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Student Motivation and Internet Technology: Are Students Empowered to Learn Science?

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Abstract: The Kids as Global Scientists (KGS) project engages students in the study of atmospheric science through the use of current imagery and on-line communication in a reform-minded, inquiry-based curricular program. This article presents case study data on one sixth-grade classroom of KGS participants during the 8-week program. Six students representing three motivation levels were selected for intensive study to help illustrate how different students view learning science and the use of technology both before and after a technology-rich program. Pre- and postassessment scores were analyzed for the entire class, and the six students' comments from individual interviews served as one example of voices for each motivation group. Results indicated that students made significant gains in weather content knowledge as measured by written assessments, and interviews revealed a high level of student motivation and satisfaction with the project. We conclude with a discussion of the program characteristics we believe are important for creating a learning environment that fosters the motivation and achievement we observed. © 2000 John Wiley & Sons, Inc. J Res Sci Teach 37: 459–479, 2000.

Over the past several decades, computer technologies have become an integral part of our society, changing many aspects of our lives including our interactions with one another, both at work and at home. Recent projections claim that in just a few years, 60% of all jobs will require the technological skills that only a fraction of Americans now have (Gore, 1998).

The use of computers and network technologies in classrooms has become increasingly commonplace as well. According to the Office of Technology Assessment, virtually all schools have one or more computers (95%) (Congress, 1988).

Being prevalent in classrooms by no means implies, however, that technology is either well used or well understood. Many projections about the use of network technologies appear

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rosy, suggesting, for example, that computer technologies will be distinct from the use of previous technologies in the classroom such as television, and will qualitatively change the educational scene (Sharp, 1997). Other groups recognize that the amount of research data supporting learning differences with technology is scant, and therefore, at a minimum, more research is needed to evaluate appropriate roles and uses for Internet technologies in K–12 classrooms.

Perhaps the early research results on students' use of network technologies in classrooms help explain the mixed responses. Results demonstrate that whereas more and more classrooms are now able to tap the resources of the Internet, 81% of Internet use in classrooms is for Web surfing (Market Data Retrieval, from Mc Laughlin, 1997). Research by groups who specifically design Internet activities to promote higher-order thinking demonstrates that students do not spend much of their time working toward understanding or evaluating the information they retrieve, but instead focus on finding quick answers and making shallow interpretations of information (Wallace, Kupperman, Krajcik, & Soloway, 2000). Not surprisingly, a large majority of early research and resource money has focused on issues of hardware and access rather than examination of best approaches for teacher support or fostering student learning (Shaw & President's Committee of Advisors, 1997). Because of this lack of emphasis on scaffolding support or learning, several of these early studies have concluded that teachers are often not successful in achieving their learning goals for students using the Internet (Gomez, Burgess, Marx, & Clay-Chambers, 1997; Hunter, 1995).

In part to address this shortcoming in evidence on the learning and motivational outcomes affiliated with organized Internet-rich curricular programs, we planned a case study-design research study that would focus on the learning and motivation of one classroom of students actively involved in one of these emerging reform-minded, Internet-rich science programs. We believed that with a case study we might begin to develop information that would help address the following questions: What powerful science learning and motivational opportunities for students, if any, do Internet technologies offer? What curricular features maximize productive use of Internet technologies for learning science?

The goal of this study was to examine these complex questions through the focused examination of one Internet-rich science program for middle school learners, called Kids as Global Scientists (http://www.onesky.umich.edu). We present the implementation of our program in many coordinated classrooms nationwide, as well as our research results from one focus classroom that examined whether our program was effective in increasing student motivation and science content achievement.

Conceptual Framework

Computers and technology are generally touted as being effective in increasing student motivation (Kulik, Bangert, & Williams, 1983; Software Publishers Association, 1995). However, such praise is often stated without regard to the specific aspects or applications of these technologies responsible for such motivation. Recent curricular innovations using the Internet, including particular aspects of telecommunications such as E-mail, can capitalize on students' general interest in computers and social communication or collaboration. For example, some Internet science projects link students, teachers, and scientists through E-mail or World Wide Web–based message boards, providing a forum for cross-classroom discussion and communication. A brief discussion of the general features of network projects that apply to student motivation and achievement will provide a framework for understanding the specific features in the Kids as Global Scientists program.

Network Programs, Learning, and Motivation

A number of network science projects have been enacted in recent years (Fishman & Pea, 1994; Lenk, 1992; Weir, 1992; Riel, 1987; Center for Applied Technology [CAST], 1996; Songer, 1998a). These projects share a model in which groups of individuals, whether students, teachers, or scientists, share data and collaborate on scientific issues and current events. Whereas all focus on sharing products of some kind using network technologies, the programs differ in many ways including focus audience, their role for and use of technological tools, teacher autonomy, and flexibility of data collection standards. In the research performed on these network science programs, individuals have described several features that have been variously attributed to contributing to a high level of student motivation and performance. These common features include communication, collaboration, authenticity, access to real-time information, and first-hand resources.

Communication and Collaboration

Network projects can capitalize on the role of communication and collaboration in meaningful learning (Newman, Griffin & Cole, 1989). They provide the opportunity for communication with peers and professional scientists around the world. This type of communication has been found to influence students' interest and accountability in positive ways (Lenk, 1992; Software Publishers Association, 1995; Songer, 1996, 1998a). It is also a possible explanation for an observed increase in the engagement of students not normally interested or successful in science, as well as reduced levels of absenteeism during program runs (Lenk, 1992; Software Publishers Association, 1995; Songer, 1996). Communication in network projects is characterized by social and academic interactions with peers and scientists, including the exchange of scientific data, personal experiences, and observations. These interactions create opportunities for friendships and a broadened understanding of the perspectives of others (Means & Olson, 1995). It is also possible that direct communication with practicing scientists decreases stereotypical views of scientists held by students (Weir, 1992). Honey, Moeller, Brunner, Bennett, Clements, and Hawkins (1991) suggested that girls think about technology as "embedded in and facilitating human interaction" (p. 3). Therefore, the use of technology to interact with others may make intuitive sense to girls, a group normally alienated from the masculine technological world view that permeates our society (Cockburn, 1988).

