypothermia		
	3/4	N/A	Temperature		
	3/9	N/A	Temperature & tilted earth and uneven heating		
	3/11	N/A	Temperature & convection cycle		
	3/12	Responding to messages from other participants	Wind & Beaufort Scale		
	3/16	N/A	Global wind pattern		
	3/18	Curriculum Question (Winds)	Wind		Cycle 2
	3/19	Curriculum Question Communication (Winds)	Wind		
	3/25	Real-Time Precipitation Activity & Cloud Coverage	Precipitation & Clouds		Cycle 3
	3/26	Real-Time Humidity and Real-Time Temperature & Pressure Activity	Humidity, Temperature & Pressure		
Phase III	3/30	Elementary Weather Fronts & What will the Weather Be Like Tomorrow?	Fronts & Forecasting		
	4/1	Wrapping-up KGS			

Message Board Writing in the Computer Lab

Classroom Discussion about the Message Board

Note. N/A means non-KGS activities

Figure 4. Level of Understanding Shown in the Cycle 1 Messages (*n* = 8)

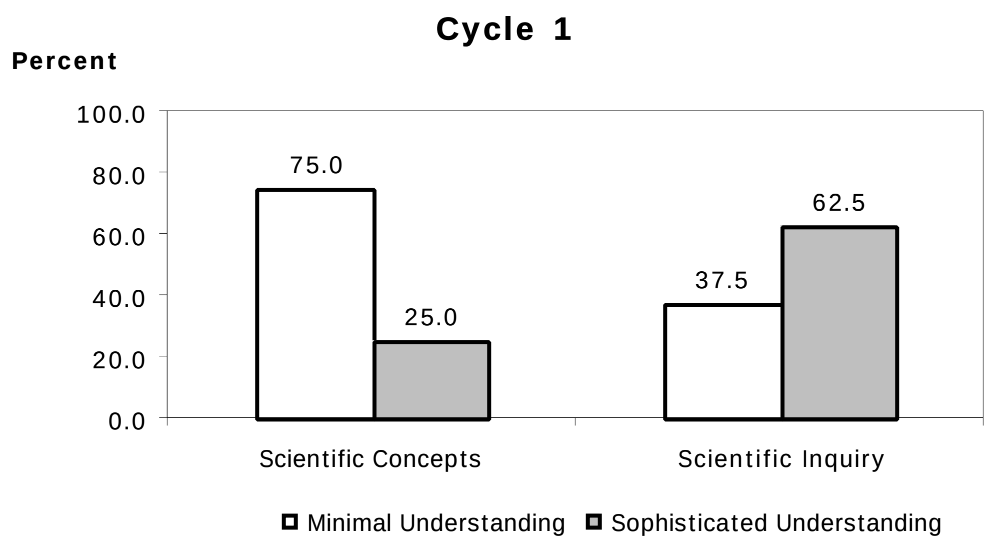


Figure 5. Level of Understanding Shown in the Cycle 2 Messages (*n* = 10)

