One Modem, Many Kids:
A Case Study of a Middle School Classroom
Participating in the Kids as Global Scientists '97 Program

Rosalind Kam and Nancy Butler Songer
The University of Michigan

Contact Information:
Rosalind Kam (kamr@umich.edu)
One Sky, Many Voices Research Team
1228 School of Education
610 East University Ave.
Ann Arbor, MI 48109
http://www.onesky.umich.edu/NARSTpaper

Paper presented at the Annual Meeting of
the National Association for Research in Science Teaching
San Diego, California
April 19, 1998

INTRODUCTION

Context and Purpose of the Study

This case study took place in a middle school classroom which participated in an innovative Internet-integrated curriculum program known as Kids as Global Scientists (KGS) '97. The program involved an eight-week curriculum in which students worked in small groups in their classrooms on a series of learning activities designed to develop an understanding of weather. These activities included collecting local weather data, sharing of student-collected data, and communication with peers participating in KGS worldwide as well as weather specialists.

The purpose of this study was to observe the nature of learning and instruction in a classroom in which the teacher was a first-time participant in the KGS program. Of particular interest is the fact that this teacher had limited access to the Internet, through one modem in his science classroom. This teacher was therefore attempting to implement an Internet-integrated curriculum without the infusion of high-technology hardware that is typically associated with testbed sites of research projects involving the use of technology.

Although many calls have been made for wider implementation of such innovative technology-enriched curricula (e.g. U.S. Congress Office of Technology Assessment, 1995), success in classrooms does not come easily. We hope that by analyzing the dynamics of what takes place in the classroom, this paper can help teachers and researchers better understand the challenges involved in the implementation of innovative curricular programs.

Research Questions

This study is framed by the following questions: What is the nature of learning and instruction in a classroom with a teacher participating in the KGS program for the first time? In particular, how do the students and the teacher enact the features of KGS such as collaborative learning in small groups, exchange of information and data with distant peers, and communication with weather specialists, within the constraints of limited access to the Internet? How does this learning experience affect the students’ self-perception of ability, motivation to learn, and attitudes towards science? What are the pedagogical implications of this learning experience for classroom practice?

THEORETICAL FRAMEWORK

The KGS Learning Approach

The learning approach embodied in the KGS program is based on providing students with the inquiry tools and resources needed to develop rich understandings and questions focused on a specific content area in science (Songer, 1996). Specifically, this approach includes the following central features: the study of real and complex problems associated with weather phenomena; the use of multiple on-line and off-line information sources including real-time data, peers and mentors in many locations; problem-based research with emphasis on reflective questioning, data collection, analysis, comparisons and predictions, and inquiry-based activities; exchanges of questions and responses among students, peers and mentors; the development of knowledge beginning with local phenomenon and then extending it to other locations; collection of firsthand, local data, and comparing with data collected by others; the participation of students as providers of information and data; the role of teachers as facilitators of student research rather than as information providers; and participation in a learning community (Songer, 1996).

The collaborative features of the KGS learning approach are rooted in the recognition that learning involves the social construction of knowledge (Vygotsky, 1978), and the concept of distributed expertise (Aronson, 1978). In collaborative learning, distributed expertise and multiple perspectives enable learners to accomplish tasks and develop understandings beyond what they could achieve alone (Edelson, Pea & Gomez, 1996). Additionally, Koschmann et al. (1994) contend that collaborative learning offers a way of addressing some of the known failures of traditional methods of instruction and provides opportunities for exposure to multiple perspectives and interpretations, as well as opportunities for learners to articulate their knowledge.

In the KGS program, students become experts in different content areas and become resources for their peers. Integral to the nature of social interactions in the construction of knowledge is the discourse that takes place in the community of learners (Brown, 1994). This communication requires learners to organize what they know and to enables them to identify gaps in their understanding. In the case of KGS, the discourse community extends beyond the classroom to that of the larger community of participants in the worldwide program.

Students' Self Perception of Ability, Motivation to Learn, Attitudes towards Science, and Gender Differences

Self-Perception of Ability

Students' *self perception of ability* is a construct of self-worth theory proposed by Covington. According to Covington (1992), self-worth is a basic need of all individuals. People are primarily motivated by the need to perceive themselves as competent. Due to the value placed on achievement by society, students may associate high self-worth with high academic ability.

Motivation to Learn

Pintrich and Schunk (1996) define *motivation* as the process whereby goal-directed activity is instigated and sustained. This definition is based on a cognitive view of learning. It places importance on goals as the impetus for and direction to action. From a goal theory perspective, Ames (1984) relates students' motivation to three types of goal structures that students may have: competitive, cooperative and individualistic. When students work in groups, competitive students may be motivated to outperform others to demonstrate high ability. Cooperative students may demonstrate social responsibility by paying attention to one another's efforts and reinforcing individual members' efforts that enhance group performance.

Students' motivation is also influenced by their perception of the autonomy orientation of the classroom environment. Allowing students to have a say in establishing priorities in task completion, method or pace of learning raises their perception of control, and this is a significant factor affecting their engagement in learning (Ames, 1992).

Attitudes towards Science

Students' *attitudes towards science* refer to "general enduring positive or negative feeling about science, and should not be confused with scientific attitude" (Koballa & Crawley, 1985, p. 223). The research shows that children's attitudes toward science appear to become less positive as they progress through the elementary grades, and become even less positive as students move onto middle school and high school (Koballa, 1995).

Gender Differences

The sixth grade students in this case study were all 11 or 12 years old, which can be considered the early adolescent years. Previous research has shown that early adolescence is a particularly difficult transition period for girls, with significant declines in girl's self-confidence as they move from childhood to early adolescence (AAUW, 1992). For the students in this study, it also marks the age at which they transition from elementary to middle school. According to the AAUW report,

> Gender differences in confidence are strongly correlated with continuation in math and science classes. Math confidence is the surety a student has of her or his ability to learn and do well in mathematics (p. 28).

The report questions why reforms in science education are apparently working for males but not for females, and calls for more research on issues of confidence in studying possible causes of the gender gap in science.

Studies which show a gender difference in self-perceptions of ability in most cases find that females have lower self-perceptions of ability than males (Wigfield, Eccles, and Pintrich, forthcoming). This contrasts with studies that examine actual achievement or performance, which show either few gender differences or that females outperform males (Linn & Hyde, 1989). Wigfield et al. suggest that this discrepancy be attributed to a response bias, with boys being more self-congratulatory and girls being more modest.

In terms of motivation, differences between males and females in their motivation for achievement has often been proposed as an explanation for gender differences in achievement and, more recently, as an explanation for the smaller number of women in math and science careers in comparison to men (Meece & Eccles, 1993). Schofield (1995) ascribes the smaller number of females than males enrolled in computer science classes to the educational practices that emphasize the link between computers and masculinity in society and the social isolation of girls who choose to pursue their interest in computers.

Koballa (1995) reports that several studies of the relationship between gender and attitudes toward science conclude that girls have less positive attitudes toward science than boys, with these differences becoming more pronounced by ages 13 and 17. Other studies suggest that the attitudes of boys and girls differ depending on whether the biological or the physical sciences are considered. A study by Harvey and Edwards (cited in Koballa, 1995) concluded that 9 to 12-year old girls were less interested in physical sciences and more interested in biological sciences than boys of the same age.

Teachers' Beliefs and Pedagogical Approaches

Teachers' belief systems influence their teaching and those beliefs are generally consistent with classroom practice (Olson & Singer, 1994). Similarly, O'Loughlin and Campbell (1988) assert that prior beliefs influence how new information is processed; therefore, teachers' beliefs are likely to have a profound influence on their actions. An understanding of teachers' beliefs is important in helping researchers and curriculum developers understand how and why teachers teach the way they do, and whether innovative curricula may present conflicts with the pedagogical approaches with which they feel comfortable.

The theoretical framework of innovative programs are often couched in a theoretical language based on cognitive psychology, which differs from the practical language used by teachers, and the incommensurability of the two languages creates dilemmas for teachers (Olson, 1981). In describing a study with an innovative science curriculum project, Olson argues that teachers resolved this dilemma by translating the language of the innovative design into familiar terms, derived from their concern to exert a strong influence in the classroom.

