



The Impact of Electronic Networking on Student Interactions During an Ant Biomonitoring Problem Solving Science Investigation

Rita A. Hagevik

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Abstract

The use of electronic networks has been identified as one of the ways technologies can enhance instruction. This study examined the impact of using an electronic network on the development of students' ideas about the use of ants as bioindicators of an environment. A hyperstudio stack guided students enrolled in a general science course through the steps of skillful problem solving as they conducted the biomonitoring



experiment. Vygotsky's theoretical framework of social constructivism was used in interpreting the findings of this study. Differences in student interactions, problem solving abilities, attitudes, and conceptual understanding between classes that teleconferenced and those that did not were compared. Two classes of eighth graders used Microsoft Netmeeting and jointly planned and conducted the experiment. Two other classes of eighth graders conducted the experiment independently. Analyses of the data did not indicate any gains in problem solving ability for either group or differences in attitudes toward the

experiment. Open-ended response surveys and interviews with teleconferencing students indicated that electronic networking enhanced conceptual understanding of biomonitoring. Differences in interactions between the two groups were evidenced by the analyses of transcripts of group discussions. The dialogs of the telecommunication classes revealed that they asked more questions, praised and encouraged each other more often, and accepted each other's ideas more frequently. Their interactions were more indirect or characteristic of dialogue as compared to the more direct, lecture type (univocal) interactions of the non-teleconferencing classes. The results of this study indicate that electronic networks have the potential to increase the types of interactions that promote the construction of ideas. Using the electronic network in the context of a problem solving investigation encouraged horizontal peer interaction, enriched conversations and led to an increase in students' understandings of using biomonitors to monitor an environment. This study illustrates an effective use of learning with technology that can enhance student learning and instruction.

Introduction

The major goal of science education is to produce students that are scientifically literate and are ready to function in a technologically oriented society (National Research Council [NRC], 1996). The National Science Education Standards provides both a vision of this goal and recommendations for achieving the vision. Although the Standards address several key criteria for achieving the vision, inquiry into authentic questions is identified as the central strategy for teaching science and technology is indicated as one of the foci of instruction as well as a mechanism for learning science. Technology is one strategy for facilitating the teaching of science. However the cost in organizational time and instructional money for set-up, training, and support for technology based instruction increases the need to identify effective ways to incorporate technology into science instruction.

The use of electronic networks has been identified as having potential for enhancing instruction. Riel (1990) states that an electronic network can be beneficial instructionally for acquiring knowledge, developing new instructional strategies, increasing self-esteem, and developing strong social interactions that enhance learning. The interactive ability of electronic networks has been shown to produce a better quality of work among students and to be motivating and exciting to students (Levin & Cohen, 1985). An electronic network can be "the supplier of resources, or a way to collaborate on projects in different locations, or a means to share results with a wider audience" (Levin & Thurston, 1996, p. 47). Students' writing has been shown to improve because of the motivational impact of the "audience effect" and the immediate feedback about their work. When students work together to create their written products, they create essays of increased quality (Mehan, Moll & Riel, 1985).

Electronic networks can also break down the isolation that exists within and among schools and offer teachers and students an opportunity for authentic learning. The networks encourage teamwork, collaborative inquiry and facilitate individualized instruction (Levin & Thurston, 1996). Students can collaborate with others and verify, discuss, and modify their knowledge. "When teachers shift classroom lessons from whole group instruction to small group investigation or team projects, there is an improvement in instruction and learning which

fosters prosocial patterns of peer interactions and relationships" (Riel, 1990, p.445). Networks make it possible to create highly interactive groups of students and teachers that would normally remain isolated from each other.

In science classrooms, electronic networks are emerging as a method of using technology to communicate and discuss scientific findings with others. The GLOBE project, KidsNet by National Geographic and Feeder Watch by Cornell University are all existing projects that allow students to communicate and share their findings with others and discuss their results globally. These electronic networks create "microworlds" of student learners. Students become critical of each others' work as they collaborate on projects (Brienne & Goldman, 1989). By addressing a problem shared across the different locations, students learn to transfer solutions used elsewhere to their own problems. This is one strategy for dealing with the difficulty people have with transferring knowledge from one domain to another. For example, in a research study by Levine, Miyake, and Cohen, (1987) students tackled a problem in their own community, the problem of water shortages, and shared their solutions with others. They also acquired science concepts in an instructional setting that provided dynamic support for the acquisition of problem solving skills.