Research on the social construction of knowledge suggests that collaboration is an effective means of increasing student achievement and motivation to learn if facilitated well (Cohen, 1986; Weir, 1989). Often collaboration is fostered because information from others is needed to complete the objectives of the project, such as to synthesize multiple data to understand patterns.

Authenticity

The authentic nature of network projects can be one of their unique features, although it is difficult to measure the impact of authenticity on learning. By authentic activities, we refer to the activities that provide opportunities for students to use research or analysis tools and data more commonly used by professionals. In many cases, students use the same or slightly modified data and tools as those used by professional scientists. Several studies have at least anecdotal results which indicate that the authentic activities within networked projects can positively influence student motivation (Fishman & D'Amico, 1994; Lenk, 1992; Means & Olson, 1994; Songer, 1996, 1998a). In the KGS project, for example, sensational weather events occur often during our programs. These teachable moments allow students, teachers, and scientists from distant locations to discuss the developing front, volcanic eruption, or school evacuation with each other, and often with the individuals affected by the unusual event. Also, participants can discuss these phenomena within a time span of hours or days rather than later when the immediacy or severity of an event has dissipated.

Access to Real-Time Information

The Internet provides expanded opportunities for classroom participants to access current information from around the globe. With the use of satellite imagery, for example, students have access to real-time (happening now) or near-time (happened within the last few hours) weather imagery and information. Students report feeling empowered and intrigued by following current, meaningful phenomena (Lenk, 1992; Songer, 1996, 1998a). As a part of a real-time event, some students testify that they feel their contributions are important, as, for example, their hurricane landfall predictions are evaluated relative to those of the National Hurricane Center scientists. In these situations, participants can become empowered to be more equal-status observers and hypothesizers about an event in which no one knows the outcome.

First-hand Resources

Often network science activities add a new resource for learning science in the availability of current or first-hand information. Instead of using static resources such as textbooks or Internet sites for scientific information, professional scientists can be queried in tackling many unknown events such as new or novel phenomena that are not widely represented in traditional text-based resources, phenomena unique to a given geographic region, and individual discrepant events present in real-time data (Lee & Songer, 1999; Wallace, Kupperman, Krajcik, & Soloway, 2000).

Previous Research Results on the KGS Program

Although many research questions on the impact of network science programs remain unanswered, previous research on the KGS program demonstrates that students consistently show improvements in several areas including content understandings, control of their own learning, and time on task. In two recent studies, two different populations of students (one inner-city urban, one suburban) demonstrated statistically significant improvements on science content and inquiry (Songer, 1998a, Songer, Lee, & Kam, 1999). In a study examining the role of threaded discussions on student learning, KGS students demonstrated greater initiation of conversations and control of their own learning compared with more traditional discussion forums (Lee & Songer, 1999). Recent data from project teachers demonstrate that, whereas 66% of teachers had not previously participated in Internet-integrated curricular program, only 14% rated this program as difficult to implement, and 28% found the program easy to implement. A self-report of how well the program worked in their classroom resulted in 59% of the teachers stating that the program worked very well, a statistic highly unusual for a technology-rich program of any kind, but particularly unusual for a program targeting urban schools (Songer, 1999).

Network Project Challenges

A critical factor in implementing these programs continues to be the successful brokering and guidance of students and teachers toward best and appropriate use of these tools for measurable content and inquiry gains for all. As also documented by Becker in his national surveys (1999), we found that teachers struggle with many management issues, such as small groups of students performing different activities at different times, the composition of appropriate messages to other groups, collecting and analyzing current data, and asking many questions all at once, most of which do not have textbook-available answers. Teachers must tolerate noise and management difficulties, and the imminent unreliability of technology. In KGS, we work with these challenges in many ways, including providing backup resources such as Internet-smart CD-ROMs which come with built-in storms for when network access is unreliable or unavailable.

Another challenge surrounds the issue of scaling from small numbers of project participants to much larger numbers of more diverse participants. Difficulties regarding management, personal attention, and quality control become more acute as the numbers rise. As these projects become more prevalent and resources more available, the types of teachers who participate change as well. In the first several years of KGS, for example, all of the teachers were volunteer, self-starting risk-takers. In a move to incorporate a wider range of schools, we have shifted our focus to a much wider range of teachers, including a focus on urban sites and districtwide scaling where first-year results show statistically significant content gains in all 19 urban minority classrooms in our local inner-city district (Songer, Lee, & Kam, 1999). We continue to work to expand our understanding of scaling and brokering of our work to diverse audiences.

Although these recent studies have begun to characterize learning gains and attitude changes among student and teacher participants, there are very few studies that can articulate the kinds of motivational changes occurring, if any. We believe the field has lacked appropriate mapping of strong and varied assessment instruments for these learning environments, including content measures that more articulately characterize qualitative and quantitative understandings, and attitude and motivation instruments well known in other disciplines.

Drawing on work in educational psychology, we looked at research in motivation and self-efficacy by Bandura and others (Bandura, 1986; Shunk & Hanson, 1989) to assist us in articulating and measuring the kinds of attitudes we might observe. The literature identified five main categories of attitudes relative to motivation, including self-efficacy, control, interest, value, and goals/goal orientation. We probed attitudes in all of these areas, but for our purposes, the construct of self-efficacy appeared most relevant to our work.