Research into teachers' use of technology in their teaching identify certain characteristics of teachers that succeed in technology integration. According to a study by Honey and Moeller (1990), teachers' educational beliefs played an important role in whether and how they chose to make use of technologies in their classrooms. Those teachers who were high in technology integration ("high-tech" teachers) believed in student-centered approaches to learning (such as inquiry methods, collaborative learning, hands-on practices) and had used the technologies to implement this philosophy.

Those teachers who elected not to use technology were more diverse in pedagogical beliefs. Some teachers, despite believing in student-centered learning, were deterred by personal fears or inhibitions towards technology, had problems with accessibility and scheduling of equipment, or had limited knowledge of the approaches in using technology. Still others held on to their belief in traditional practice (following the routines of the textbook, using a lecture format, need to "cover" mandated curriculum requirements). These teachers reported not using technology because they feared it would undermine their authority with students or because they would not have enough time to complete the curriculum requirements.

Teachers who take on the challenge of participating in innovative curricular programs that utilize technology face many uncertainties in their roles. These include their willingness to recognize and feel comfortable not knowing everything about the technology, a willingness to seek out help and support, and a willingness to learn alongside and in collaboration with their students (Songer, 1998).

Feedback from teachers who have participated in KGS in previous years has revealed that first-time participants in KGS have tended to focus on getting the activities in the program done, and it is not until the third year of participation in KGS that teachers feel they understand the learning approach and its underlying philosophy (Songer, personal communication, February 1998).

BRIEF OUTLINE OF THE KGS '97 CURRICULUM

The Kids as Global Scientists program is aimed at engaging middle school students in inquiry and research on atmospheric science using an Internet-integrated curriculum. Students become local experts about their specific topic area, based on the distributed expertise approach to learning. The curriculum is designed to make science more authentic for students by having them collect their own weather data and work with real-time weather imagery as scientists do. Throughout the eight-week program, students work in small groups within their classrooms on a variety of activities. Through the use of telecommunications, they share their knowledge and data with their peers around the world and with on-line Weather Specialists.

The eight-week curriculum is divided into three phases. Phase One (2 weeks) is an **introductory phase** where students introduce themselves, their school, geography and local weather characteristics to other participants through a Message Board on the Internet. They also take photographs and record audio messages to be sent to the project staff for distribution to all participants on a compact disk (CD-ROM).

In Phase Two (3 weeks), which is the **research phase**, students become experts on one of the four main topic areas: (1) clouds and humidity, (2) precipitation, (3) temperature and pressure, and (4) winds. They collect daily local weather data using weather instruments, send their data to the community of participants, and research their topic areas using a variety of resources. Students communicate with each other and the weather specialists to comment or ask questions about their topic area. They also perform hands-on experiments in their classrooms and learn to interpret real-time satellite maps.

In Phase Three (3 weeks), which is the **exchange phase**, students analyze data by exchanging and comparing their data with data from other selected sites, and synthesize what they have learned by making weather predictions and communicating their predictions about the chosen sites. Towards the end of this phase, they publish aspects of what they have learned by writing news articles, personal stories or poems about weather for an on-line newspaper.

KGS '97 differed from previous versions of KGS in several aspects. The number of participants rose from 6 schools in 1992 to a record 80 sites from 5 continents and an estimated 4000 students in 1997. The main changes in the program involved the use of an Internet-based Message Board as the main tool for electronic communication, instead of e-mail. On-line information and data were accessed through the use of user-friendly web browsers such as Netscape, rather than through File Transfer Protocol (FTP). The interdisciplinary features of KGS were strengthened with the addition of writing for an on-line newspaper and sharing weather folklore.

DESCRIPTION OF THE RESEARCH

The Research Setting

This study took place in a public middle school in a small college town in the Midwestern region of the United States. Four classes taught by the same teacher participated in KGS '97. In order to gain access to the classroom, we offered to assist the teacher in the classroom for the first two classes of each day. The classes that were studied were the two sixth-grade classes in which the first author provided classroom assistance on a daily basis. Each class had science for one forty-five minute period five days a week. The teacher had over ten years experience of teaching science.

The total number of students in the two classes was 52, of which 24 were in one class and 27 were in the other class. The students comprised of 51% females and 49% males, of which there was a range of achievement levels. About 90% of the students were Caucasian-American, with the minority comprising African-American, Asian-American, Hispanic-American and multiracial students.

The study took place in the science teacher's classroom. At the front of the room was a long teacher's workbench, and a large chalkboard mounted on the wall. Student sat at rectangular wooden tables in pairs facing the chalkboard and the teacher's work bench, except when they were working in groups. On the left of the teacher’s work bench was a cart with a large screen television, video cassette player and a Macintosh computer connected to the Internet by a modem. There were also two old (Apple IIe) computers, one on the right of the teacher's work bench, while the other was at the back of the classroom. On the back wall was a projection screen with an overhead projector. The sides of the room were lined with work benches and sinks. Built-in cabinets above and below the work benches stored various science equipment and other classroom aids.

Science textbooks and reference books were piled on one work bench, as were folders containing students' work-in-progress. One corner also had a small exhibit of a variety of science paraphernalia. A rack of reading material was in a corner of the room. A stack of newly delivered newspapers lay on a table near the door. Various piles of student worksheets were also on this table. The teacher's work bench was covered with science equipment, folders, teaching aids and miscellaneous items.

Four computers, without Internet connection, were also available on carts with advance reservation from the school's Media Center. When available, these were stationed in the hallway outside the classroom.

Data Collection

The KGS 1997 program took place for a duration of eight weeks from January 27, 1997 until March 21, 1997. This study is based on the two classes in which the first author was a participant-observer for almost every school day during the eight weeks. Data was collected from multiple sources including field notes, student pre- and post-instructional surveys, copies of students' group folders, individual reports, and artifacts, interviews with eight students, and interviews with the teacher.

Field Notes

The main events or curriculum activities that took place during the class were recorded each day in order to document the development of the curriculum unit as enacted in this classroom. The field notes were coded for type and duration of activity, and student engagement in learning.

Student pre- and post-instructional surveys

Pre- and post-tests were administered to students in all schools participating in KGS as part of a larger study conducted by the KGS research team. These tests consisted mainly of content-area questions. The students in this study were given modified versions of the KGS tests, which we will term **pre- and post-instructional surveys** for the purpose of distinguishing the modified version from the KGS tests. These surveys included additional questions of particular interest to this study. The post-test contained the same items as the pre-test as well as additional items related to the curriculum.

From the student surveys we hoped to find out whether there were any changes in students' attitudes in several areas. These include: attitude towards science, perception of difficulty of learning science, self-perception of ability in science, attitude towards working in groups, learning preferences, willingness to share information with others, attitude towards participating in group discourse, attitude towards using computers for learning science, perceptions toward communications with others in the KGS discourse community, and expectations of achievement at the end of the unit.

The student pre-instructional survey could not be administered before the start of the unit due to scheduling difficulties and was administered two days after the start of the unit in both classes. The student post-instructional survey was administered to both classes on the last day of the KGS '97 program.

Students' artifacts

Messages sent by students to the electronic Message Boards during the Weather Unit were retrieved and copied as text files from the Message Boards. Copies were made of students' group folders containing their group work, as well as of the individual assignments.

Student interviews

Four students from each class were interviewed to probe their perceptions on items similar to those asked in the surveys. This was done to triangulate the data from different sources. From the student interviews we wanted to find out their attitudes towards science, towards computers, towards group work, and their perception of how relevant learning about the weather is to them. Each student was interviewed once early in the program, and again after the conclusion of the KGS program.

Teacher interviews

The teacher was interviewed at the end of the KGS program. Two short interviews were conducted immediately after the program ended and a long, comprehensive interview was conducted subsequently. The two short interviews focused on the teacher's method of grouping students and his characterization of the learning styles and background of the eight students who were interviewed.

From the teacher interviews we hoped to find out why he decided to participate in KGS '97, his pedagogical beliefs, his preferred style of teaching, his perception of his students' learning styles, his assessment of the disposition and level of motivation of the eight students, how he became interested in using technology, his views about using computers in the classroom, what amount of effort was involved in attempting the KGS curriculum and pedagogical approach, what difficulties he encountered and how they were overcome, and what he hoped to achieve in participating in the KGS program.

