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Literacy Network: Using Computer Network Technology to Support Deaf Students' Meaning Making in Science

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Deaf children often have extreme difficulty with written language. In fact, the acquisition of written language may be the most difficult problem a deaf child faces (Strong, 1988). Studies examining the reading and writing abilities of deaf students indicate that, on the average, the written language produced by deaf high school students is only about 60% intelligible (Johnson & Kadunc, 1980), and the average deaf student leaves high school with a fourth grade reading level (Allen, 1986). Many deaf individuals cannot read for pleasure and information seeking, nor can they share ideas through writing. Because of their limited literacy, many deaf students cannot fully benefit from formal schooling. As adults, they are kept from significant participation in the work place, and the hearing culture at large. Improving the literacy skills of deaf children is a critical step towards improving their lives and their life chances.

Computer network technology has great promise for enhancing deaf students' literacy practice in school. Typically, this technology has software programs for word processing, for group conferencing, for sending and receiving electronic mail (e-mail), and for data storage and analysis (database programs). The integration of this technology into subject matter areas makes it possible for deaf students to share their thoughts and ideas with teachers and other students in writing, and thus to experience written language as a tool for communication and thinking in the context of meaningful learning activities. This kind of approach towards learning reading and writing has been advocated by educators of the deaf (e.g., Johnson, Liddell, & Erting, 1989; Luckner & Isaacson, 1990; Staton, 1985), and its effectiveness has been demonstrated by both cognitive and educational research (e.g., Peyton, 1988; Staton, 1985).

Even though network technology has great potential for enhancing literacy development and subject matter learning in deaf students, the impact of this, and other educational technologies ultimately depends on the social and instructional contexts in which they are used. For instance, teachers' goals and strategies for integrating the technology into their curricula are important factors that mediate its impact on students' learning (Honey & Moeller, 1990; Moeller, Reich, & Bell, 1991; Moeller, Bell, & Reich, 1993). Little is known yet about the specific conditions of network use that are most effective in enhancing the literacy development of deaf students. Therefore, an important step in the development of a network supported curriculum for deaf students is to experiment with different implementations of the technology and compare the impact of these implementations on students' literacy development.

The Literacy Network Project provided such an opportunity during the last year. This project is a multi-year collaborative effort between the Center for Children and Technology (CCT) and the Lexington School for the Deaf to develop a model program for the use of local area network technology in subject matter areas to enhance literacy development and science learning in deaf students. For several years now, high school students at the Lexington School for the Deaf have been using a networked system of computers that is equipped with communication software (group conferencing, electronic mail, and word processing) in their science classes. In these classes, discussions and activities are conducted in written English over the network. During the 1992-93 school year, the use of the network was expanded from two pilot classes that had been involved from the beginning of the project, to the entire high school science department. Five science teachers integrated the use of the network into eight different high school science classes ranging from the pre-high school level (between 8th and 9th grade) to 11th grade. The expansion of the Literacy Network Project thus made it possible to document how the network was used by different teachers in different classes, and to compare the effectiveness of different implementations of the technology for student learning.

The teacher's involved in the Literacy Network Project included two teachers who had been using the network for 4 years, and three teachers for whom the use of network and computer technology was more or less novel. The teachers received a brief introduction into the use of the network from the computer coordinator of the school, and met periodically with staff from the Center for Children and Technology to plan for and reflect on the use of the technology. The network was being used intensively by all eight participating science classes during a two-month period in the spring of 1993. This period of implementation was accompanied by formative research. The purpose of this paper is to report the findings from this research and to discuss its implication for the development of network-supported learning environments for deaf students.

Research

The formative research conducted during the 1992-93 school year had three major goals (see Figure 1):

1) to document how the network was being used by different teachers in different science classes;
2) to assess the impact of the use of the technology on teachers;
3) to evaluate the impact of different implementations of the technology on students' literacy development and science learning.

The overall purpose of this research was to obtain information to make necessary revisions in the model program, and to identify conditions of network use that are most effective to promote students' literacy development and science learning.