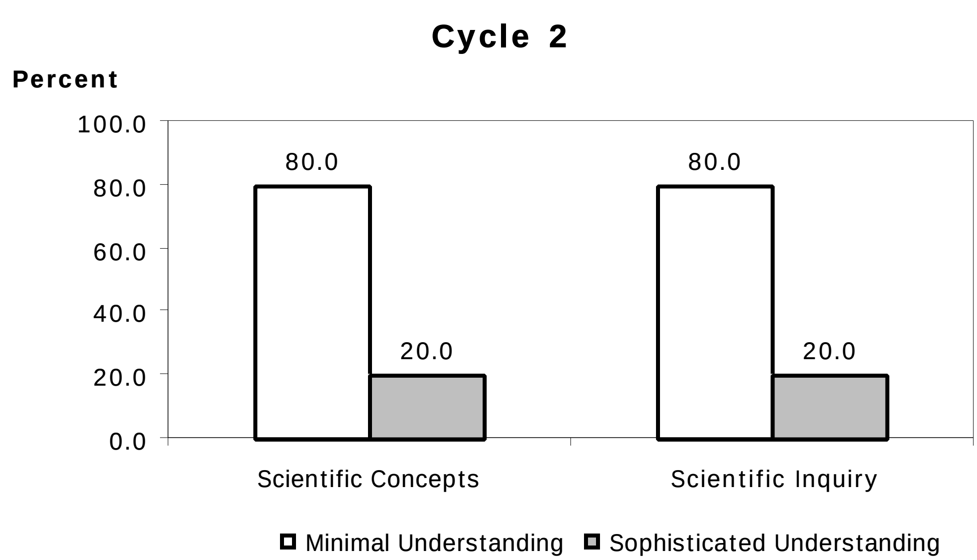


Figure 6. Level of Understanding Shown in the Cycle 3a Messages (*n* = 9)

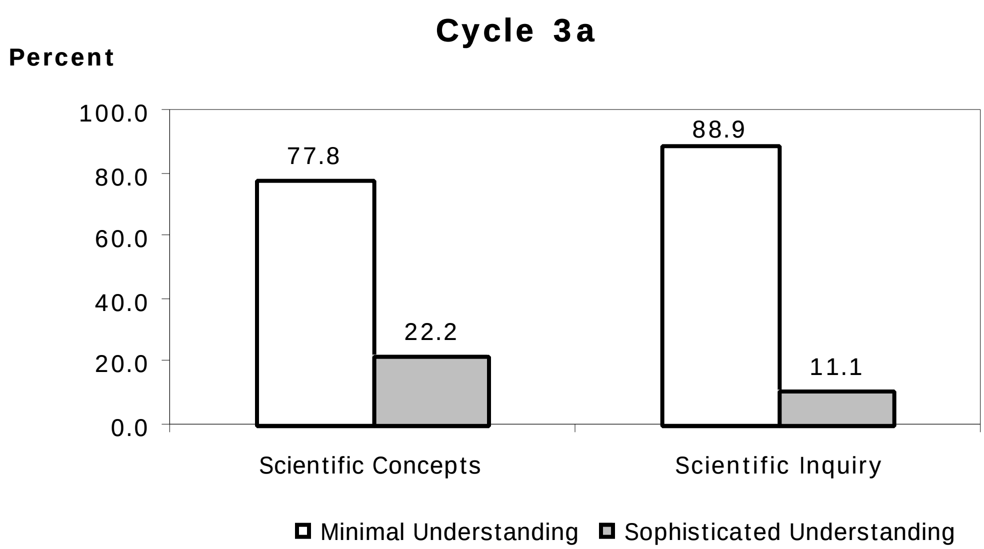


Figure 7. Level of Understanding Shown in the Cycle 3b Messages (*n* = 5)

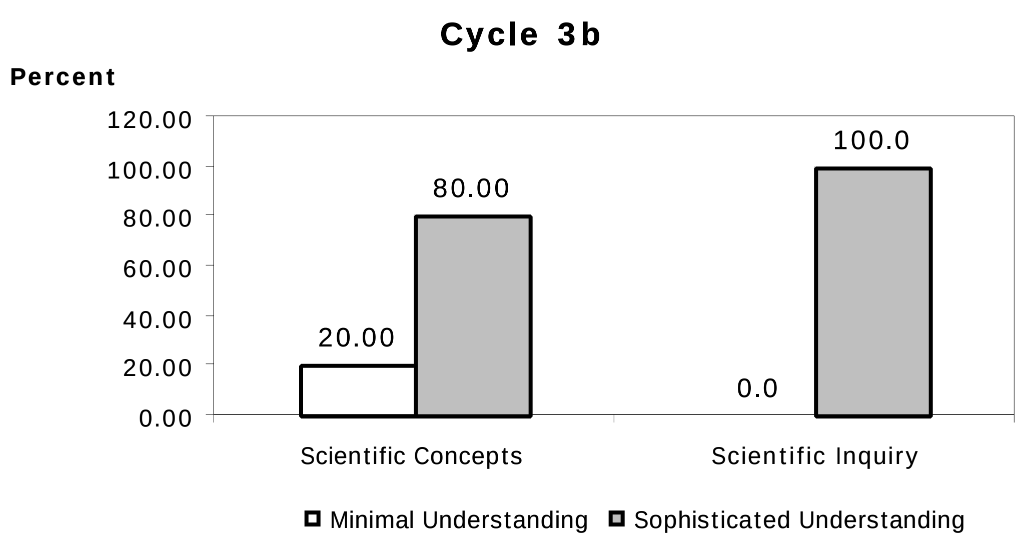


Figure 8. Frequency of Three Levels of Teacher's Scaffolding in Each Cycle (*N* = 299)