FINDINGS

This paper will report the preliminary findings on the changes in the teacher's pedagogical approach, the nature of teaching and learning in the classroom, and students' attitudes and perceptions towards learning science before and after participating in the KGS '97 program. A more complete analysis of the findings, including students' artifacts and interviews, and the triangulation of data from all sources, will be reported in a forthcoming paper.

The Nature of Teaching and Learning in the Classroom

Teacher's Preferred Pedagogical Approach

The classroom observations and teacher interviews provided an insight into the teacher's pedagogical beliefs and preferred teaching style. The teacher has several years' experience teaching science, is enthusiastic about science, and has a curiosity about scientific phenomena. He has a gentle but firm demeanor with his students. He has established some classroom routines, such as using a bell to denote time to transition to a different activity. In his words, he preferred style of teaching was to "stand up in front of the class and teach, and tell the students what to do". In this style of teaching, he used whole-class instruction to introduce a new idea or concept, and then used a question-and-answer format to develop the concept. The dialogical approach he used involves seeding the discussion with one or more questions, inviting students to answer individually, as well as providing a comfortable environment for students to raise questions, relate individual experiences or share ideas. His philosophy with regard to questions from students is, “The only stupid questions are the ones not asked,” which he would repeat if any student commented that another student's question was stupid.

The teacher also enjoyed doing dramatic demonstrations of science experiments to pique students' interest and set the stage for classroom dialogue and discussion about the scientific concepts involved. This approach espouses a teacher-as-performer philosophy. He also liked to use currently occurring phenomena to spark a discussion and invited students to relate their own experiences where relevant.

The teacher has had more than ten years experience teaching about weather, as a part of the Earth Science curriculum in middle schools. He has also recently authored the weather curriculum for sixth grade, currently being used in all middle schools in this school district, and has previously participated in several weather curriculum projects such as the Globe Project and Blue Skies. He expressed having been somewhat dissatisfied with everything that he had tried.

<u>Trying A Different Pedagogical Approach</u>

The teacher was motivated to try out the KGS program after attending a presentation about KGS for science teachers for his school district. When asked what made him interested in participating in KGS, he said,

> "I saw some kind of promise in the idea of having an Internet part of the weather curriculum, because weather's in real time, and it's intrinsically interesting to see images of the weather that there is now, and the weather that's coming, and communicate with people, and certainly with people in other parts of the country about the weather they're experiencing. So I wanted to experience it first hand. I was also encouraged very strongly by my curriculum coordinator to give it a try."

In trying out the KGS program for the first time, the teacher decided that he would do what he believed the curriculum outline expected him to, and "see what happens". He apparently wanted to "test" the curriculum to "see if it works". In an interview, when asked whether he had certain expectations about the curriculum, he said, "I was having an open mind to see, um, what would happen."

<u>Summary of the nature of teaching and learning in the classroom</u>

The following description, based on daily observations in the classroom by this researcher, is a summary of how this teacher interpreted the KGS '97 curriculum. Prior to the beginning of the eight-week program, the teacher engaged students in all four of his science classes in a pre-activity to introduce their school and their location to other KGS participants. He took photographs of his students outdoors, to show the winter scene at that time, and indoors, to show the science classroom and significant areas of their school. He also tape-recorded a two-minute introduction to the school, featuring various students voices describing themselves and their school, to accompany the photographs.

Phase One. At the beginning of KGS, the teacher assigned students to mixed-ability groups of four. Most groups consisted of two boys and two girls, with a few exceptions. Each group was assigned a specialty content-area that was to be the focus of their study. These were: (a) Clouds and Humidity, (b) Precipitation, (b) Temperature and Pressure, and (d) Winds. In their small groups, students researched various resources about their specialty area, guided by open-ended "curriculum questions" provided in the KGS worksheets. Other than the activity sheets provided by the KGS curriculum and the sole computer for accessing Internet resources, additional resources made available by the teacher included textbooks, reference books, newspapers, two to four additional computers not connected to the Internet, a laserdisc containing information on weather, and a computer game containing a quiz on weather. At the beginning of each week, the teacher distributed to each group a list of required and optional activities that he had prepared, together with the scores attainable for each activity and the grading standard. In their groups, students could work on the activities at their own pace, in any order, preferably completing the required activities before the optional ones.

The teacher usually began each lesson by a ten-minute whole-class session that included general instructions, a whole-class dialogue about a recent or currently occurring phenomena, and an occasional demonstration. It was during this time that the teacher was observed employing his preferred pedagogical approach described earlier, such as a question-and-answer review of the previous day's learning, an attention-getting demonstration involving a science phenomenon, whole-class discussion, and instructions for the day. During this time, students sat in their seats individually and listened, watched or answered questions when called upon.

The students then spent the rest of the time working independently in their groups, stopping only about three minutes before the end of the class for a quick review. The students were responsible for determining what to do within their groups, based on the general instructions from the teacher, and the weekly "to-do" list from which they could choose core and optional activities. During this time, students sat or stood together in their small groups, asking each other questions, making decisions about what to do, arguing at times, and usually proceeded to work on an activity. Students did not stay in the classroom all the time; some activities required them to go outside (to collect weather data), and sometimes they moved around the classroom getting resources like books, newspapers and instruments for conducting experiments.

During the group work, the teacher moved from group to group, sometimes clarifying the instructions to students, and at other times providing specific instructions for an activity, guidance, explanations, and resources. Learning was student-centered, and the role of the teacher shifted from being the leader, performer, and primary information provider to multiple roles as a manager, facilitator, guide, monitor, as well as resource person.

In Phase One of the curriculum, students answered the pre-instructional survey, researched local characteristics about their location and weather, and wrote introductory messages to other schools. In small groups, they first composed messages to send to other schools on paper, then took turns to type their messages using the sole computer with a modem in their classroom, to send to the KGS Message Board on the Internet. They researched newspapers, almanacs, and asked their teacher about local geography and weather to write about in their messages. Following the introductory activity, students began their research based on a worksheet containing open-ended curriculum questions about their content specialties. They used a variety of resources for their research, including textbooks, reference books on weather, almanacs, newspapers, and the Internet. However, the Internet was not used as their primary source of information as the computer was most often used for typing messages on the Message Board.

During the first phase we assisted in the classroom by showing the students how to send messages and then they took turns to type their own messages. We also helped to type messages after school, especially when they ran out of time (since the students usually typed very slowly!). We printed out the sets of messages from the four Message Boards and made copies for the students to read, since it was not feasible for students to both send and read messages from the only Internet-connected computer in the classroom.

Phase Two. In Phase Two of the curriculum, students learned how to use weather instruments specific to their specialty area. The teacher taught the use of a specific instrument to each specialty group in turn. These included maximum and minimum thermometers, barometers, sling psychrometers, rain gauges, cloud charts, Beaufort wind scales and wind chill charts. Students then went outside for a few minutes every day for three weeks to collect weather data such as the daily maximum and minimum temperatures, atmospheric pressure, relative humidity, amount and type of precipitation, cloud type and percentage cloud cover, wind speed and direction. They returned to report their data and send it to the Internet to share with other KGS schools. In the classroom, they continued to work on the curriculum questions specific to their specialty, refining and elaborating their answers by doing more research.

In the second week of Phase Two the teacher instructed the groups to choose a different specialty to learn, and to team up with another group with a different expertise to teach them how to collect weather data and learn from them. Students in each pair of groups taught each other how to read the weather instruments in which they had become experts. In the third week of Phase Two the groups chose a third specialty to learn and teamed up with another group. In this way, in three weeks, each group of students had learned about collecting data methods for three specialty areas, while they continued to research the concepts of their originally-assigned specialty area.

Each group of students also took turns to use the four computers-on-carts that the teacher had borrowed from the Media Center. These computers were placed in the hallway outside the classroom, and did not have Internet connections. As such, real-time weather maps were downloaded from the Internet using the Blue Skies software in the morning before classes began, and then transferred to the computers-on-carts outside the classroom. Groups of students then took turns to use the Blue Skies archived data to learn how to interpret weather maps using an activity sheet designed for this purpose.

Students also selected activities from the week's "to do" list of core and optional activities the teacher had provided, such as writing a story or poem about weather, making a cloud chart, making their own barometer, or doing an experiment such as “tornado in a bottle” or investigating evaporation. These experiments were explained by the teacher or the researcher to individual groups which chose to do them and the students set them up and carried them out on their own.