Methods

The research included eight classes that used network technology during the 1992-93 school year. Pre- and post-test data was obtained for a total of 39 students. For each of these classes, we examined the patterns of network use, and evaluated the development of students' science skills and writing over a two- months period. Information about network use was obtained from multiple sources, including a teacher questionnaire, conversations with the teachers, and records of writing produced on the network.

To evaluate the development of students' science skills, the teachers suggested to focus on students' comprehension of written science materials, and their ability to answer questions about it. Processing written information, and answering questions are important science skills. The teachers designed a written test that presented students with five short paragraphs about different science topics. The test asked students to read each paragraph and then to answer, in writing, 5 to 7 questions about it. Figure 2 shows an excerpt from the test to illustrate its organization. The test was designed in such a way that different question types were included (i.e., how, what, where, when, why, who). Students were asked to complete the test during class time, at the beginning and end of a two-months interval of intensive network use. An overall score for each test was derived by adding the number of questions that students answered correctly.

The evaluation of students' writing development was based on writing samples that were collected at the beginning and the end of a two-months interval of intensive network use. The writing samples were elicited by the science teachers as part of students' class assignments, and were produced in response to such question as "What is your favorite science topic? What do you know about it, and why do you like it?". Students had about 20 minutes to complete the assignment. To assess students' writing performance, we adopted a criterion-referenced, scoring method, the ESL Composition Profile (Jacobs, Zinkgraf, Wormuth, Hartfiel, & Hughey, 1981), which is designed to measure the communicative effectiveness of writing produced by students for whom English is a second language. Since for many deaf students English is a second language, this scoring method seemed well suited to evaluate their writing. Following this method, each writing sample received a holistic score that was derived from the ratings on five subscales (content, organization, vocabulary, language use, mechanics). Each of the subscales represents a dimension that is assumed to contribute to communicative effectiveness, and each of which is weighted for its estimated significance to effective communication. Figure 3 lists the subscales of the Profile and lists the weights that are associated with them. Students' writing samples were scored by one reader. For reliability purposes, 20% of all writing samples were scored twice, and correlations were computed. The intra-rater reliability for the overall communicative effective score was .96, and for the different subscales it ranged between .65 (mechanics) and .96 (content).

Findings

The following quotes illustrate the response of students and teachers to the experience of participating in the Literacy Network model program:

> *The most thing that I have enjoyed in science lately is going to computer room. Not just because of the chatting through by computer. Last week, I really like when you had the five pictures up on the borad and have the students to look at it and to explain what we had seen. It's better than to sit in the classroom and listen to teacher's lecture. So, I hope that next year my science class would do the computer again.*
> (Comment from a pre-high school student written on the network)
>
> *I enjoyed experimenting with different ways of presenting discussion topics....I hope the teachers continue to find interesting ways to use the network.*
> (Comment from a Literacy Network Teacher)
>
> *I would love to continue using the network with all my classes in the future. I have observed many positive results from its use to date.*
> (Comment from a Literacy Network Teacher)
>
> *This was my first introduction to computers. I will try to become more familiar with computers because I've seen how well the students respond.*
> (Comment from a Literacy Network Teacher)

The enthusiastic response by students and teachers is mirrored in the quantitative data that we collected. In several classrooms, contingent on the conditions of network use, students' science thinking and writing skills improved substantially. In the remainder of this section, we will briefly summarize teachers' responses to the experience of using network technology in their classes, describe how the network was used in different science classes, and discuss how different patterns of network use relate to student learning outcomes.

Teacher Responses

Overall, the teachers had very positive reactions to the experience of using the network, despite occasional problems that they met with and the extra preparation time that they had to put in. The teachers perceived the impact of network use both for teaching and learning as very positive.