In summary, research indicates that the use of electronic networks has potential for enhancing learning. This study examined the benefits of electronic networking in a different context, that of using telecommunications in a collaborative process as two classes of students planned and carried out a scientific investigation. Collaboration occurred after each step of the scientific process through a series of teleconferences in which students had verbal and visual contact with each other. They chose their problem together and developed a hypothesis, designed the procedure, and discussed the results electronically as a group. Students drew conclusions and discussed problems encountered collectively using the network. To ascertain potential benefits of using telecommunications, students who used telecommunications were compared to students who did not communicate with each other electronically but did engage in the same science investigation. Therefore, this study considers the potential for learning with technology not just from technology (Dillon & Gabbard, 1998) and addresses the growing body of research on technology uses in science education.

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Research Questions

The purpose of this study was to investigate the use and effectiveness of electronic networking in a problem-based science experiment conducted by eighth grade students. The following questions guided the study:

1. Are there differences in attitudes between students who do and do not use an electronic network during a scientific investigation?
2. Does the use of an electronic network enhance learning?
3. Does the use of an electronic network impact classroom interaction?

Theoretical Framework

This study applies the theoretical framework of social constructivism to interpret the impact of an instructional unit developed to teach the critical thinking skill of problem solving to students in the context of an ant biomonitoring experiment. Two classes of students used an electronic network to provide peer collaboration and interaction between classrooms while two other classes of students collaborated with peers within the respective classrooms.

While it is true that constructivism is difficult to define and that many models have been proposed, constructivism is not any

particular model, but something that looks like each of them under appropriate circumstances (Wertsch & Toma, 1995). The model in this study assumes that all knowledge is social in nature and that learning occurs in a context of social interactions that leads to understanding (Rohler & Cantlon, 1997, p. 8). Learners are given opportunities to restructure information and connect new material with previously known



information. They generate questions and gather information, as they are actively involved in the problem solving process. As the students verbalize how to solve problems, adults and peers provide verbal cues that lead them to see the problem more clearly. According to Vygotsky, this area in which optimal learning can occur is called the zone of proximal development (ZPD). Wertsch (1985) defined the ZPD as: "The distance between the child's actual developmental level as determined by independent problem solving and the higher level of potential development as determined through problem solving under adult guidance and in collaboration with more capable peers" (pp. 67-68). The assistance provided by an adult or more capable peer in the ZPD is called scaffolding and is characterized by the social interaction among students and teachers as they internalize knowledge, skills, and dispositions valuable for the learners (Rohler & Cantlon, 1997). The teacher or more capable peer guides the learner's emerging understanding and offers assistance as needed in this verbal relationship. However, this process can also be facilitated by interactions with equal-ability peers in horizontal relationships. As the teacher and the students discuss the problems, students learn to think, construct, and clarify ideas. The group interaction will allow students to recognize when their comprehension is not adequate and promote understanding that a number of different ideas are possible, although different than their own. The group clarification process and a shared information base deepen the comprehension of the individuals in the group (Hatano & Inagaki, 1991). The teacher and students co-construct knowledge, gain new understandings, and feel responsible for their own learning and the learning of others (Roehler, Hallenback, & Svoboda, 1996). Conceptual change occurs as the students integrate these concepts into a conceptual schema and transform the experience into a coherent system (Howe, 1996). Thus, the internalization process of learning begins on the social plane and moves to an inner plane where the information becomes a part of the individual's evolving knowledge base (Rohler & Cantlon, 1997).

METHODOLOGY

Subjects

To reduce the effect of differences in school populations, two school sites with similar student demographics were chosen from the same county and community in the southeastern United States. The teacher-researcher served as a full time teacher at one of the school sites. A science teacher from the other school site volunteered to be a part of the research project. Each teacher

selected two classes enrolled in a required eighth grade, general science course to participate in the study (n = 100). Before beginning the study of 100 participants, it was ascertained that no student had prior experiences with either the content or the methodologies planned for the study. The two teacher participants selected one class, each which met from 11:15 - 12:00 PM daily, to participate in a scientific investigation using an electronic network. An additional class of each teacher participant was selected to conduct the same scientific investigation independently.

Instructional Activities and Procedure

In planning the instruction for this project, the steps of skillful problem solving and scientific method were interrelated and purposefully taught using experimentation.

The rationale for this approach was based on the understanding that problem solving skills are critical to the process of conducting scientific investigations. "In problem solving in science, we want students to use what they know to construct possible solutions to problems and to determine whether they will work" (Swartz, 1991. p.70). Swartz and Parks (1994) recommend infusing instruction in the problem-solving process into investigations by using graphic organizers and verbal maps to guide students through the steps of skillful problem solving. In this study, scientific inquiry through experimentation was used to guide students through the problem solving process. An ant biomonitoring experiment was selected for this study because it uses the steps of scientific inquiry as defined by the National Science Education Standards (NRC, 1996) and incorporates the teaching of skillful problem solving as the critical thinking skill necessary to do "scientific inquiry". Dr. Stephen Peck of the Environmental Monitoring Assessment Program, USEPA, the United States Department of Agriculture and Dr. Harriett Stubbs and Dr. Norman Anderson of Sci-Link, North Carolina State University (1997, 1999), developed the protocols used to conduct the ant biomonitoring experiment. The ant biomonitoring experiment had been tested on approximately 1,000 students before this study took place.