As they worked in groups, some students became immersed in their work or were otherwise engaged in the activities they were doing. Others appeared to be floundering in their tasks, occasionally bored, off-task, or waiting to get the attention of the teacher to ask for directions. Some groups worked on their tasks together, but most groups had two students go off to attend to one task while the others attended to another task, or sat around aimlessly, or wandered around watching other groups. From time to time the teacher stayed with a group and provided guidance, directions for an experiment, or answered questions from students about their tasks.

Towards the end of Phase Two most groups began to take responsibility for their own learning activities. Although Phase Two was marked as three weeks long in the written curriculum, it was enacted in about four weeks, as students continued to research and refine their answers to the curriculum questions from Phase One, collected three weeks of local weather data daily, and engaged in a variety of activities such as the real-time weather map interpretation, hands-on experiments, and taking turns to use the computer to send messages, read real-time weather maps or research their curriculum questions. An ice storm occurred during this time, and students wrote individual stories about their experience with this severe weather. This "Writing for an on-line Newspaper activity," was a suggested activity from Phase Three of the curriculum. Students composed their stories on paper as a homework assignment. The stories were not posted on-line due to the lack of time.

Phase Three. In Phase Three students shared what they had learned with students in other schools. We downloaded and printed sets of data from their school and other schools for the teacher from the KGS web site, and made photocopies of these sets of data for the students. They drew graphs of the weather data they had collected and compared it to data from another KGS school. Some groups continued to work on Phase Two activities that they had not completed. Each group of students took turns to make a presentation to the whole class about the specialty area on which they had focused their research. They also organized their group folders into sections marked with tabs.

As Phase Two had taken more time than suggested in the curriculum, there were only two weeks left to complete Phase Three. There were also several interruptions to their schedule such as assemblies and special events that had resulted in canceled or shortened classes. There was insufficient time for the Data Analysis and Synthesis activities to be completed. Towards the last week of KGS '97, there was not enough time to carry out the Investigating Weather Fronts activity in the way suggested in the curriculum, and it was not possible to continue with the weather unit because of the school schedule. The teacher therefore decided to teach about Weather Fronts on two half periods using a whole-class instruction approach to save time. Students spent the other half periods of the last two days answering the post-instructional survey. We interviewed the teacher on three occasions at the conclusion of the eight-week program.

Teacher's Opinion about the Strengths of the KGS curriculum

The teacher felt that one of the strengths of the KGS curriculum was the idea of introducing the curriculum questions to the students at the very beginning and having the students work on them for a long time, "even if it necessitates for the students to flounder around for a while and to answer the questions very incompletely or even incorrectly, but to establish those questions early on, and just hang with them for a long time." He also expressed that "I think it's always a strength when groups of kids teach other groups of kids, um, I think that happened in the data collection, and it happened when the kids made presentations to the other students about their curriculum questions."

Problems Identified by the Teacher

The problems he identified included (a) having only one computer connection, (b) having to pace himself with the other (KGS) schools, (c) conflicts within some groups of students, (d) passive students who did not contribute as much as other members of their groups, and (e) feeling overwhelmed by the workload. In elaborating on the last problem, he said:

> I had just finished a very overwhelming project of the science fair, and KGS started the minute the science fair ended, and really, I was not, um, I wasn't prepared mentally, for the amount of work that I had to do during, that I found myself doing during KGS. Maybe I could have managed it a different way, but checking the [student] folders every week ... just took hours and hours and hours of work. It's more work to ... supervise groups who are doing things different from one another than it is to supervise groups that are all basically doing the same thing.

Teacher's Opinion about Students' Learning

However, despite these problems, he felt that his students were "likely to retain quite a bit of what they learned because the kids had a lot of ownership in what they did learn" He added, "they had more control, and more choice ... and because we reiterated so much on the fundamental curriculum questions, and kept coming back to them, that I think ... the kids developed some ownership of some of those concepts and made them their own."

Student Attitudes, Perceptions and Motivation

The following findings are based on the student pre- and post-instructional surveys. Of the 52 students in the two classes observed, two students were not present for one of the surveys, while one returned incomplete surveys for both pre and post surveys. Data from these three students was removed from the survey data set, and the following results are reported for a total of 49 students (28 male, 21 female). Two of the boys were diagnosed with learning difficulties.

The matched item responses from the pre and post survey were compared for all students as well as by gender. Table 1 summarizes the findings for the surveys. (We have included only the items on attitudes and perceptions that are the focus of this paper.) We will elaborate on the findings for each item below.

TABLE 1: Students Attitudes and Perceptions

Item		Pre-survey (% responses)			Post-survey (% responses)		
1		like a lot	like a little	don't like	like a lot	like a little	don't like
Attitude towards science	Boys	71	28	0	75	25	0
	Girls	67	33	0	71	29	0
	All	69	31	0	73.5	26.5	0
2		not difficult	a little difficult	very difficult	not difficult	a little difficult	very difficult
Difficulty learning science	Boys	57	43	0	57	43	0
	Girls	33	67	0	57	43	0
	All	47	53	0	57	43	0
3		above average	about average	below average	above average	about average	below average
Perception of ability	Boys	50	43	7	50	43	7
	Girls	24	76	0	24	76	0
	All	39	57	4	39	57	4
4		like a lot	like a little	don't like	like a lot	like a little	don't like
Attitude towards group wk	Boys	32	64	4	35	61	4
	Girls	52	48	0	42	57	0
	All	41	57	2	39	59	2
5		by myself	in a small group	w/ whole class	by myself	in a small group	w/ whole class
Learning preference	Boys	25	29	46	21	57	18
	Girls	14	48	29	19	52	19
	All	20	37	39	20	55	18
6		like a lot	like a little	don't like	like a lot	like a little	don't like
Discussion in groups	Boys	43	57	0	22	57	11
	Girls	38	57	5	52	48	0
	All	41	57	2	41	53	6
7		often	some-times	hardly/ never	often	some-times	hardly/ never
Frequency using computers	Boys	39	46	14	54	43	4
	Girls	48	38	14	48	48	5
	All	43	43	14	51	45	4
8		like a lot	like a little	don't like	like a lot	like a little	don't like
Attitude using computers in science	Boys	54	39	7	54	36	11
	Girls	48	43	10	48	48	5
	All	51	41	8	51	41	8
9		A	B	C	A	B	C
Expected grade	Boys	86	14	0	61	32	7
	Girls	71.5	14	10	81	19	0
	All	80	14	4	69.5	26.5	4

1. <u>Attitudes Towards Science</u>

This item in both pre and post surveys read, "Compared to other school subjects, science is a subject that I: (a) like a lot, (b) like only a little, or (c) don't like." Figure 1 summarizes the results for this item.

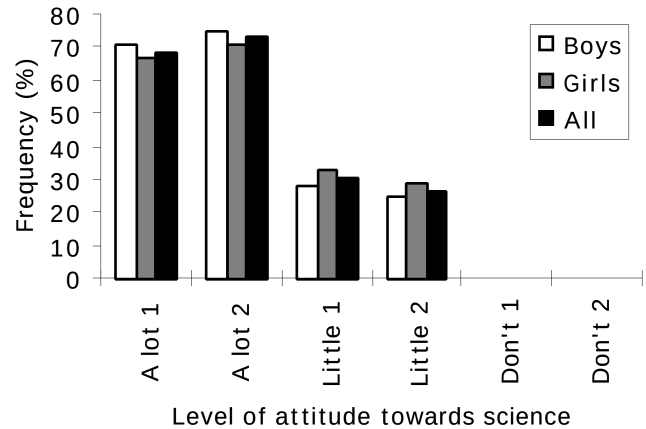

Figure 1. Students' attitudes towards science.

Key: A lot 1: Like a lot (Pre) A lot 2: Like a lot (Post)
Little 1: Like a little (Pre) Little 2: Like a little (Post)
Don't 1: Don't like (Pre) Don't 2: Don't like (Post)

The majority (69%) of students indicated a high positive attitude towards science in the pre-instructional survey, with 67% of girls and 71% of boys stating that they liked science a lot, and no one stating that they didn't like science at all. There was an overall increase in positive attitude towards science, but this increase was not statistically significant. This result remained consistent when analyzed by gender.