Perceived impact on student learning. All of the teachers indicated that the use of the network had an important impact on students and their learning. Figure 4 outlines how teachers thought network use affected their students: All teachers observed that students in networked classrooms were more motivated to learn and participate than students in regular classrooms. Most teachers indicated that students also spend more time on task, and collaborated more with other students in a networked classroom. Furthermore, the teachers observed that students' use of appropriate science vocabulary and their descriptive skills improved. Some teachers pointed out that while they were able to observe improvements' in these skills for most students, some students did not show marked improvements. In some cases this was attributed to students' lack of computer skills.

Perceived impact on themselves and their teaching. The teachers reported that the experience of using the network in their science classes also had an important impact on themselves. Figure 5 summarizes teachers' observations. The use of the technology made it possible for them to experiment with presenting discussion topics in different ways; it gave them an impulse to learn more about computers; it made it necessary for them to spend more time to plan and prepare for classes (the teachers pointed out that they need twice as much preparation time for a network class compared to a regular class); it provided an opportunity for them to collaborate around issues of logistics (such as scheduling) and the design and use of network-based activities. All of the teachers indicated that they would like to continue using the network next year, preferably with more training and support to integrate the network into their curricula.

Problems. The teachers indicated that they ran into several problems while using the technology. These problems, however, did not deter them from using it. The most frequently mentioned problems (summarized in Figure 6) include: scheduling conflicts for the computer lab; too few computers in the computer lab for classes with more than 7 students; the location of the Apple network on the second floor is too far from the science classrooms on the third floor; students' lack of computer skills; technical problems with the software or hardware; lack of teacher training in both computer basics and ways of integrating the use of the network into the curriculum; regular lessons are too short for network-based activities.

Patterns of Network Use

The use of the network in different classes varied along three major dimensions: the frequency of use (number of periods per week), the types of network applications that were used (group conferencing, e-mail, word processing), and the number and types of different literacy activities that students engaged in. The left half of Figure 7 summarizes the patterns of network use for seven of the Literacy Network classes (data on network use was not available for one class).

The classes that participated in the Literacy Network project this year got to use the technology from 1 up to 3 periods per week. For some of the classes, network use was limited to one period per week because of scheduling conflicts. This was particularly true for the four pre-high school classes, which all had science at the same time. In order to provide equal access to these four classes, each could spend only one out of their four periods per week in the computer lab. The extent to which students used different types of network applications also differed across classes. In some classrooms, students' got to use only one type of application (i.e., only group conferencing, or only word processing), and in other classes, students got to use each of these applications in about equal proportions. Each of the teachers had a distinctive pattern of using the applications. Some showed a preference for one particular kind of application, while others showed a preference for using all three types. The teachers who were more experienced in network use, tended to use more than just one application in their classes.

There were also differences across classes in terms of the number and type of literacy activities that students engaged in. In some classes, students used the network only for a review activity (students answer questions posed by the teacher) or report writing, while in other classes students engaged in several different types of network-based activities, ranging from discussions of current science topics, to taking tests, to keeping a journal about their experiences in science class, to students questioning each other about science topics, and to exchanging social messages. The range of activities was broader for the teachers who had previous experience with using the network compared to the teachers who used the network for the first time this year.

Overall, teachers' strategies for using the technology in particular ways appeared to be mediated by such factors as students' ability levels, teachers' expertise with using the technology, and access to the technology.

Effectiveness of Different Patterns of Network Use

While our data show an overall improvement of students' science thinking and writing skills, the student learning outcomes differed to some extend between the different classrooms. Figure 8 illustrates the average pre- and post-test performance on the questions tests and the writing sample in the different classrooms. As can be seen in Figure 8, performance increases on the questions test were not necessarily coupled with improvements in writing.

Performance increases on the questions tests were obtained in six of the eight classes. In four classes the performance increase was large (ranging between 13% and 23%) and in two classes it was moderate (7%). For two classes post-test performance on the questions test remained at the pre-test level. Within each class the pattern of pre- to post-test differences for individual students varied to some extent. While the pattern of performance increase for most students corresponded to the average pattern of the class, in almost every class there were also one or a few students whose pattern of performance increase did not correspond to the average pattern of the class. For instance, in class 8 which on average showed a high performance increase on the questions test, there were four students whose post-test scores increased, and one student whose post-test score remained at the same level as the pre-test. It is important to note that performance increases were generally obtained across the different question types. That is, improvements in students' scores on the post test were not associated with differential improvements in only one or a few types of questions, such as “why” questions or “how” questions.