Bandura defined *self-efficacy* as one's personal beliefs about their performance abilities in a given domain. In other words, self-efficacy describes one's belief that they can do the task, and their confidence in pursuing it. Bandura stated that self-efficacy influences many aspects of learning, including an individual's choice of activities, effort, persistence, and task accomplishments. Shunk and Hanson (1989) discussed how observing the successful behavior of others who are perceived as similar to yourself raises the self-efficacy of observers and motivates them to try or persist longer. In one study, students who observed the success of a peer developed higher self-efficacy than students who observed the success of an adult teacher (Shunk & Hanson, 1985). These authors stated,

> Similarity is especially influential when individuals are uncertain about their capabilities, as when they lack task familiarity and have little information on which to base efficacy judgments or when they have experienced difficulties and possess doubts about performing well. (p. 155)

In our study, we developed a motivation questionnaire containing a total of 18 items, 8 of which probed students' attitudes on self-efficacy. Details of this instrument and our results are provided subsequently.

In summary, previous research on network science programs provides many interesting and positive projections of the potential for enhanced learning outcomes and increased motivation with these programs. In fact, little sound evidence exists that can help articulate the kinds of attitude or motivational changes students in these programs might exhibit, as content understandings or ownership of learning improves. The case study described here was conducted to better understand student achievement and motivational attitudes in one of these programs, the KGS learning environment. As such, the study was designed to achieve the following objectives directly related to our two research questions. First, we worked to identify the motivational and content profiles of a small set of various learners interacting with one Internet-rich curricular program, as one view into what kinds of powerful learning and motivational opportunities, if any, exist for students. The second objective was to use the insights gained from addressing the first objective to identify curricular features that support content learning and positive self-efficacy among various types of students in KGS and similar Internet-rich learning environments.

Methods

The Kids as Global Scientists Program: An Overview

Kids as Global Scientists is an 8-week atmospheric science network program in which middle school students use inquiry-based curricular and Internet software program to study general weather topics such as wind, precipitation, temperature and pressure, and clouds and humidity collaboratively with students and professional scientists distributed across North America. The program was developed as an inquiry-focused curricular program that scaffolded the development of content understandings through three phases: introductory, development of expertise, and sharing. In the first phase, small groups of students introduce themselves to each other and their content through activities that initiate learning in one of four main topics. During the second phase, students focus their study on one topic, either wind, precipitation, temperature/pressure, or clouds/humidity. Students collect local weather data with weather instruments and share and critique their data with others. Students look for patterns in their local weather and ask questions to students studying the same topic in different locations, perform hands-on investigations, use real-time satellite maps, and investigate severe weather and environmental issues related to their topic. Professional meteorologists also interact with the students and serve as real-life experts with whom students can become familiar and ask individual questions. In Phase 3, students apply their understandings through data comparisons and prediction making of current weather events. Near the end of this phase, students share personal stories and expertise through an on-line newspaper.

During this run of the KGS program, approximately 3500 students from 80 classroom locations participated in this program. This study focused on one of these classrooms, a sixth-grade class performing the Kids as Global Scientists: Weather program. The school has two computer labs with a total of more than 60 computers, of which half are connected to the Internet at ISDN rates. Regarding anonymity of participants, all of the names used in this article are pseudonyms.

Our rationale for conducting research in this site with a good technological infrastructure involves our desire to fine-tune and evaluate our emerging program before expanding to more challenging sites. In subsequent years, we have implemented our program both with much higher numbers of participants (i.e., 11,000 participants in 240 sites in 1999) as we have shifted our focus to low-socioeconomic staus, inner-city sites such as Detroit Public Schools. We strongly believe that studies such as this one, in which the technology and other aspects of the infrastructure were strong, lay important groundwork for the extremely challenging work we are currently performing.

Data Analysis and Instruments

This study was conducted using an adaptation of qualitative research methodologies of Spradley (1980) and Chi (1997). This process included the collection of a variety of data including field observations, videotapes, E-mail correspondence transcripts, individual interviews, and written assessments. Using Chi's eight-step analysis protocol, we first looked for major themes from the various data sets. The bulk of the themes emerged from the interview transcripts. Themes were then organized and examples from the data were listed in each category to illuminate patterns. In addition, we devised our own instrument, a motivation questionnaire, to identify various students to serve as class representatives. Content assessments were scored according to a coding rubric and analyzed with an analysis of variance (ANOVA) comparison of means for statistical significance. A more detailed description of the major data sources follows.

Motivation Questionnaire

Before the project began, 18 students completed a 18-item motivation questionnaire designed to identify students' perceptions about themselves in five areas of motivation, including self-efficacy, control, interest, value, and goal orientation. In this questionnaire, 8 items probed self-efficacy, 3 probed control, 2 focused on interest, 2 focused on value, and 3 focused on goal orientation. Table 1 illustrates five of the items and identifies which category of motivation that question probed.

Coding. There were 18 questions; 16 were multiple choice and 2 were short answer. Using only the multiple choice questions, questionnaires were coded and assigned 3 points for a high, 2 points for a moderate, and 1 point for a low motivation response. One question indicating expected grades was coded on a 5-point scale. As a result, there were 50 points possible. Student scores ranged from 45 to 26. Based on their total scores, students were divided into three groups as outlined in Table 2.

Focus Students. Based on the motivation scores and input from the classroom teacher, a boy and a girl were selected from each of the three groups to serve as voices for their group. Although we realize that students with similar scores responded variably to the questionnaire, thereby distinguishing themselves from their classmates, we focused our study on these groups as a way to discuss how students with generally similar profiles interact with the KGS curriculum. As such, this is a case study of those six students whose responses, we suggest, are useful in understanding how various types of students may interact with the project.