2. <u>Perceptions Of Difficulty in Learning Science</u>

This item in both pre and post surveys read, “For me, learning science is: (a) not difficult at all, (b) a little bit difficult, or (c) very difficult.” Figure 2 summarizes the results for this item.

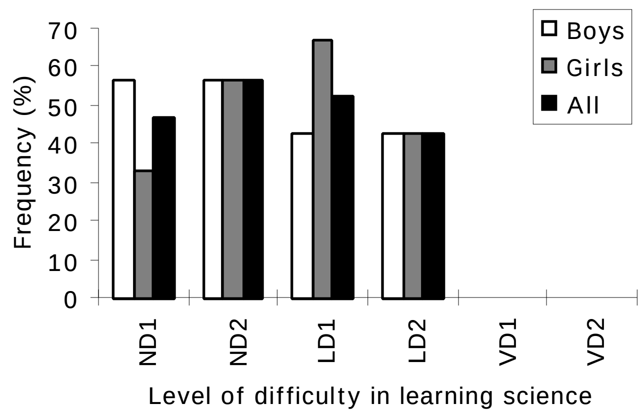

Figure 2. Students' perceptions of difficulty in learning science.

Key: ND1: Not difficult at all (Pre) ND2: Not difficult at all (Post)
LD1: A little bit difficult (Pre) LD2: A little bit difficult (Post)
VD1: Very difficult (Pre) VD2: Very difficult (Post)

There was a 10% overall increase in perception that science was not difficult at all, with 57% of students indicating in the post-instructional survey that learning science was not difficult at all, compared to 47% in the pre-instructional survey. This increase was not statistically significant. No one perceived science as very difficult in both surveys. However, analysis by gender revealed a significant decrease in perception of difficulty in learning science among girls. A two-tailed t-test for paired samples showed that the increase, from 33% to 57%, of girls indicating their perception that science was not difficult at all was statistically significant ($p = .021$, $\alpha = .05$) There was no change in perception of difficulty of learning science for boys, with 57% consistently indicating that science was not difficult at all for them in both tests. The increase in perception that science was not difficult at all could therefore be entirely attributed to girls.

3. Self-Perceptions Of Ability In Science

This item in both pre and post surveys read, “Compared to other students, I think in science class I am: (a) above average, (b) about average, or (c) below average.” Figure 3 summarizes the results for this item.

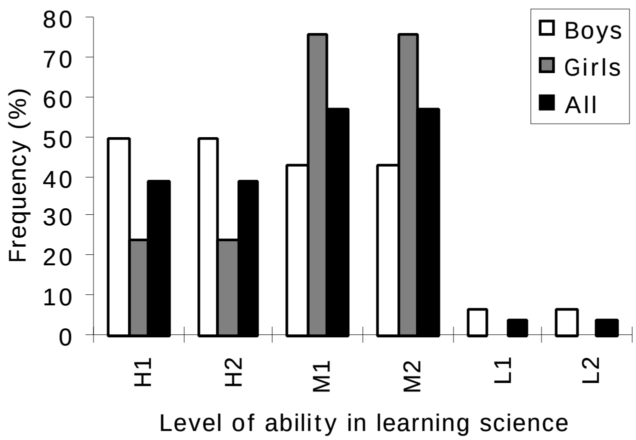

Figure 3. Students' self-perceptions of ability in science.

Key:	H1	High:	above average (Pre)
	H2	High:	above average (Post)
	M1	Medium:	about average (Pre)
	M2	Medium:	about average (Post)
	L1	Low:	below average (Pre)
	L2	Low:	below average (Post)

There was no change in self-perception of ability between the two surveys. Only 24% of the girls perceived themselves as above average compared to others in science class, while most girls (76%) perceived themselves as about average. For boys, however, 50% perceived themselves as above average, while 43% perceived themselves as about average and 4% as below average.

4. Attitudes Towards Working In Groups

This item in both pre and post surveys read, "Working in groups is something I: (a) like a lot, (b) like only a little, or (c) don't like at all." Figure 4 summarizes the results for this item.

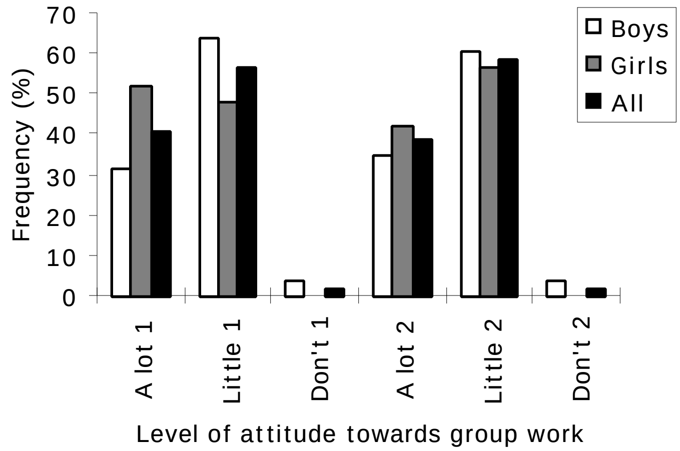

Figure 4. Students' attitudes towards working in groups.

Key: A lot 1: Like a lot (Pre)
Little 1: Like a little (Pre)
Don't 1: Don't like (Pre)
A lot 2: Like a lot (Post)
Little 2: Like a little (Post)
Don't 2: Don't like (Post)

There was no significant difference in positive attitude towards working in groups between the two surveys. 41% of all students indicated that they liked working in groups a lot in the first survey and 39% indicated the same in the second survey. Less than 5% of the students did not like working in groups in either survey. Analysis by gender showed that while boys remained somewhat consistent about their attitudes towards working in groups, there was a 10% drop in the percentage of girls who liked working in groups a lot. However, this decrease was not statistically significant.

5. Learning Preferences

This item in both pre and post surveys read, "I learn science better when I am: (a) by myself, (b) in a small group, or (c) with my whole class." Figure 5 illustrates the results for this item.

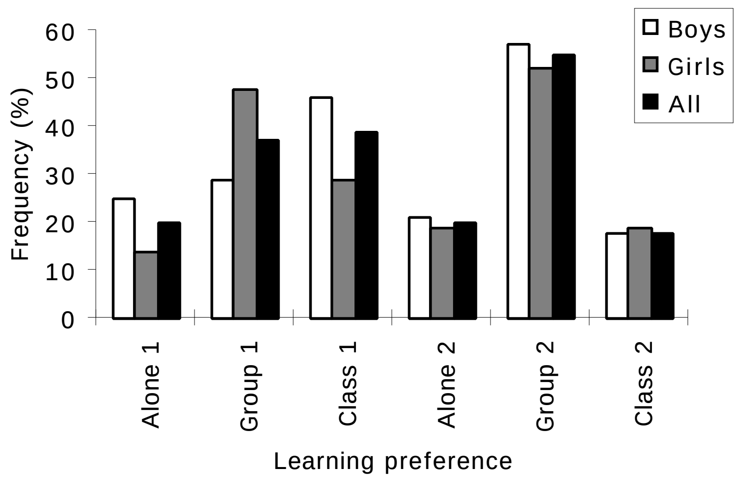

Figure 5. Students' learning preferences

Key:	Alone 1:	By Myself (Pre)
	Alone 2:	By Myself (Post)
	Group 1:	In a Small Group (Pre)
	Group 2:	In a Small Group (Post)
	Class 1:	With the Whole Class (Pre)
	Class 2:	With the Whole Class (Post)

There was an increase (from 37% to 55%, a change of 18%) in the number of students who indicated that they preferred learning science in a small group, rather than learning individually ("by myself") or with the whole class. The percentage of boys who preferred learning science in a small group nearly doubled from 29% to 57%. The increase was less marked for girls, from 37% to 55% indicating this learning preference. For boys, this change in learning preference was mainly at the expense of a preference for learning science with the whole class. Both boys and girls who preferred learning by themselves remained somewhat consistent.

6. Attitudes Towards Participation In Group Discussion

This item in both pre and post surveys read, “Discussing science with group members in science class is something I: (a) like a lot, (b) like only a little, or (c) don’t like at all.” Figure 6 illustrates the results.