Prior to the study, a hyperstudio stack of the framework of the ant biomonitoring project was developed to guide the students through the problem-solving technique. The steps in skillful problem solving (Swartz & Parks, 1994) were intertwined with the steps in the scientific method. All four classes followed the same framework using the hyperstudio stack (Figure 1). The four classes, two working independently, and two working collectively through four teleconferences, formulated a problem, hypothesis, procedure design, data collection, and conclusions. The responses and data of each class were recorded in text boxes in the hyperstudio stack. The teachers collaborated to develop a three-week calendar so that all the classes completed the same parts of the study on the same day.



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Meridian: A Middle School Computer Technologies Journal
a service of NC State University, Raleigh, NC
Volume 6, Issue 1, Winter 2003
ISSN 1097 9778

URL: <http://www.ncsu.edu/meridian/win2003/problemsolving/2.html>

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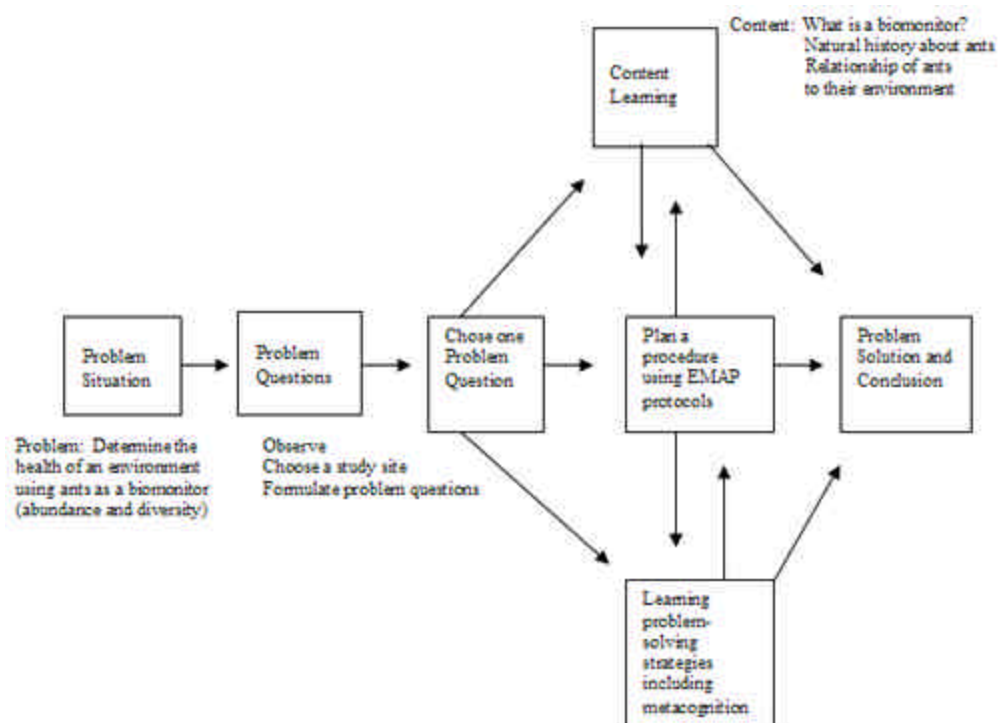
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Figure 1 Problem-Solving/Ant Biomonitoring Experiment Framework (modified from Swartz, p. 125, 1996)



First, each class was introduced to the concept of biomonitoring in the background section of the stack. Then by class, the students silently walked around their school campus looking for and observing ants. After returning to class, they brainstormed questions they might want to ask about ants. These were recorded in text boxes in the hyperstudio stack. Finally, each class decided on a study site on their school campus and a problem question regarding ants and where they lived. The individual classes selected their own sites and chose the following questions: "How does the distance from a wall affect the population of ants?" and "Will more ants be found in the sun or the shade?" The two telecommunication classes had four teleconferences. The time and goals of each teleconference was predetermined by the teachers and communicated to the students beforehand. The goal of the first teleconference was to determine the problem question, the second to determine the procedure, the third to discuss the results, and the fourth to draw a collective conclusion from the data. The goals of each teleconference were met, however one topic often carried over into the next teleconference. For example, the site and placement of the pitfall traps in relation to the data were discussed during the conclusion teleconference and the results were clarified and discussed again. The teleconferences were conducted using Microsoft Netmeeting and averaged 37 minutes per session. Students were instructed to take notes and record what was discussed during each teleconference. Students could see each other but communications were typed into text boxes. One computer in each classroom was projected onto a screen using a digital projector. Students took turns typing in responses that came from the class.