Content Assessment

All students completed a written assessment at two time intervals: before and after the 8-week program. The assessment was designed to measure content learning in atmospheric science. The assessment administered before the program contained 33 questions, 20 of which were open-ended and 13 were multiple choice. The postassessment contained 35 questions; 22 of

Table 1
Sample questions from the motivation questionnaire

Self-efficacy
In general, I believe
(a) I can do some assignments well, but not all.
(b) I can do any assignment well.
(c) I can only do a few assignments well.
Interest
In terms of effort, I
(a) Sometimes try my best.
(b) Rarely try my best.
(c) Alwasy try my best.
Self-efficacy
When my teacher asks a question in class, I
(a) volunteer (raise my hand) to answer a lot
(b) never volunteer to answer
(c) volunteer to answer every once in a while
Control
If I don't understand something on my homework, the first thing I do is
(a) look it up or keep trying by myself
(b) skip it
(c) ask somebody for help
Goal orientation
(a) I wish my grades were better.
(b) I am happy with my grades.
(c) I don't care about my grades.

which were open-ended and 13 were multiple choice. Ten of the questions in each assessment were released NAEP assessment items (NAEP, 1990), used to evaluate KGS students on standardized general science and weather-related science questions. The pre- and postassessments were essentially identical, with questions reworded to reflect having completed the project for the postassessment. All of the questions were coded using a coding rubric developed by our project staff and found to be >90% reliable.

Interviews

Six focus students participated in informal initial interviews at two times (before and after the program) to ascertain more information about their attitude toward school and learning; background knowledge of weather, computers, and the Internet; and expectations for the project. The researcher presented the interview questions below as written and, consistent with Spradley (1979), offered probes when necessary to encourage student responses and/or clarification. The interview transcripts were then reviewed for themes and organized, and patterns that

Table 2
Motivation groups

Group	Score	*n* in group
High motivation level	41–50	5
Medium motivation level	31–40	11
Low motivation level	≤30	2

Table 3
Sample science content assessment questions

Give an example of what causes the precipitation in your area to be the way it is. Please write your answer in a complete sentence.
What do you think the clouds and humidity are like in the area that you wrote to? Please write your answer in a complete sentence.
Think of a weather topic you would like to know more about. Please write a good question to send to your scientist that would help you learn a lot more about that topic.
You have just received the following e-mail message from a group of sixth-graders:
Our names are Jill and Ron, and we are studying wind in Boulder, Colorado this semester. We have kind of heavy winds here. We don't have tornadoes because we live too close to the mountains. There are no hurricanes in Colorado because there are no oceans near us.
Write a good question to send back to these students that will give you a clearer idea about what the winds are like in Colorado.
Which of the following should a science class do to find out which wind direction is most common during these times of cloudy skies and wet weather in their town?
A. Check a weathervane, thermometer, and barometer daily.
B. Make a chart of the different cloud formations shown in an encyclopedia.
C. Keep a record of daily rainfall for an entire year.
D. Record wind direction, cloud conditions, and rainfall daily for at least 4 months.

emerged from the data were listed under each theme. The classroom teacher and student teacher were also interviewed after the program with regard to their perceptions of these six students' performances and the project in general.

Results

Whole Class

Pre- and postcontent assessments were analyzed for the entire class ($n = 18$). A two-tailed, paired t test revealed that as a whole, the class improved significantly from the pre- to the postassessment on content questions ($p < .05$). Similarly, because the students were to become experts on a particular topic area, we compared student performance on content questions about their topic with the performance of students not studying that topic. An ANOVA comparison of the means showed that each group scored significantly higher on the postassessment content questions related to their topic than their classmates who studied a different topic. It was not surprising that students who studied a specific topic did better than students who did not study that same topic; however, these results show that their differences in knowledge on the postassessment were not due to chance.

Motivation Groups

Pre- and postassessment scores were also analyzed to see whether there was a difference in achievement between motivation groups. In other words, we wanted to know whether students with a certain motivation profile showed greater content gains than others. As our cell sizes were small, we did not expect significant results and did not see any ($p = .5$). Nevertheless, there were consistent patterns between content and motivation profiles; the high motivation group demonstrated the highest content mean score, the moderate motivation group had the middle mean score, and the low motivation group had the lowest mean score.

Table 4
Follow-up interview questions

General project questions	Pretend that you are explaining the Kids as Global Scientists project to someone who has never heard about it. What would you say? What were some of the best or most exciting things that happened during the Kids as Global Scientists project? What was frustrating? Explain.
Collaboration	How did you get along with the members of your group? What types of activities did you work on together in this project? What types of activities did you work on alone? Think of another group project you've worked on. What types of things did you work on together? Were those things different in any way from the KGS group activity? If so, how?
Assessment	What assignments have you received grades for on the Kids as Global Scientists project? How do those grades compare to other grades on similar assignments you've gotten in science? If they are different, why do you think so?
Learning	Tell me what you learned about (your topic). What did you learn about the other topics? What was the primary resource that you learned this information from? Are there other questions about weather you have that you did not get answered? Were you satisfied with the quality of information you received about your topic through this project? How does the amount and quality of learning about weather from KGS compare to other topics you've learned about in science this year? What new things (techniques/commands) did you learn how to do on the computer during this project?
Teacher role	What types of things did your teacher(s) teach and do during KGS? How would you describe the role of your teacher during KGS? Was your teacher's role any different from her role in science class usually?
Communication	How many messages did you send and receive from other schools? How many messages did you send and receive from your mentor? How did this correspondence influence your interest in the project? What did you learn about the sites you wrote to?
Time on task	In our preinterview you said you could usually spend about (*x*) amount of time working on something. How did KGS tasks compare with this? (Why if different.)
Motivation	How would you rank the KGS project in comparison with all other units in science this year? Explain. If the student was motivated by the experience: Why were you motivated differently by/more interested in this project? If they weren't motivated by the experience: What about KGS did not motivate or interest you? Can you think of any school activity that you might be very excited about?