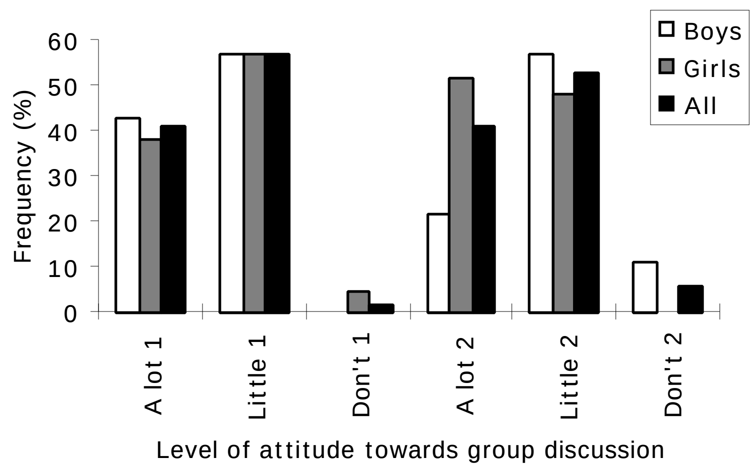

Figure 6. Students' attitudes towards participation in group discussion.

Key: A lot 1: Like a lot (Pre)
Little 1: Like a little (Pre)
Don’t 1: Don’t like (Pre)
A lot 2: Like a lot (Post)
Little 2: Like a little (Post)
Don’t 2: Don’t like (Post)

Although overall results indicated little change in attitudes towards participation in group discussion, analysis by gender revealed otherwise. For girls, there was a shift towards liking group discussion more, with a change from 38% to 52% of girls indicating that they liked discussing science with group members a lot. For boys, however, the shift was in the negative direction, with a change from 43% to 32% of boys indicating that they liked discussing science with group members a lot. In addition, 11% of boys decided that they did not like discussing science with group members at all in the post survey, compared to none in the first survey. However, these results were not statistically significant.

7. Frequency Of Using Computers

This item in both pre and post surveys read, "How often do you use computers? (a) often, (b) sometimes, or (c) hardly ever / never." Figure 7 illustrates the results.

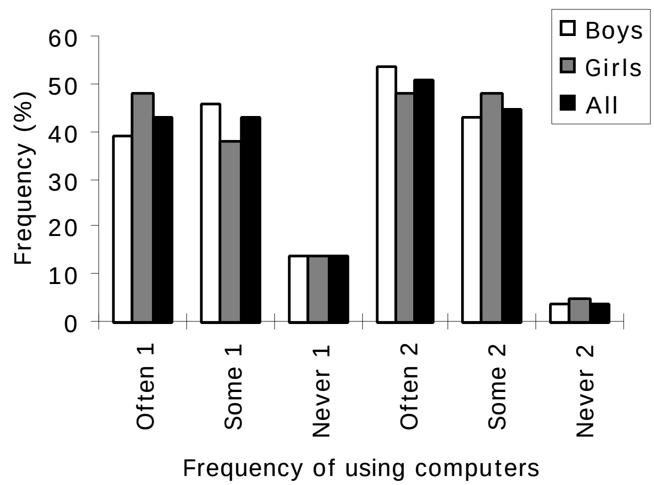

Figure 7. Students' frequency of using computers.

Key:	Often 1: Often (Pre)	Often 2: Often (Post)
	Some 1: Sometimes (Pre)	Some 2: Sometimes (Post)
	Never 1: Hardly/Never (Pre)	Never 2: Hardly/Never (Post)

The frequency of using computers is included as supporting data for the attitudes towards using computers. Overall, in the pre-instructional survey, 43% reported using computers often, 43% used computers sometimes, and 14% hardly ever or never used computers. In the post-instructional survey, the corresponding figures were 51%, 45% and 4% respectively, indicating a significant increase in overall frequency of computer use during the KGS curriculum (p = .019, α = .05). Note that this use is not confined to computers in the classroom. The question was "How often do you use computers?" and should be taken to include use at school, at home or elsewhere. For girls, there was no significant increase in frequency of computer use. However, for boys, there was a significant 15% increase in frequency of computer users to 54% (p = .017, α = .05). Thus, although computer use increased overall, this was attributed to boys, while girls continued to lag behind boys in frequency of computer use.

8. Attitudes Towards Using Computers For Learning Science

This item in both pre and post surveys read, “Do you like to use computers for learning science? (a) like a lot, (b) like only a little, or (c) don’t like at all.” Figure 8 illustrates the results for this item.

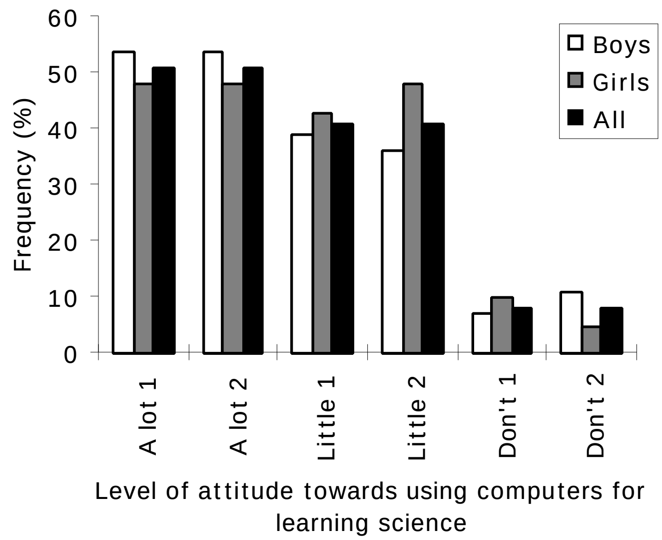

Figure 8. Students' attitudes towards using computers for learning science.

Key: A lot 1: Like a lot (Pre) A lot 2: Like a lot (Post)
Little 1: Like a little (Pre) Little 2: Like a little (Post)
Don’t 1: Don’t like (Pre) Don’t 2: Don’t like (Post)

Students’ attitudes towards using computers for learning science remained consistent, for both boys and girls. In the pre-instructional survey, 54% of boys and 48% of girls indicated that they liked using computers for learning science a lot, 39% of boys and 43% of girls indicated they liked it a little, while 7% of boys and 10% of girls indicated that they didn’t like it at all. There was little change in this distribution in the post-instructional survey.

9. Expectations Of Achievement At The End Of The Unit

This item in both pre and post surveys read, “I expect to get the following grade in science at the end of the KGS unit: A, B, C, D, or E.” Figure 9 illustrates the results obtained.

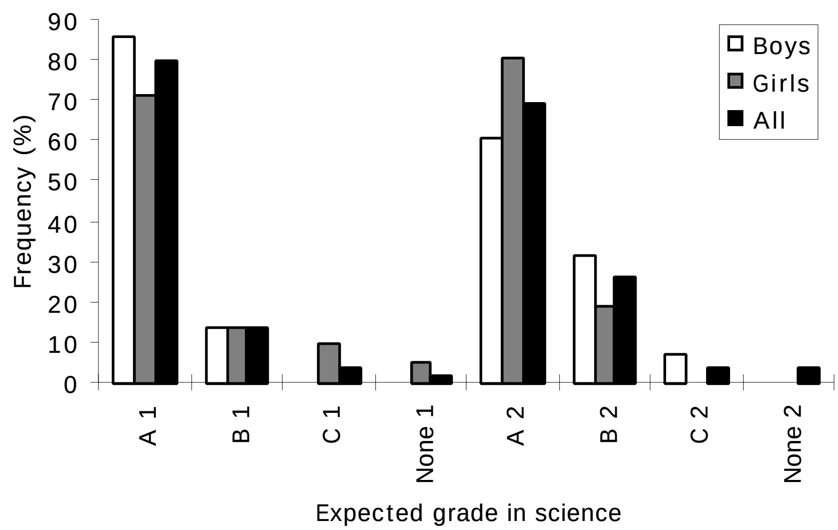

Figure 9. Students' expectations of achievement at the end of the unit.

Key:

A 1:	A (Pre)	A 2:	A (Post)
B 1:	B (Pre)	B 2:	B (Post)
C 1:	C (Pre)	C 2:	C (Post)
None 1:	No response (Pre)	None 2:	No response (Post)

In the pre-instructional survey, 86% of boys indicated that they expected to get an ‘A’, while only 71% of girls indicated the same expectation. However, the post-instructional survey revealed marked changes in expected achievement. 81% of girls indicated that they expected to get an ‘A’ while only 61% of boys expected this grade. While overall there was no significant change in grade expectation, there was a significant decrease in the grade expectation of boys between the two surveys (p = .004, α = .05).