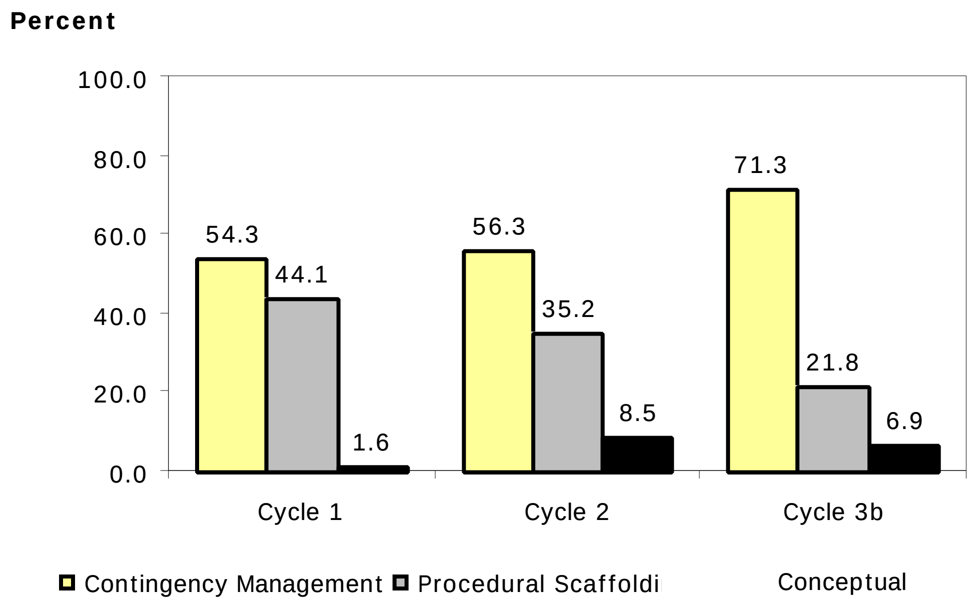
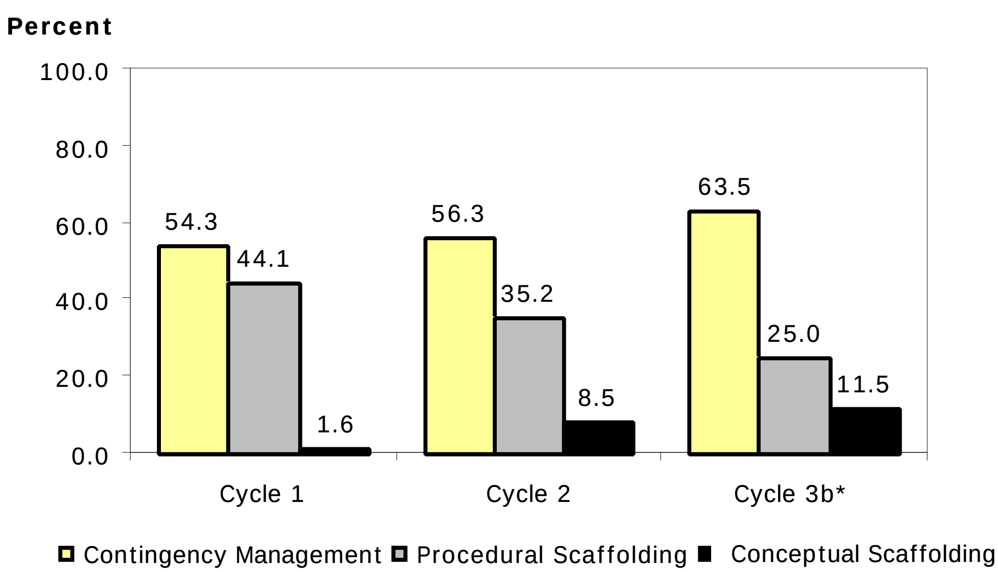


Figure 9. Percent of Difference Levels of Teacher Scaffolding by Cycles Revised



Note. Cycle 3b* excludes the first half of the computer lab time when the class encountered the network problems.