The Case Studies

The six focus students selected for intensive study participated in informal interviews at the inception of the project to generate student profiles. As mentioned earlier, the informal interview questions were organized around several categories: achievement and motivation, time on task, general attitudes toward school, learning style, and experience with weather and computers.

Based on these interviews and motivation questionnaire results, a composite description of each focus student was developed. These composite profiles were used to summarize preproject

Table 5
Postassessment scores per area of expertise

Clouds and humidity	Mean = 2.65, $p < .05$.
Precipitation	Mean = 1.92, $p < .05$
Temperature and pressure	Mean = 3.75, $p < .05$
Winds	Mean = 1.80, $p < .05$

characteristics which, we hoped, could be used as context for the focused study of these students throughout the program, and the follow-up interviews at the conclusion of the program. Each preprogram composite is presented briefly below.

Robby. Robby is a White male who was identified as a low motivation student on the questionnaire. In the initial interview, he described himself as someone who likes to "goof around" and who does not get very good grades as a result. When asked how long he can spend working on a task or assignment in class, he said he can work for about 2 min because "there's a lot of other things to do like talk." The only thing he likes about school is seeing friends. He had not studied weather before that he could remember, except when a local television meteorologist came to give a talk at his school. He said he did not care much about weather, because "Mother Nature creates it and there's nothing you can do about it."

Gwen. Gwen is a female of mixed-race decent. She also scored in the low motivation group. In the initial interview, Gwen said that she gets average grades because she does not work as hard on her work as she should. Gwen thinks she can spend 3–5 min on a task in class before she needs to take a break and start talking to her friends; "I usually get in trouble for talking too much." The things she likes about school are seeing friends and writing in language arts. In fourth grade, she learned some things about weather such as the difference between Fahrenheit and Celsius, but that is all she remembers. Because her dad works with computers, she knows a lot about them. Gwen thinks KGS will be different from other units in science because they will get to talk to other schools: "It will be fun."

Jared. Jared is a White male who represents the moderate motivation group level. In the initial interview, he said that he thinks his *B* and *C* grades are okay because *C* is average. Jared thinks he can spend about 45 min working on a task uninterrupted. In art, he could work longer, though. He likes seeing friends at school and said that he guesses "learning is a pretty big part of life," so that is okay, too. He dislikes taking tests, but otherwise learning can usually be fun. Jared would prefer to work on an assignment that is "just right" in terms of a challenge level, but "a few hard ones and a few easy ones are okay, too." He has learned some things about weather before, especially about clouds. He likes computers and looks forward to talking to other people in KGS.

Kate. Kate is a White female who is also in the moderate motivation level group. She is soft-spoken and timid at times. She gets *A*s and *B*s because she tries really hard. She is very proud of her grades. Kate thinks she can spend about 20 min working on a task before needing a break. Sometimes she can work a bit longer when she's writing because she likes it a lot. She thinks school is okay; she likes learning and seeing friends but she dislikes homework. Kate would prefer to work on an assignment that challenges her because if something is too easy, it is boring. She studied weather in third grade but she does not remember much except that they measured the amount of rain. She has not used computers much at school, but she likes them for word processing, E-mail, and the Internet. She thinks KGS will be fun because they will get to use computers and talk to people and learn from them.

Danny. Danny is a White male who is in the high motivation group. He is very outgoing and talkative. He gets good grades because he tries really hard and sticks with things until he is done. Danny can work on a task “for however long the teacher wants me to” without getting distracted. He likes school because he gets to learn new things and see friends, plus “it would be boring to be at home.” He prefers to work on challenging assignments because things that are too easy are boring. Since he wants to be a meteorologist when he grows up, he knows a lot about weather at the start of the project. Danny knows which types of clouds bring rain and knows some things about hurricanes. He has not studied weather in school, just on his own. He thinks KGS will be exciting in that you get to talk to people and learn about where they live.

Allison. Allison is a White female who is also in the high motivation group. She comes across as calm, conscientious, and mature. She says she gets good grades because she works hard and is smart. Allison says she can spend a long time on a task and does not need breaks, especially when it is one of her favorite subjects. She likes school a lot because she enjoys learning new things and enjoys doing things at school that cannot be done at home. She prefers to work on assignments that are just right in terms of challenge level so that they are not too discouraging and not too easy. Allison has not studied weather in school before but has seen satellite images on computers. She knows a lot about computers and thinks KGS will be interesting because she will get to talk to people and learn “what’s happening right now.”

Elaboration of Patterns through Follow-up Interviews

Postinterviews were transcribed and analyzed to illuminate patterns or discrepancies with other project data such as content pre- and postassessments, motivation questionnaires, and teacher interviews. The student postinterview data are presented in two sections: achievement and motivation.