DISCUSSION

Earlier in this paper we stated that this study is framed by the following questions: What is the nature of learning and instruction in a classroom with a teacher participating in the KGS curriculum for the first time? In particular, how do the students and the teacher enact the features of KGS such as collaborative learning in small groups, exchange of information and data with distant peers, and communication with weather specialists, within the constraints of limited access to the Internet? How does this learning experience affect the students' self-perception of ability, motivation to learn, and attitudes towards science? What are the pedagogical implications of this learning experience for classroom practice?

Teacher's Beliefs and Pedagogical Approaches

The teacher in this study was most comfortable in a role where he controlled or directed the learning activities in his classroom. This teacher was willing to risk giving up some degree of control of his classroom learning environment when he decided to try the KGS program. His participation in the program was voluntary; although he had been encouraged to try it by the district science coordinator and provide feedback on whether he would recommend the curriculum for the district. Therefore it could be inferred that it was not a high-stakes risk: it was not the success of his participation that was to be evaluated by his district, it was the success of the curriculum.

In the case of the study by Olson, the teachers were participating in an Integrated Science Project which was based on a central-curriculum-project system. Their participation was presumably not voluntary. Teachers in Olson's study said they experienced a dilemma because of a tension between their commitments about teaching and those urged by the innovation (Olson, 1981).

Although the first author participated in the classroom as a support person from the KGS research team, we intentionally did not attempt to influence the teacher to use a particular pedagogical approach, nor did we make judgments about his practice or discuss with him whether or not his practices were "right". We wanted to observe how he interpreted the curriculum in his own way. As he commented in a post-KGS interview, he felt overwhelmed by the amount of effort he found himself doing. This is consistent with the finding by Songer (personal communication, February, 1998) that teachers participating in KGS do not feel comfortable about the curriculum and sufficiently knowledgeable about the underlying philosophy of the program until their third year of participation. In this teacher's classroom, during KGS his pedagogical approach changed significantly from being teacher-directed and well-controlled in terms of selection, pace, scope and sequence of activities, to one which was teacher-guided, but student-determined and controlled with regard to selection, pace, scope and sequence of learning activities. The management of multiple groups at the same time, each engaged in different activities, posed a great challenge to the teacher, who braved it for almost the whole eight weeks. He reverted to his preferred pedagogical approach only during the last three days of the program. This change was to enable him to teach the "Weather Fronts" topic, which he felt was very important, in the short time that was left. He emphasized to his students that questions on Fronts frequently appeared in the state's standardized science tests. The decision of the teacher to revert to his preferred practice implies that he may have felt more confident that this approach would enable him to teach more efficiently. This is consistent with the literature that indicates the resilience of beliefs with respect to change (Pajares, 1992).

With regard to the use of technology, the teacher did not appear to be overly discouraged that he had only one modem connection to the Internet. He expressed his appreciation for my assistance with the typing and printing of the Message Board and retrieval of weather data reported by this and other schools. However, he had a wide repertoire of weather-related resources made available to his students, collected over the years, including text and reference books, newspapers, charts, worksheets he had created for use with a laserdisc, and even an old Apple IIe computer game on weather, all of which were used at different times by the students during this program. For the teacher, the lack of Internet-connected computers required him to lower his prior expectations for using real-time weather maps and Internet-available information, and substitute them with archived weather maps and non-computer resources.

Students' Attitudes and Perceptions

The majority of students in this study indicated a high positive attitude towards learning science. The finding that more boys than girls liked science a lot is consistent with studies on the relationship between gender and attitudes toward science (Koballa, 1995). The slight increase in positive attitude towards science in both boys and girls, although not statistically significant, suggests that the KGS curriculum may have the potential to motivate more students to learn science in a way that does not discriminate between the sexes.

With regard to perception of difficulty of learning science, the results showed that there was a statistically significant increase (24%) in the percentage of girls who perceived science as not difficult at all. It is interesting to note that with this increase, the distribution of girls who perceived science as either not difficult at all (57%) or a little bit difficult (43%) matched that of the boys, who maintained the same distribution in both surveys. It appears that the KGS curriculum may have considerable potential for reducing the perception that science is difficult for girls, and therefore raise their confidence in science to match that of boys. A possible explanation is that the design of the classroom activities encouraged more girls to perceive science to be as easy as boys did. This concurs with research that indicates that everyone has access to the same experience if students begin working on an activity in small groups with little direction from the teacher, and subsequent discussion results in more participation by girls (AAUW, 1995).

The data on self-perception of ability in science appears to reinforce studies that report lower self-perceptions of ability in females (Wigfield, et. al, forthcoming). On closer examination, however, we agree with Wigfield et. al's suggestion that this discrepancy may be attributed to a response bias, with boys being more self-congratulatory. Bearing in mind that the item "Compared to other students, I think in science class I am ..." provided students with only three choices, viz. above average, about average or below average, it would be reasonable to expect the responses to follow an approximately normal distribution, or possibly one that is skewed in favor of a higher perception of ability. This appears to be so for the girls. Half the boys, however, perceived themselves to be above average.

Regarding group work, it appears that girls found working in groups less appealing than they perceived at the beginning of the unit. The most common reason students gave as an elaboration to this response is that it depends on whether the student can get along with the other members of the group. Where the group cohesiveness was low, students were less likely to retain a positive attitude towards working in groups.

Taken together with the item on learning preference, however, it appears that despite whatever difficulties they may have had in their particular groups in this unit, on the whole more students indicated a preference for learning in groups at the end of the KGS curriculum. The change in learning preference was greater among boys, although the increase was not statistically significant. From my observations, a possible reason is that boys enjoy the opportunity to be released from the restriction of staying in their seats during whole-class instruction. The KGS experience of working in groups afforded them with greater control over their learning compared with whole-class instruction, and this may have increased their engagement in learning, as suggested by Ames (1992).

Another possible reason is that hands-on experiments and other activities usually take place in small groups. It is likely that the boys' preference is due to the association of group work with activities rather than the experience of being in a group *per se*. This is consistent with the finding that boys' attitudes towards participation in group discourse shifted in the negative direction, indicating that boys found discussing in groups less appealing. In contrast, girls found discussing in groups more appealing. However, these changes were not statistically significant.

In the case of using computers for learning science, although students' attitudes remained consistent in both surveys, girls lagged behind boys in liking to use computers for learning science as well as percentage of frequent users. This parallels the finding pertaining to girls' attitudes towards science. However, it is important to note that frequency of computer use was limited by accessibility to computers.

Girls indicated an increase in expectations of achievement at the end of the KGS curriculum, while boys lowered their expectations. A possible explanation for this finding is that girls' significant increase in the perception that learning science was not difficult at all, coupled with a slight increase in self-perception of ability, provided them with the confidence to expect higher levels of achievement for themselves.

While there may be concern that boys indicated lower expectations of achievement at the end of the curriculum, we offer two explanations. One possible explanation is that some of the boys are likely to have over-rated themselves, and realized after working in groups that there were others who were better than themselves. We should point out that the teacher informed his students that grades for this unit would depend on their group work, which leads us to offer a second, more plausible explanation. Since 50% of the boys consistently perceived themselves as being above average, their lowered expectation may be due to an attribution of lower ability to members of their respective groups, particularly since most groups were heterogeneous in gender and ability. In other words, the "others" pulled down their grades.

IMPLICATIONS OF THE STUDY

For Students

The KGS program appears to provide girls with increased confidence of their ability to learn science. The significant increase in girls' perceptions that learning science is not difficult at all indicates that this program may allow girls to have learning experiences in science that do not perpetuate the image that science is a subject "for the boys," or that girls are not pre-disposed to learn science. It is premature for this study to determine the actual reasons for the girls' increased confidence in learning science. It is possible that the social learning experience in this study allowed girls to realize that they were just as good as the boys. Another factor that may be considered is the wide scope of learning experiences that KGS afforded, which encompassed written communication with distant peers, oral communication with classmates, individual use of scientific instruments in a group setting, peer teaching, hands-on experiments, use of weather maps and information from the Internet, all of which provided students with a variety of learning experiences. As this study was not designed to specifically probe gender differences in the KGS program, there is potential for more research in this area.