The two telecommunication classes chose similar sites on their respective school grounds and formulated one problem question. This allowed them to perform one experiment collectively but share results from each school site. Their problem question was "Do ants prefer grass or dirt?" The classes then developed a procedure, conducted the experiment, and collected and recorded the data. They graphed the data and drew conclusions from the data that answered their problem question. At the end of the hyperstudio stack all students were asked to "think about their thinking". These results were recorded in the text boxes of the hyperstudio stack.

Data were collected through a variety of techniques. Written surveys using an open-ended response format were used to collect information about students' conceptual gains as well as student attitudes about the investigation. Group lab reports and pre- and post assessments of problem solving were collected from both groups of students and scored. Student dialogues were captured through the use of audio and videotapes and by typed verbal dialogues from the Netmeetings for the teleconferencing classes. Four students randomly selected from each group were interviewed upon completion of the project. During the taped interviews, they were asked to define biomonitoring, to explain the importance of biomonitoring, and to describe their favorite part of the experiment. Other questions asked during the interviews were used to verify the validity of information received in the surveys.

Data Analyses & Results

Analyses of the data from each of the several sources were used to make comparisons between the telecommunications and non-telecommunication students.

Cognitive gains

Differences in students' ability to effectively engage in problem solving were assessed in two ways. An extended written response assessment developed by Robert Swartz (1991) and used in a national study in 1994 was used to assess students' problem solving ability. This extended written response assessment was piloted by the teacher-researcher in 1996 with a sample of 100 students with similar academic characteristics. Based on the results, the assessment for this study was reworded to improve clarity and specificity. A pre- and post-test was given to each student involved in the study to assess changes in their problem-solving ability (Swartz, 1991). A random sample of twenty tests from the telecommunication classes and twenty tests from the non-telecommunication classes was scored using a grading rubric (A. Fisher, personal communication, July 25, 1998). A t-test was conducted to determine the differences between the two groups. The results indicated no differences between the pre- and post-tests for either group.

The conclusions from the group lab reports that resulted from the investigation provided a second source of information about the enhancement of students' problem solving skills. During the investigation, all students worked in lab groups of two or three. Each lab group produced a lab report following a detailed rubric. The conclusions of each lab report were scored according to a Multiple Rating Assessment method developed by Alec Fisher and Michael Scriven (1997). The criteria for the grading rubric were established prior to beginning the investigation and were distributed to students before they wrote their lab reports. The criteria selected had been identified by Costa (1990, 2002) as evidence of appropriate application of thinking skills in the context of problem solving. In his book, *Developing Minds* (2002), Costa states that the characteristics of a good thinker include elaborating reasons, looking for alternative as well as multiple possibilities, deliberate analyzing of possibilities, and looking for evidence that is in support of or against the solution. Therefore, elaboration of ideas, citing supporting evidence, and analyzing possibilities became the primary criteria for scoring. For each criterion, lab group responses were rated on a 0-2 scale. A score of 2 represented a complete response, 1 a fair response with some weaknesses, and 0 an unacceptable response. The criteria subscores were then totaled for each group to establish a lab report conclusion score. The teacher-researcher and an independent scorer scored all of the lab report conclusions establishing an interrater reliability of 0.79.

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Volume 6, Issue 1, Winter 2003

ISSN 1097 9778

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The lab group conclusion scores of the telecommunications and the non-telecommunication groups were compared using SAS statistical software (see Table 1). A Chi-square test was used to examine teacher * model interaction and it was found not to be significant ($P > 0.25$). A block design without teacher interaction reported a lab mean of 3.35 out of 5.0 and a weak association between the telecommunication and non-telecommunication lab group conclusions ($F = 1.28$). A larger sample size and additional repetitions of the model would be needed to determine if there were significant differences in the lab group conclusions.

Table 1: Analysis of Lab Report Conclusion

R-Square	Root MSE	F Value	Lab Mean	Coeff Var	Pr > F
0.303684	38.29653	1.283451	3.351351	7.41	0.0021

A third source of information about cognitive gains in the context of the investigation was collected by means of responses from an open-ended survey administered to all students at the end of the project. When students were asked what they would change about the experiment, 27% of the teleconferencing group and 38% of the non-teleconferencing group indicated that changing the procedure or reducing the number of variables would improve the experiment. The validity of the responses demonstrated that students learned important concepts about experimental design. They were also asked to indicate what other questions they could answer by engaging in this type of experiment.