Achievement

Quality of Learning. Although the class improved in general from the pre- to the postassessment, there were some notable differences within the cases regarding the coherence and accuracy of their knowledge in the follow-up interviews. For example, the two focus students characterized as low in motivation did not appear to understand that they did not hold accurate understandings of the weather concepts they studied. Gwen (low motivation) thought she understood her topic, temperature and pressure, but her explanation about air masses was convoluted and inaccurate. When asked what she had learned, she digressed into personal stories about various weather topics without connecting these stories to learning. Robby (low motivation) said he thought he learned about the same amount in KGS as in other science units. However, he did not show any improvement on the postcontent assessment. In addition, when asked about content in his topic area, he responded with mostly confused and incorrect answers. He said, “I really don’t remember anything we’ve done this year really. I don’t think I learned anything.” Nonetheless, one day during classroom observations, he gave a very nice example of the difference in air molecules in a high-pressure and low-pressure situation. Based on this experience, it seems that either he believed he did not remember what he had learned or the conditions of the interview and postassessment were not suitable vehicles for revealing his knowledge. Despite believing that he did not learn anything, Robby ranked the KGS project a 9 out of 10 in comparison with all other science units that year. Unfortunately, being satisfied with the program does not seem to be enough to ensure that our low motivation students achieve a reasonable level of proficiency on our content assessments.

In contrast to these low motivation level students, the focus members of the moderate- and high-level motivation groups could explain several concepts from their area of content expertise with accuracy and coherence. The only distinction between these two groups was what they learned about topics outside of their content area. (It is important to note that students were not held responsible for information outside of their content area.) Allison and Danny (high motivation) both indicated that they had learned some about topic areas outside their expertise from reading through weather books while researching their own topic, and by paying attention to films and teacher minilectures in class on the other topics. Jared and Kate (moderate motivation), as well as Robby and Gwen (low motivation), said they had learned nothing about the other topic areas. These results suggest that having students become experts in one topic area promotes success among our moderate and high motivation profile students while not preventing students from learning about other topic areas if they are so inclined.

Quantity of Learning. Three of the students thought they learned more in KGS than in other science units; the others thought they learned the same amount. None of the students thought they learned less. Jared (moderate) and Danny (high) thought they learned more because of the “fun” nature of the project.

> Jared: I guess we learned a lot more in Kids as Global Scientists than other stuff, because, just again, the Internet was really fun to do. . . . The next day, you’re like, oh, I want to go down to the computer lab and do that and then you would want to learn about it if you used something that was fun.

Danny (high) commented that KGS created different learning opportunities than using textbooks or performing labs in science. He said that “in this, you could actually go to the source and it was just more fun, you were more active.” Having access to real-time information for him was one of the distinguishing factors in KGS. Kate (moderate) thought she learned more because of the length and depth of the project.

> Kate: I learned more in this because it was longer, and we got to look in all these different places for information. And we had to do all these questions on it so we learned a lot.

Robby (low) also thought the length of the project helped him. Although Robby did not think he learned anything, he actually had a more favorable attitude toward learning in this project because having more time made him believe he had more opportunities to learn.

> Robby: I guess you could, like, think, really. You had time. Instead of like on these projects out here, they’re, like, in one period to do the whole thing and this time you

> had so many days. We had every day, like, one day you could be off and goofing around, then the next day I'd be working . . . so you can get a good grade.

The length of this project and the depth into which students can investigate their topic area suggest changes in classroom instruction. Most units at the middle school level are conducted for short periods and address the details of scientific phenomena in a more cursory way than KGS (Linn, DiSessa, Pea, & Songer, 1994). The students' comments suggest that perhaps for a range of students, longer programs which allow increased time to explore concepts or make up for goof-off days can result in a positive effect on students' perceptions and performance.

Motivation. In the follow-up interviews, each medium and low motivation student reported an increase in the amount of time he could spend on a KGS task. Robby, Gwen, and Kate stated that the main reason for this was that working on the computer or composing E-mail is more engaging than other classroom tasks. Robby (low) alluded to the fact that the authentic nature of communicating with others increased his ability or desire to concentrate.

> Robby: I could concentrate longer when I was writing [on the computer] because I was really thinking about writing and whenever I wasn't writing I didn't really care.
>
> Kate (moderate) suggested that collaborating with others helped her engagement level.
>
> Kate: I could probably spend more than 20 minutes because the time went pretty fast, because of working with partners and on Netscape.

Jared (moderate) said he could focus longer because he wanted to "write it down and get it so it's good" because the project was "fun."

When asked how corresponding with other students and mentors influenced their interest in the project, all students responded enthusiastically. Correspondence appeared to influence the amount of time and effort they were willing to invest in writing messages, as well as potentially increasing their interest in learning about weather.

> Robby (low): [Communicating on the Internet] was different. . . . It made it more like you wanted to do more. We wanted to talk back and have them send back data soon.
>
> Gwen (low): It was good because . . . you're not in the class all day, like, listening to the teachers' lectures and their story about what you have to do, or reading a book, you know?
>
> Danny (high): Well, you got to get what the kids thought, too, like, you got to see what other kids thought about how their winds work and they had to learn the same stuff we did, so it was kind of better 'cause they were doing the same things we were.
>
> Allison (high): [Communicating] made you want to write more. Getting messages made you want to just like doing the interactive talk.

Furthermore, the KGS program got high marks from the interviewees. Five of them gave it an 8 out of 10 or higher, whereas Kate (moderate) ranked it in the middle of all the science units she had done that year. Kate mentioned that she preferred units that devote a majority of time to hands-on labs, rather than time split between computer and hands-on activities. When asked why they were motivated by KGS, the interviewees provided some more insightful answers.

> Allison (high): I like using the computers and the Internet; we got to go places that not the whole class was doing.

Jared (moderate): I liked the group and the computers. I think the group is good because it's like three or four minds. And computers were fun.

Gwen (low): It was neat to talk to people around the world and cooperate with them to share data. I was good at cooperating in this.