For Teachers and Curriculum Developers

Although the availability of technology-rich equipment can provide classrooms with the maximum opportunities for participation in Internet-integrated curricular programs, it is neither a guarantee nor a prerequisite for success. The key to the effectiveness of this Internet-integrated program is not maximum access to the Internet, but the learning approach in which Internet use is integrated. In the KGS learning approach, the Internet is regarded as a tool and resource for communication and research to facilitate learning through socially constructed knowledge communities, where participants are both providers and consumers of information. Use of the Internet is integrated with a variety of learning experiences that emphasize multiple on-line and off-line information sources. Therefore the effectiveness of the program does not hinge solely on Internet use.

This case study shows that participation in the Kids as Global Scientists program can positively impact students' learning experiences even with minimal access to the Internet. However, this required the teacher to plan and make available a variety of activities and resources to work on in the classroom so that students could take turns to use the computer. Classroom management and organization thus posed significant challenges to the teacher, and required him to relinquish some control to the students.

How teachers deal with such challenges to their practice is dependent on their pedagogical beliefs about their role in the classroom. Open-ended inquiry learning and collaborative knowledge construction often conflict with the traditional knowledge-transmission approach prevalent in schools, as well as pose additional challenges for classroom management. Clearly, a teacher who has been comfortable with strong teacher control will experience some conflict with a curriculum which emphasizes more student control. The extent of conflict between a teacher's pedagogical beliefs and the learning approach intended by the curriculum innovators is a likely indicator of how closely the teacher's interpretation of a curriculum matches the "intended" curriculum. Cronin-Jones (1991) concluded that successful implementation of a curriculum was hampered by the incongruence of teachers' existing belief structures with the underlying philosophy of the intended curriculum.

While teachers are often blamed for failing to implement innovative programs by researchers, such a stand is based on the view that teachers should implement these programs in exactly the way the developers intended. This view has two flaws. Firstly, this view does not take into consideration the variation between different sites that render it unreasonable to expect that a curriculum can be implemented in the same way at every participating site. Secondly, innovative curricula may be couched in the theoretical language of academics, and it cannot be presupposed that teachers readily understand their implications for practice without some form of "translation" (Olson, 1981).

We argue that the implementation of curriculum innovations *should* be expected to vary according to the unique characteristics of each classroom situation, such as the characteristics of the teacher, the students, and the resources available. The first includes the teacher's own level of experience and level of comfort with the features of the innovation, degree of ownership with respect to the teacher's participation in the program, pedagogical beliefs, personal strengths and expertise. The second includes the students' abilities, learning styles, socio-cultural background and motivation to learn. The third includes the variety, accessibility and reliability of resources including technology. No curriculum developer can therefore expect to see uniform implementation across different sites, nor expect that teachers can implement exactly what the developer intended.

The KGS program does not expect teachers to follow the written curriculum to the letter as a measure of success. It is intentionally designed as a flexible curricular shell, not as a complete instructional package, with the recognition that teachers have their own resources and repertoire of successful practices. The KGS curriculum outlines a set of "core" activities and "extension" activities that teachers are free to select according to their particular classroom needs and constraints. It provides the framework for a *suggested* curriculum for teachers to adapt, rather than an *intended* one. We recognize that teachers who elect to try out innovative curricular programs are willing to take both the challenges as well as the risks. We regard a successful implementation of the KGS program as one in which the teacher interprets the key features of the KGS learning approach in a way that makes sense to him/her, and adapts the curriculum according to the particular needs of each classroom.

The KGS program provides an exciting, although challenging, alternative to the traditional didactic teaching approach. The KGS learning approach encourages students to take more ownership in their learning, by actively participating and taking control of the selection, pace, scope and sequence of learning activities that make science personally relevant to them, with the teacher's skillful guidance and management. The emphasis on multiple learning experiences, using both on-line and off-line resources in a variety of activities, has the potential to provide more opportunities to meet the needs of different types of learners, including raising girls' confidence levels in science to match that of boys'.

REFERENCES

American Association for University Women Educational Foundation. (1992*). The AAUW report: How schools shortchange girls.* Washington, D.C.: AAUW Educational Foundation and National Education Association.

Ames, C. (1984). Competitive, cooperative, and individualistic goal structures: A motivational analysis. In R. Ames & C. Ames (Eds.). *Research on motivation in education* (Vol. 1, pp. 177-207). New York: Academic Press.

Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Educational Psychology, 84* (3), 261-271.

Aronson, E. (1978). *The jigsaw classroom.* Beverly Hills, CA: Sage.

Blumenfeld, P.C. (1992). Classroom learning and motivation: Clarifying and expanding goal theory. *Journal of Educational Psychology, 84* (3), 272-281.

Brown, A. (1994). The advancement of learning. *Educational Researcher 23* (8), 4-12.

Brown, A., Ash, D., Rutherford, M., Nakagawa, K., Gordon, A., & Campione, J. (1992). Distributed expertise in the classroom. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations.* New York: Cambridge University Press.

Brown, J., & Weiner, B. (1984). Affective consequences of ability versus effort ascriptions: Controversies, resolutions, and quandaries. *Journal of Educational Psychology, 76,* 146-158.

Covington, M. (1992). *Making the grade: A self-worth perspective on motivation and school reform.* New York: Cambridge University Press.

Cronin-Jones, L. (1991). Science teacher beliefs and their influence on curriculum implementation: Two case studies. *Journal of Research in Science Teaching, 28* (3), 235-250.

Edelson, D. C., Pea, R. D., & Gomez, L. M. (1996). The Collaboratory Notebook. *Communications of the ACM, 39* (4), 32-33.

Honey, M., & Moeller, B. (1990). *Teachers' beliefs and technology integration: Different values, different understandings.* (Technical Report No. 6) Washington, D.C.: Office of Educational Research and Improvement.

Koballa, T.R., Jr. (1995). Children's attitudes toward learning science. In S.M. Glynn & R. Duit (Eds.) *Learning science in the schools: Research reforming practice.* (pp. 59-84). Mahwah, NJ: Lawrence Erlbaum Associates.

Koballa, T.R., Jr., & Crawley, F.E. (1985). The influence of attitude on science teaching and learning. *School Science and Mathematics, 85,* 222-232.

Koschmann, T.D. (1994). Toward a theory of computer support for collaborative learning. *The Journal of the Learning Sciences, 3* (3), 219-225.

Linn, M.C., & Hyde, J. (1989). Gender, mathematics, and science. *Educational Researcher, 18*, 17-19, 22-27.

Meece, J., & Eccles, J. (1993). Introduction: Recent trends in research on gender and education. *Educational Psychologist, 28,* 313-319.

O'Loughlin, M., & Campbell, M.B. (1988). Teacher preparation, teacher empowerment, and reflective inquiry: A critical perspective. *Teacher Education Quarterly, 15* (4), 25-53.

Olson, J. (1981). Teacher influence in the classroom: A context for understanding curriculum translation. *Instructional Science, 10,* 259-275.

Olson, J. R., & Singer, M. (1994). Examining teacher beliefs, reflective change, and the teaching of reading. *Reading Research and Instruction, 34* (2), 97-110.

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62* (3), 307-322.

Pintrich, P.R., & Schunk, D.H. (1996). *Motivation in education.* Eaglewood Cliffs, NJ: Prentice-Hall.

Schofield, J.W. (1995). *Computers and classroom culture.* Cambridge: Cambridge University Press.

Songer, N.B. (1996). Exploring learning opportunities in coordinated network-enhanced classrooms: A case of kids as global scientists. *The Journal of the Learning Sciences, 5* (4), 297-327.

Songer, N.B. (1998). Can technology bring students closer to science? In K. Tobin and B. Fraser (Eds.). *The international handbook of science education.* The Netherlands: Kluwer.

U.S. Congress, Office of Technology Assessment. (1995). *Teachers and technology: Making the connection.* Washington, D.C. U.S. Government Printing Office. [On-line]. Available: http://www.ota.gov.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Wigfield, A., Eccles, J., & Pintrich, P.R. (forthcoming). Development between 11 and 25. In D. Berliner & R Calfee (Eds.), *Handbook of educational psychology.* New York: Macmillan.