Figure 10. Frequency in Percent of Teacher Visit (*N* = 299) to Each Group

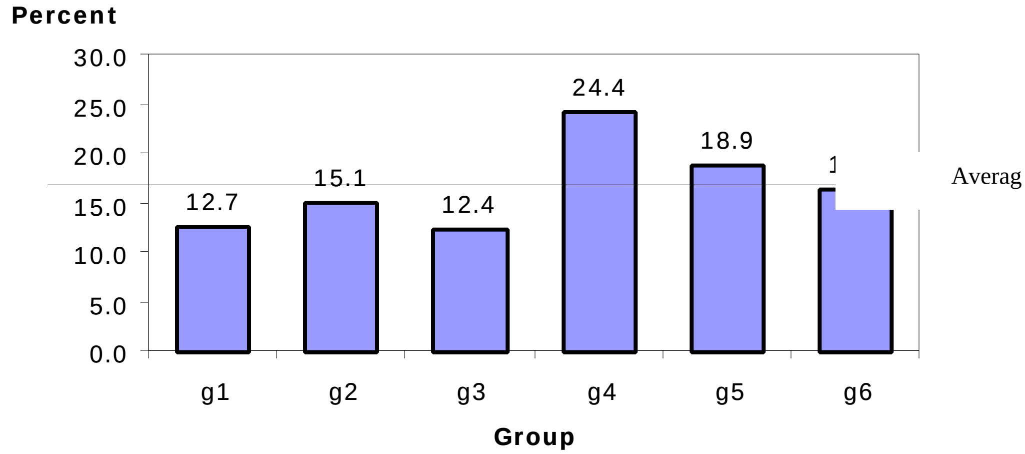


Figure 11. Frequency of Three Levels of Teacher Scaffolding in Each Group (*N* = 299)