Embedded in these statements are references to several of the characteristic features of the KGS program. The project seeks to capitalize on the use of communication, collaboration, authentic tools of scientists, and access to real-time data. The students' comments in this study, across a range of motivation levels, provide support for the importance of these features in increasing student satisfaction with this program.

Teacher Interviews

Interviews with the classroom teacher and the student teacher were conducted at the end of the program and transcribed to elucidate their perceptions of students' performance and their explanations for that performance. Special attention was given to comments that supported or refuted the role of the features of network projects suggested in the conceptual framework on student motivation and achievement.

The student teacher was impressed with the depth of knowledge the students learned about their content area. When asked how she thought the depth of knowledge gained by students compared with other science units, she responded enthusiastically:

> Oh, I think it was definitely deeper . . . you should look at some of these graphs they analyzed 'cause they're so great. We had them find relationships between pressure and temperature and pressure and wind speed and they all could do it. They all, you know, "Oh! That's what [that is]." It visually put it on paper for them and it worked! They understood why and they can tell you why and it's great.

When asked what factors contributed to this depth of student understanding, she included accessing multiple sources of information, collecting weather data themselves, analyzing their own data in comparison with others', and having a sufficient amount of time to make connections among their experiences and knowledge.

Anne, the regular classroom teacher, noted that the KGS curriculum provided a new forum in which students could interact, altering some classroom dynamics and thereby providing new opportunities for achievement and confidence. She used Allison (high) as an example. She commented that Allison is a "brilliant" person who often does not get her needs met in class. The boys blurt out answers before she has time to be called on, and therefore she gets stifled in class participation.

> So you think of ways to overcome that and one way is to have them work on the Internet because everybody's voice is equal on the Internet. You know, there's no blurting and there's no, you know. . . . Here she is and she's able to communicate without these social and structural barriers in classes. So, I think that for [Allison], or girls like [Allison], especially, this is a really good way to overcome some of those stupid obstacles that they face in classes.

Not only does the KGS learning environment network science project support a change in classroom instruction that can benefit students, it can also support a change in the nature of communication in the classroom. Although some outgoing and confident students tend to dominate the communication patterns of the classroom on a daily basis, many others get left behind. The new methods of communication, in addition to other facets of the learning environment explored in this study, create opportunities for new patterns of student participation and motivation.

Anne also discussed the impact of correspondence on student learning and motivation. As a veteran of the project for 4 years, Anne has witnessed the program with many students over the years. For the interview, Anne printed out and shared the following correspondence that a group of girls initiated with their mentor, a professional meteorologist in the same state.

> Fri., March 1, 1996
> Dear Meteorologist,
> Hello our names are Darcy, Jane and Sally. We are happy today sense [sic] the weather has finally improved! We go to Colorado Middle School. We are in sixth grade. We are the precipitation group. So far we have learned how snow works. We will write to you later.
> Sincerely,
> Darcy, Jane and Sally
>
> Thu, March 7, 1996
> So how does snow work? I would like to know, because I am writing a book about snow. By the time I'm done with the book, you will not be in 6th grade any more.
> Neil Drake
> Colorado Climate Center
>
> Fri., March 15, 1996
> Dear Mr. Drake,
> This is how snow works. Ice crystals form around dust or other small particulates in the atmosphere when water vapor condenses at temperatures below the freezing point. Partly malted [sic] crystals grow in size up to 7 to 10 cm in diameter. (: we hope this helps you:)
> Isn't the weather here strang [sic]. Well we got to go,
> Bye,
> Darcy, Sally and Jane
>
> Fri., March 15, 1996
> Hey, thanks for the help with my snow book. How much snow did you get yesterday? We only had about 4 inches on the ground, but it contained close to 1.00 inch of water. That made for some amazing slushballs.
> Neil Drake
>
> Mon., March 18, 1996
> Dear Mr. Drake,
> This is Darcy, Jane and Sally again. Glad that we could help you with your book:). On Friday we got 0.1 cm, (what a lot huh)!!! Obviously we didn't get very much Precipitation. So what have you been working on in your book? We have learned about how hail, fog, rain, mist, dew and yes snow. If you want to know please write us back!!!!!
> Sincerely,
> Darcy, Jane and Sally:)

Anne mentioned that the reason why she chose to discuss this example was because of the way in which this illustrated to her a somewhat unusual motivational experience for those girls' learning. The students were motivated to learn because they enjoyed helping a weather professional. The girls spent extra time in class seeking out the information they needed to carry on a scientific conversation with the scientist. Anne was thrilled with this correspondence.

> I just think, wow, you know, in what other circumstance could I get a meteorologist to talk to these girls? I've had guest speakers, but then you still have the problem of loud people blurting things out and these girls don't do that. Gosh, just to go and talk to this man, totally intimidating, but he's somehow anonymous on the Internet. I've never seen anything like it and I've never been able to set up anything even close to that [without the Internet].

Such an opportunity to have meaningful dialogue with someone who is knowledgeable is unique and exciting for students. These comments demonstrate that authenticity, communication with professionals, and collaboration among students are three aspects of network science programs such as KGS which can support content gains and opportunities for the development of self-efficacy, including opportunities for students such as these girls to feel confident in their ability to provide useful information to others.

Discussion

In the introduction, we stated that we hoped our case study would help address the question: What powerful science learning and motivational opportunities for students, if any, do Internet technologies offer? Our results show that students reaped both learning and motivational benefits through participation in KGS, a reform-minded, Internet-rich program. The motivational benefits are best represented by the construct of self-efficacy that Bandura (1986) defined as one's personal beliefs about his or her performance abilities in a given domain. Self-efficacy influences one's choice of activities, effort, persistence, and task accomplishments. The term *empowerment* is often used to reflect feelings of self-efficacy that positively influence one's accomplishments.