Students in the teleconferencing groups (33%) and in the non-teleconferencing groups (47%) were able to suggest applying the experimental design used in the ant biomonitoring experiment to a different experiment using ants or another animal. When students were asked to apply the technique of skillful problem solving to other situations, only four of fifty students from the teleconferencing classes and three of fifty students from the non-teleconferencing classes were able to transfer the technique to a new situation. A response that problem solving could be used to resolve an argument with family or friends would be an example indicative of transfer. It was not surprising that there was little evidence of transfer since the process must be emphasized and repeated for transfer to occur. Furthermore, transfer requires abstract thinking and developmentally most 13-year-old students are transitioning from concrete to an abstract level of thinking. Therefore, few students were able to transfer the technique of skillful problem solving to new situations.

The most important difference elucidated from survey responses were the number of students in the telecommunicating classes (11), as compared to the number of students in the non-telecommunicating classes (2), who suggested using what they learned from the ant biomonitoring experiment to plan or change the experiment and then repeat it. The telecommunicating students had evaluated the experiment and their results and were able to suggest ways to change the experiment in order to get more reliable results. From their conclusions and discussions, the teleconferencing classes better understood the concept of how to use bioindicators to monitor an environment and the importance of repeated trials in order to get reliable results.

In an open-ended response format students were asked to explain other questions that they would like to answer using the same type of experimental design. Students in the non-telecommunicating classes responded (44%) that they would include and observe other animals besides ants found in the pitfall traps whereas telecommunication students responded (44%) that they would observe other animals besides ants by looking for them in their habitats. Only the telecommunication classes redesigned the ant biomonitoring experiment using a different problem question (29%). In conclusion, these results indicate that the students in the telecommunication classes were more successful in evaluating the ant biomonitoring experiment and applying it to new situations.

Interviews further supported the findings from the open-ended responses that the students in the telecommunications classes more clearly understood the concept of biomonitoring. Biomonitoring was defined in the hyperstudio stack as using living organisms to study change in the environment. Therefore, a complete and correct answer would include both components of the definition. Since none of the students had prior knowledge of biomonitoring, any understanding of this subject resulted from participation in the investigation. Three of the four telecommunication students defined biomonitoring correctly whereas only one of the four non-telecommunication students was able to define it correctly. Furthermore, the students who defined biomonitoring correctly were able to give reasons why it was important that substantiated their descriptions. Students who understood the concept said things such as, "It is important because we should know about our environment and how much it changes every day" and "It is important because you find out how humans are changing the environment, by pollution for example ". Students that did not understand the concept said things such as, "It is important because we need to

understand animal behavior and its patterns". Therefore, open-ended responses and the interviews seem to indicate that the telecommunications students were more likely to grasp the concept of biomonitoring than the non-telecommunication students.

Student Attitudes

Several questions in the open-ended survey addressed students' feelings about what they liked or disliked about the investigation. The individual responses to the questions were placed in categories and the telecommunication and non-telecommunication classes were compared.

Some students in the teleconferencing groups liked the teleconferences (38%) but others (20%) indicated that they did not like them. Students liked setting the pitfall traps (20% teleconference and 25% non-teleconference), working outside (20% teleconference and 22% non-teleconference), and classifying the ants (16% teleconference and 22% non-teleconference). These responses indicate that students from both groups enjoyed doing the experiment. Eight of the ninety students surveyed expressed concern over the fact that the ants died and seven students did not like working with insects at all. Students in the teleconferencing group (38%) indicated that they enjoyed communicating with a class from another school. Students in the non-telecommunication group (17%) indicated that they enjoyed the class discussions. One telecommunication student said in the interview that, "Telecommunicating with other schools gives you more results and it's different from site to site." A student from the non-telecommunication class indicated that, "My favorite part of the experiment was the classroom discussion and the entire class doing an experiment together." Students seemed to enjoy the fact that each lab group was doing one part of a class experiment. As a result of this interdependence, the students were accountable to each other for collecting and sharing accurate data. These shared class results become one experiment in which everyone agreed upon a conclusion based on the results. Interviews verified the results from the open-ended response.



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Student Dialogs

Four 45-minute discussions from the non-teleconferencing classes were selected, transcribed, analyzed and compared to the teleconferencing group's dialog. The discussions chosen for transcription were days in which the discussions paralleled those of the teleconferencing classes. Student talk was transcribed and classified to ascertain peer interaction differences between groups.