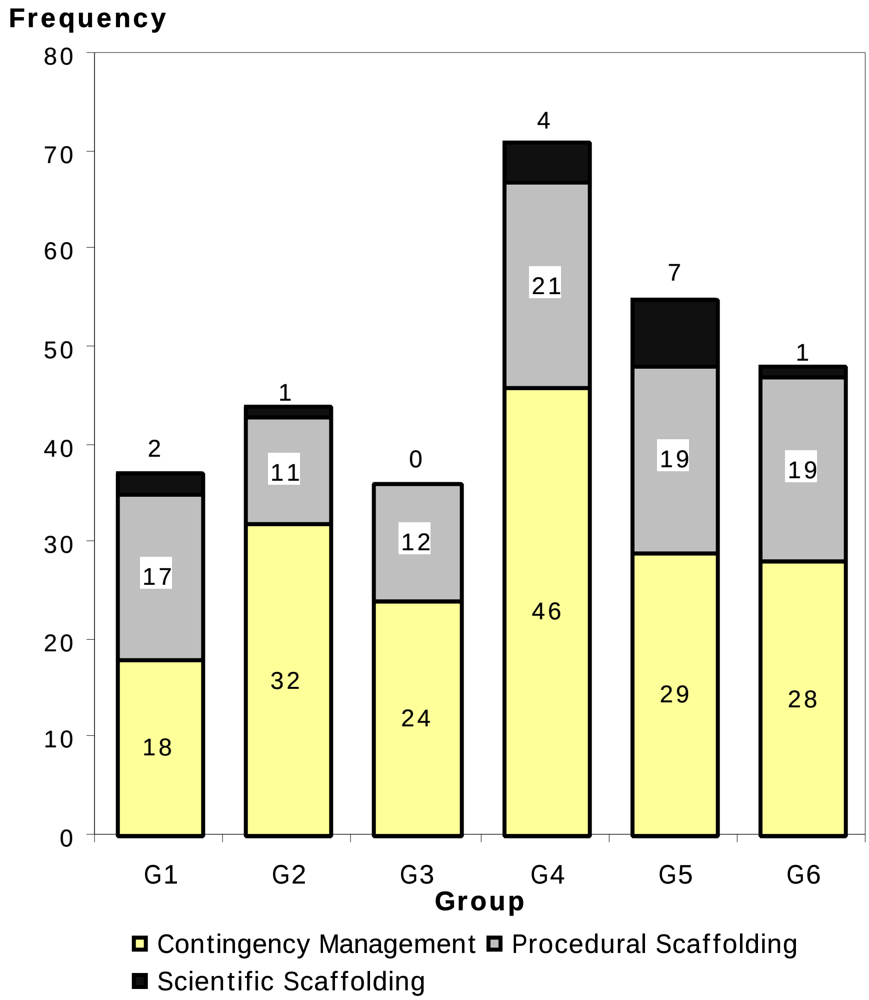


Table 1. Reasons for Understanding of Scientific Concepts Coding Categories

Minimal Understanding of Scientific Concepts
1. Concepts are naïve (personal feelings) or partially correct
2. Scientifically correct, but simple perception of facts
Sophisticated Understanding of Scientific Concepts
3. Organizing and identifying concepts on the basis of similarities and differences
4. Combining two or more concepts in a relational statement, such as “if A, then B” or “it’s A because of B.

Table 2. Examples of Understanding of Scientific Concepts Coding Category

Minimal Understanding of Scientific Concepts

Cycle 1. Introductory Messages

e.g., It is rainy here all seasons, but winter. It is very cold and snowy in the winter. In the summer it is hot and very humid.

Reason for code: Concepts are naïve (personal feelings).

Cycle 2. Question Messages

e.g., We are in need of information on the topic of winds. We would like to know how local geography affects various areas.

Reason for code: Students copy questions from worksheet verbatim. No new understanding was added.

Cycle 3. Prediction Messages

e.g., The highest precipitation is intense for today March 25,1999. But we think you already knew that if you looked on the precipitation map. What is your weather like?

Reason for code: Students present simple perception of facts (observation of current weather condition).

Sophisticated Understanding of Scientific Concepts

Cycle 1. Introductory Messages

e.g., In the summer, temperature range from about 70-100 degrees Fahrenheit, and in the winter, temperature range from about 10-30 degrees Fahrenheit. In the summertime, we do not have much precipitation, just hot, sweltering heat. In the winter we have much snow, ranging from about 2-10 inches. This past January, we had blizzard that brought snow, ranging from about 17-20 inches of snow. We hope to learn about weather and its attributes in your community.

Reason for code: Students describe local weather patterns referencing summarized scientific information (organized by comparison).

Cycle 2. Question Messages

e.g., Can you tell us how wind would be affected if it blew through a hilly area (e.g., slow down, speed up, rise, fall, etc)?

Reason for code: Students show their understanding of a relationship between elevation of earth surface and wind speed.

Cycle 3. Prediction Messages

e.g., While looking at the humidity map, we noticed that you have one of the highest humidities in the US. We made a prediction that, as a result of your humidity, that you are having a hot and wet day. Please write back to tell us if our prediction is correct.

Reason for code: Students provide reasonable evidence for their prediction using causal relational statement: "as a result of"

Table 3. Reasons for Understanding of Scientific Inquiry Coding Categories

Minimal Understanding of Scientific Inquiry
1. No development of description, explanations, prediction
2. No evidence for description, explanations, or prediction
3. No use of evidence beyond what is provided in the curriculum
Sophisticated Understanding of Scientific Inquiry
4. Formulate descriptions, explanations, questions, or predictions using students' own evidence and information (but not necessarily organized or summarized)
5. Formulate descriptions, explanations, questions, or predictions incorporating summarized evidence and information
6. Provide logical relationship between evidence and explanation

Table 4. Examples of Understanding of Scientific Inquiry Coding Category

Minimal Understanding of Scientific Inquiry

Cycle 1. Description Messages

e.g., … Our weather is crappy in the winter summers are great. We would like to get to know what the weather is like where you live….

Reason for code: Students provide no evidence for the description.

Cycle 2. Question Messages

e.g.,… We would like to know how local geography affects various areas.