We believe that our results suggest an increase in self-efficacy, or empowerment, on the part of our focus students in this case study. In this classroom, the students most likely to be uncertain about their abilities to succeed with the new challenges of an Internet science program were the moderate and low motivation students. Our results demonstrated that each moderate and low motivation level student reported improvement in the amount of time he or she would spend working on a class project. This desire to want to spend more time on a task indicates greater confidence and interest in learning that is one aspect of self-efficacy measured in this study. We believe this change in focus might be at least partially explained by the students' ability to find a learning environment in which their voices, and those of their peers, were valued and respected, thereby allowing them to view themselves as capable participants in this new learning situation. This Internet learning environment also has the potential to overcome some social barriers of a more traditional classroom, as in the example of Allison offered by the teacher.

The construct of self-efficacy from motivation research helps us begin to characterize the motivational changes which we believe are occurring in this learning environment, and it helps us articulate the aspects of the program which might influence self-efficacy. This leads us to address the second question we set forth: What curricular features maximize productive use of Internet technologies for learning science? We suggest three features which we believe are essential in empowering student learning in telecommunications-enhanced science projects: telecollaboration, authentic questions, and time to develop integrated understandings of the science concepts in context.

Telecollaboration

Our results demonstrate that students are excited to talk to other kids through interactive talk on the Internet, and that their content learning and self-declared time on task improve as a result of, among other things, productive interactions with peers and scientists. As demonstrated by students such as Allison, students who already feel empowered in their lives find this still to be the case, yet perhaps to a new degree, in KGS. However, this increase in self-efficacy is most intriguing and exciting for students such as Robby and Gwen, who are often not empowered by school experiences. Their excitement about telecollaborating is reflected in their statements:

> Robby: [Communicating on the Internet] was different. . . . You wanted to do more. We wanted to talk back and have them send back data soon.
>
> Gwen: It was neat to talk to people around the world and cooperate with them to share data. I was good at cooperating in this.

We suggest that carefully scaffolded telecollaboration is important because it fosters student participation in a meaningful arena in which their voices and those of their peers are valued and respected. Our data suggest that this participation can encourage particular types of students' effort, persistence, enthusiasm, and task accomplishments, as illustrated in the example of the girls' correspondence with their weather professional.

Although we recognize the potential of telecollaboration programs for student achievement and motivation, we also acknowledge that they are often challenging to orchestrate, and therefore these results do not automatically occur with any network project or use of the Internet (see Songer, 1998b, for more elaboration on this idea). Successful telecollaboration requires careful and appropriate use of telecommunications tools, as well as scaffolding of knowledge development that ideally can be faded over time. Scaffolding must also be provided for teachers who are unfamiliar with the use of Internet-rich curricular programs, so that they can facilitate educationally meaningful uses of this and other technologies (Songer, 1998b).

Authentic Questions

We suggest that a second important feature for student achievement and self-efficacy is the study of current and meaningful research questions, issues, or real-time phenomenon. Students have the opportunity to make significant observations, contributions, and conjectures in a real-time event, particularly when their voice is appropriately valued. Predetermined labs or recorded events do not hold the same motivational power and prestige in the eyes of students. This attitude is reflected in a comment by Danny, that in KGS, "you could actually go to the source and it was just more fun, you were more active" than in other science projects.

Our research also suggests that the objective for collaborating must be focused and found useful to students if the collaboration is to be successful. Telecollaboration proved to be authentic for participants in this study, and this authenticity promoted task persistence and effort. For example, Robby said that he could concentrate longer than usual when crafting messages on the computer because he was "really thinking about writing." It was important to him to participate seriously, and this approach reflects his empowerment as a learner.

Time for the Development of Understandings

The final important feature we suggest is having adequate time to conduct in-depth investigations of a topic. Students must be given enough time to delve into their subject to become experts on a level relevant to their age and intellectual development. Short authentic excursions away from conventional classroom activities may spark the interest of students but encourage superficial examination of complex issues. Instead, prolonged investigation of a more focused set of scientific concepts is essential to help students begin to understand complex issues and provide them with a sense of real accomplishment (Linn et al., 1994). We believe that in KGS the in-depth investigations allowed students to feel more confident about their contributions and understandings so that they could more comfortably contribute to the ongoing conversations. These feelings seemed especially salient for low and moderate motivation level students. Recall Robby's observation that "I guess you could, like, think, really. You had time. Instead of these projects out here, they're, like, in one period to do the whole thing and this time you had so many days." He felt that if one day he was "goofing around" too much, the next day he could focus on working and still learn enough to "get a good grade."

Although we think these three features—careful telecollaboration, participation in authentic questions, and availability of adequate time for in-depth investigation—are convincing, further research is needed to characterize the learning of students and teachers and to explore other features that may help explain the complexities of self-efficacy for learning with telecommunications. Investigations into the effects of network projects and changes in classroom culture will further our understanding of the potential power and limitations of telecollaboration for a wide range of learners.

Summary

The findings of this study suggest that telecommunications programs such as Kids as Global Scientists that promote current issues and opportunities for collaboration provide valuable motivational and learning opportunities for students and teachers. In our study, a variety of students found this type of learning environment an enjoyable way to investigate and learn about their own science questions. Students may learn more or less in accordance with the amount of material they usually comprehend and relative to measures such as our motivation questionnaire. However, when students find the use of the Internet and telecollaboration engaging and motivating, perhaps leading to improvement in self-efficacy, such attitudes may affect the quality and nature of understandings they will develop. Therefore, carefully designed and well-orchestrated network science projects have the potential to empower students to hold positive motivational beliefs and discover what it means to learn and do science.

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