The student dialog was analyzed using a modified version of the Flanders Interaction Analysis System (1970). Flanders did extensive classroom observation of thousands of teachers at all educational levels and in many different content areas (Reinman & Sprinthall, 1998). He categorized teacher talk into eight areas and student talk into two areas. The ten categories were grouped in two major clusters; indirect, Categories 1 to 4, and direct, Categories 5 to 7 according to Nate Gage (1978). Indirect interactions are more participatory and are more typical of the types of interactions that promote the construction of concepts. Direct interactions tend to be univocal in nature and do not promote collegial building of understanding. According to Vygotsky, indirect interactions or the collective construction of knowledge in which constructive interaction takes place is the primary mechanism of intellectual development. He believed that language is central to the development of thought and it is through words that meaning is formed and redefined. In fact, Vygotsky argued that social interactions are the basis for an individual's development (Howe, 1996). Gage (1985) found that at the secondary level, there is clear evidence that a more

direct mode leads to greater academic gains. Flanders also found that the quality and frequency of student talk had a tremendously positive effect on student achievement (Flanders & Morine, 1973).

On the modified instrument, eight categories were established with Categories 1-4 representing indirect talk and Categories 5-7 representing direct talk. Category 8 represented neither direct nor indirect talk but confusion. Confusion in this study was defined as many students speaking at the same time. This type of talk was treated as part of the total student responses and therefore is reflected in the indirect and direct percentages. Students' direct to indirect talk as well as the number of student responses per time period were compared (Table 2). To determine interater reliability (.82), the teacher-researcher and an independent scorer scored two of the four transcripts for each group.

Table 2: Students' Responses by Category for Each Class Period

Telecommunication Classes					Non-Telecommunication Classes							
One class at each school					School 1				School 2			
Category	Meeting Number				Meeting Number				Meeting Number			
	1	2	3	4	1	2	3	4	1	2	3	4
1 Accept Feelings	0	0	0	0	0	0	0	0	0	0	0	0
2 Praise/Encourage	1	0	0	9	0	0	0	0	0	0	0	0
3 Accepts Ideas	11	10	15	27	3	0	0	10	2	0	2	0
4 Asks Questions	15	11	22	17	17	3	2	3	9	2	5	4
Subtotal 1-4	27	21	37	53	20	3	2	13	11	2	7	4
5 Lecture	19	14	30	35	66	29	13	55	33	28	35	42
6 Directions	8	4	3	2	1	0	0	0	0	0	0	0
7 Criticizes	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal 5-7	27	28	33	37	67	29	13	55	33	28	35	42
8 Silence/Confusion	2	0	0	1	0	0	0	7	2	0	0	0
# of student responses	56	49	70	91	87	32	15	75	46	30	42	46
% Indirect	48	43	53	58	23	9	13	17	24	7	17	8
%Direct	52	57	47	42	77	91	87	83	76	93	83	92

Students in the teleconferencing group asked more questions (1.3 per student) than the non- teleconferencing groups (0.48 per student) and the number of questions asked remained high in the teleconferencing group for each meeting. Teleconferencing students used praise and encouragement type responses and accepted and used each other's ideas 75% more frequently than the non-teleconferencing groups. Furthermore, students in the telecommunication classes interacted indirectly 52% of the time compared to the non-telecommunication classes that interacted indirectly 18% and 15% of the time (Table 3). However, the number of student responses remained high in all groups with the non- teleconferencing class having the highest number of responses (87). All classes had some confusion when students became excited, but this was minor compared to the total number of student interactions. The most important difference in the student interactions between the two groups is the proportion of direct versus indirect dialog. The teleconferencing groups' discussions were 36% more indirect than those of the non-teleconferencing groups because they asked more questions and used each other's ideas more frequently in their conversations.

Table 3: Summary of Indirect and Direct Student Responses

Totals	Telecommunications Classes (one at each school)	Non-Telecommunications Classes	
		School 1	School 2
Indirect	138	38	24
Direct	125	164	138
% Indirect	52	18	15
% Direct	48	82	85



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Discussion and Conclusions

This study explored the differences between students that do and do not communicate electronically while conducting a science experiment. Students' social interactions, conceptual understanding, and attitudes were compared. In addition, this study sought to identify the effects of using an electronic network in the context of a problem based investigation.

The theoretical framework of social constructivism was utilized in designing the instructional plan and in interpreting the study results. Students constructed their knowledge with the assistance of more capable adults and equal ability peers. Teachers and students provided scaffolding in the ZPD as students were guided through the steps of skillful problem solving through discourses. As students discussed the problems, they constructed and clarified ideas. The group interaction caused students to recognize when their comprehension was not adequate and promoted understanding that a number of different ideas were possible. Many opportunities were provided for students to construct their knowledge through language. Learning in this type of environment provides an opportunity for students to take control of their own learning and to respect their own and each other's thinking. Teachers and students form a "thinking community" in which they clarify ideas, formulate problem questions, and solve problems collectively, thereby, gaining new understandings together.