Reason for code: Question copied from worksheet; Students use no evidence beyond what is provided in the curriculum question.

Cycle 3. Prediction Messages

e.g., Are you guys having a rain? Write back and tell me if our prediction is right!

Reason for code: Students do not formulate a prediction.

Sophisticated Understanding of Scientific Inquiry

Cycle 1. Description Messages

e.g., In the summer, temperature range from about 70-100 degrees Fahrenheit, and in the winter, temperature range from about 10-30 degrees Fahrenheit. In the summertime, we do not have much precipitation, just hot, sweltering heat. In the winter we have much snow, ranging from about 2-10 inches. This past January, we had blizzard that brought snow, ranging from about 17-20 inches of snow. We hope to learn about weather and its attributes in your community.

Reason for code: Students formulate the description using organized evidence.

Cycle 2. Question Messages

e.g., Can you tell us how wind would be affected if it blew through a hilly area (e.g., slow down, speed up, rise, fall, etc)?

Reason for code: Students formulate their own question using specific information they gathered (i.e., local geography being hilly).

Cycle 3. Prediction Messages

e.g., We predict that your weather may still be bad because in your area on the pressure map you have very low pressure. Of course you know that low pressure results in clouds and sometimes stormy weather.

Reason for code: Students provide logical evidence for their prediction.

Table 5. Coding Categories for Teacher Scaffolding in the Computer Lab[3]

Levels of Teacher Scaffolding	
CM. Contingency Management	Teacher provides minimal verbal assistance such as a short praise for the progress and solves technical problems which are not program specific e.g., *How are you guys doing? Okay, you need to restart your computer*
PS. Procedural Scaffolding	Teacher provides verbal assistance which could help students move to the next step of a given task and often resulted in student action e.g., *You can go to browse messages and respond to others*
SS. Conceptual Scaffolding	Teacher provides verbal assistance for the development of students' scientific concepts and provides models of conceptual understanding or message writing, and prompted students with relevant past experience e.g., *What do you think would be the windiest month in Michigan*?

[3] These three teacher scaffolding categories were only applied to the classroom discourse that occurred in the computer lab (not in the science classroom) while students were composing messages.

	KGS 99			Cluster 3			Ms. Lewis' Class		
	# of Participants	# of Messages	# of Messages/ participant	# of Participants	# of Messages	# of Messages/ participant	# of Participants	# of Messages	# of Messages/ participant
Students	10864	3751	0.35	1042	400	0.38	25	67	2.68
Teacher / Class *	253 teachers/ 528 classes	168 **	0.66	44 teachers/ 44 classes	20	0.45	1 teacher/ 1 class	0	0.00
Scientists	45	778	17.30	5	55	11.00	N/A ***	N/A	N/A
Admin/ Monitor	15	30	2.00	3	0	0.00	N/A	N/A	N/A
Total	**11177**	**4853**	**0.43**	**1086**	**475**	**0.44**	**26**	**67**	**2.58**

* Some teachers taught more than one class, thus, the number of teachers and classes do not match. If a teacher taught multiple classes, each of his/her classes was assigned into a different cluster.

** Out of 303 teacher messages, 135 messages were posted on the Teacher Message Board which students could not access. Thus, only 168 messages were shown to students.

*** Scientists, Administrators and Monitors were assign to each cluster not to each class. Thus, messages from them were not counted in Ms. Lewis' class messages.

Table 6. Number of Participants and Number of Messages during the KGS '99 Program

Table 7. Number of Messages Shown Each Level of Understanding by Group

	Total Msg *N*	Understanding of Scientific Concepts				Understanding of Scientific Inquiry			
		Minimal		Sophisticated		Minimal		Sophisticated	
		n	%	n	%	n	%	n	%
Group 1	6	6	100.0	0	0.0	6	100.0	0	0.0
Group 2	7	3	42.9	4	57.1	3	42.9	4	57.1
Group 3	5	5	100.0	0	0.0	3	60.0	2	40.0
Group 4	4	2	50.0	2	50.0	2	50.0	2	50.0
Group 5	9	5	55.6	4	44.4	5	55.6	4	44.4
Group 6	1	1	100.0	0	0.0	1	100.0	0	0.0