The results of the pre- and post-test to measure an increase or decrease in problem solving ability were inconclusive. Students remembered the questions

and previous answers from the pre-test because of the short three-week time frame between the two tests. Therefore, many of the answers on the tests were close or identical. It is probable that repeated exposure to the direct teaching of skillful problem solving would yield more positive results.

According to results collected by student interviews and surveys, student attitudes toward communicating electronically and toward the ant biomonitoring experiment varied. Some students enjoyed communicating electronically, but about the same number did not like it at all. Students expressed frustrations with the technology and the delays that are inherent in this type of electronic connection. It was interesting to note that an "acquaintance period" occurred between the telecommunication classes. The number of student responses increased as students became more familiar with the technology and each other. The conversation flowed liberally during the fourth teleconference and became more important than learning how to use the technology. Most students enjoyed setting the pitfall traps, classifying the ants, and going outside. Many expressed that "I have never done anything like this before". The ant biomonitoring experiment was unusual in that each student group had a distinct part in a class experiment. This design encouraged class discussions of results and conclusions which many students found valuable. Frequently, in classrooms, individual lab groups perform experiments with all lab groups doing the same experiment at the same time, each drawing their own conclusions. Students in this experiment were more positive toward the approach used in the ant biomonitoring experiment in which the entire class participated in one experiment.



Biomonitoring is a difficult two-step concept in which students must understand that living things are used to detect changes in the abiotic components of an environment. According to student interviews and open-ended survey responses, the telecommunication students were more likely to grasp the concept of biomonitoring.

The most important finding of this study is the difference in the patterns of student dialogs between the telecommunication and non-telecommunication groups. Research indicates that more indirect talk and more student talk leads to greater academic gains (Gage, 1985). Flanders found that the quality and frequency of student talk also has a tremendous effect on student achievement. Students in the telecommunication group asked more questions, praised and encouraged each other more often, and more frequently accepted each other's ideas. While the number of student responses did not vary greatly, the telecommunication classes' dialog was significantly more indirect. This supports Riel's (1990) findings in that electronic networks shift classrooms from teacher-centered whole group instruction to student-centered small group investigation teams or projects. The quality of student talk improved, and thereby the

students' understanding of the biomonitoring concept.

Students asked more questions in the teleconference group because they had something to ask questions about. Even though both groups investigated the same problem question, performed the same procedure, and choose similar study sites, their results were different because of environmental differences at respective sites. This created an atmosphere of dissonance, which motivated students to determine why. Students participated in horizontal or peer interaction 100% of the time during the teleconferences and therefore were motivated to disclose their ideas to each other because there were no authoritative right answers. In a more traditional classroom such as the non-teleconferencing classes, the teacher asks questions, and the students respond. The teacher is more direct in his or her approach and students seek to give the "right answer". In the teleconferencing groups, students motivated by the group interaction invented their own knowledge based on information proposed by others. Teleconferences during key problem-solving steps in the experiment helped students realize that there were a number of possible ideas different from their own. Students became collectively involved in an experiment in which there were many possible solutions. They were able to more successfully construct knowledge through group interaction because they had a richer more diverse data set and through indirect interactions were able to reach a collective conclusion about their experiment. Therefore, teleconferencing may assist the classroom teacher with adopting the role of facilitator, a role recommended by the NSES.

Electronic networks have other implications for education. They can break down barriers and isolation within classrooms. When communication is established between groups of students, each group benefits from the others' strengths. They share their knowledge with each other and in areas that are geographically isolated. Electronic networks can facilitate sharing a wider view. Students can gain a better understanding and appreciation for each other as they solve a common problem and work toward a common goal. This study shows that there is great potential for learning with technology not just from technology and more studies need to be conducted to identify these applications.

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Electronic Networks for Educators

AT&T Learning Network

<http://www.att.com/learningnetwork/>

Technical Educational Research Center

<http://www.terc.edu/>

Feederwatch

<http://birds.cornell.edu/cfw/>

Journey North

<http://www.learner.org/jnorth/>

WhaleNet

<http://whale.wheelock.edu/Welcome.html>

JASON Project

<http://www.jason.org/>

KidsNet

<http://www.kidsnet.org/>

GLOBE

<http://www.globe.gov>

PathFinder Science
<http://pathfinderscience.net/>

EstuaryLIVE
<http://www.estuarylive.org/>

GIS LIVE
<http://www.ncsu.edu/scilink/gislive>

The Elephants of Cameroon
<http://www.nczooeletrack.org/>

Red Wolves of Alligator River
<http://www.nczooredwolf.org/>

Ant Resources

Grids and data collection sheets can be downloaded from the Mapping Our School Site (MOSS) at www.ncsu.edu/scilink/studysite. Additional pitfall trap instructions, a picture field guide of insects, and other resources and information can be found at the site. MOSS is an outdoor environmental curriculum for teachers and students relating the living and non-living components of the environment.

Materials Resources

Ant kits, monitoring the environment series, and curriculum as well as supplies, videos, and teaching resources on ants are available from Carolina Biological Supply Company. Educators can visit the company's Web site at www.carolina.com or call 800-334-5551.

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Meridian: A Middle School Computer Technologies Journal
a service of NC State University, Raleigh, NC
Volume 6, Issue 1, Winter 2003
ISSN 1097 9778
URL: <http://www.ncsu.edu/meridian/win2003/problemsolving/7.html>
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APPENDIX A: An Example of a Multiple Rating Item

Lab Conclusion Grading Rubric

Instructions: Place the grading rubric next to the lab conclusion. Read the examples of responses that represent the number score for the criteria you are grading. Read the conclusion and assign the number of points that most closely represents the type of answer given by the students. Repeat this process for all of the criteria and then add the points together in order to assign a total score.

1. Clearly Stated Conclusion. Answers problem question and explains why. (2 points)

0 - Some of the cups had more ants than others.

1 - The cups closest to the wall had more ants or cups in the dirt had more than those in the grass or more ants were found in the sunlight than the shade.

2 - Cups numbered 2 and 3 had the most ants because they were closest to the wall or the cups in the dirt had 10 more ants than those in the grass because the area was heavily traveled or it was difficult to determine if there were more ants in the sun or shade because some of our cups were vandalized but the experiment did show 2 more ants in the sun than the shade.

2. Details to Support Conclusion. Uses specific cup numbers, numbers of ants and sizes of ants or describes environment in which cups were placed. (2 points)

0 - Some cups had two ants but others had 10 ants or there was a larger population of red ants than black ants in our testing area.

1 - Cups 9 and 10 had fourteen ants but the other cups had less or the grass environment contained the most red ants with 25 followed by the dirt environment with 10 ants or we found 8 black ants and two red ants and they were all small in size.

2 - Cups 9 and 10 had fourteen ants while cup 11 had eighteen ants because they were in the shade or in the grassy area there were 59 ants compared to 20 in the dirt area and 17 in the middle area or there were 7 small black ants and one large black ant and one small red ant and one medium red ant and the ants preferred the sun over the shade.

3. Clear, detailed, elaborate. Explains why they think they got those results. (2 points)

0 - Section missing

1 - Our hypothesis was proven, there are more ants next to the wall or our hypothesis was right and ants do prefer grass over dirt or we found 5 black ants and 1 red ant in the sun and 3 black ants and 1 red ant in the shade, so ants prefer sun over shade

2 - There are several explanations of why we obtained these results, one is that ants tend to stay away from disturbed areas or 28 black ants were counted in the grass but only 4 were found in the dirt because there was more food for the ants in the grass or ants prefer the sun over the shade because there were more plants on the sunny side of our site.

APPENDIX B

CATEGORIES OF MODIFIED FLANDERS INTERACTION ANALYSIS

INDIRECT

1. Accepts or clarifies feelings: Predicting or recalling a feeling in a non-threatening manner, feelings can be positive or negative.

2. Praises or encourages: Praises or encourages action or behavior. Humor that releases tension. "Tell me more" statements are included.

3. Accepts or uses others ideas: Clarifies, builds, or develops ideas suggested by another student.

4. Asks questions: Asks a question about content or procedure.

DIRECT

5. Lectures: Gives facts or opinions about content or procedure, expresses his or her own ideas.

6. Gives directions: Directs, commands, or gives orders.

7. Criticizes or condemns another student: statements that are made to change the behavior or opinion of another student and are negative and directed "at" another person.

8. Silence or confusion: Pause, wait time, or confusion.

INDIRECT (No. 1-4) / TOTAL # OF RESPONSES = % OF INDIRECT RESPONSES

DIRECT (No. 5-7) / TOTAL # OF RESPONSES = % OF DIRECT RESPONSES

APPENDIX C

SKILLFUL PROBLEM SOLVING AND THE SCIENTIFIC METHOD

Why is there a problem? ----- Background

What is the problem? ----- Problem Question
--

What are the possible solutions
to the problem? ----- Hypothesis/Procedure

What would happen if you solved Data/Results
the problem in this way? -----

What is the best solution to the
problem? If you did it again, what
would you do differently? ----- Conclusion

Source for skillful problem-solving: *From Infusing the Teaching of
Critical and Creative Thinking Into Content Instruction* (p. 78), by R.
Swartz and S. Parks, 1994, CA: Critical Thinking Press and Software.

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Meridian: A Middle School Computer Technologies Journal
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Volume 6, Issue 1, Winter 2003
ISSN 1097 9778
URL: <http://www.ncsu.edu/meridian/win2003/problemsolving/8.html>
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