Increases in the communicative effectiveness of students' writing were observed in three out of six classes (for one of the classes, post-test writing samples were not available, and for another class the post-test writing samples were not produced under the same conditions as the pre-test writing samples and thus were not included in the data analyses). Writing performance increases ranged between 4% and 9%. As for the questions test, the pattern of pre- and post-test writing performance of individual students was variable within classes, and improvements of students' post-test scores tended to be due to improvements in all five aspects of writing performance that were evaluated (i.e., content, organization, vocabulary, language use, and mechanics).

There were distinctive patterns of network use associated with classrooms that showed different patterns of performance improvements on the questions test and in writing. Figure 7 summarizes both the pattern of network use and the pattern of performance improvements for the different classes.

Improvements in students' performance on the questions test appeared to be associated with a substantial use of the group writer. As shown in Figure 7, for those classes that showed moderate or large improvements on this test, the predominant network application used was the group writer. This application allows students to use writing in a highly interactive manner as they participate in written discussions with their teacher and fellow students. The interactivity that this kind of application allows for makes it possible for students to demand clarification of written utterances, and to observe how written language is used in a variety of ways for the same purpose (e.g., answering a particular question) by different people. This may help students to attend more to the subtle meanings of written language. An additional characteristic that the classes with substantial improvements on the questions test share is that their pre-test performance was relatively low, compared to the classes for which performance did not improve. It is possible that the use of the network may particularly benefit the question and text comprehension of those students who function at a lower reading ability level.

Improvements in writing performance were observed in those classes in which the network was used frequently (2 or 3 periods per week), and in which students got to use different types of network applications (i.e., group conferencing, e-mail, and word processing) in about equal proportions. Furthermore, the students in these classes were engaged in a broad range of different network-based activities, such as journal writing, discussions about science topics, written questioning and interviews, and so on.

Implications for Program Development

The results of the evaluation research have helped to identify practices involving network technology that are effective in promoting deaf students' development of science thinking and writing skills. These findings suggest ways that the use of the technology could be revised, and how the model program could be further developed.

Network Use

The results of the research indicate that there are distinctive patterns of use network associated with improvements in different aspects of students' performance (i.e., the communicative effectiveness of their written language, question and text comprehension). In order to achieve specific learning outcomes, teachers need to target their use of the technology (such as frequency of use, the type of applications used, and the kinds of network-based activities) to these outcomes. Our results suggest that to enhance both the communicative effectiveness of students' writing and their science thinking skills, such as question comprehension, network technology should be used frequently and consistently, and in a variety of different kinds of network-based activities, such as journal writing, written questioning and interviews, and discussions about science topics. On the basis of the experience of the teachers who have been involved in the Literacy Network project for some time, the technology is most effective if used consistently throughout the school year. Because of logistical problems, this was difficult to do for all of the Literacy Network teachers during the last year. However, the experience of using the technology for a short period of time, with clearly defined learning goals appeared to be beneficial to the new teachers who used it for the first time. It made it possible for them to experience the use of the technology without feeling too overburdened by it.

Scheduling

One obstacle to effective network use that the Literacy Network teachers met with this during the last year, had to do with access to the computer lab. Because of the increase in the number of classes that used network technology during that year, there was a bigger competition among teachers for computer lab time. This was particularly true for those classes that had science at the same time. Competition for computer lab time also arose between Literacy Network teachers, and teachers who used the computer lab for other purposes, such as keyboarding classes. Clearly, as more teachers and more classes get involved in the Literacy Network Project, there will be a greater need for coordination of scheduling. There are several strategies that schools could peruse to deal with scheduling issues around limited resources. First, different network-using classes could be scheduled for different time slots during the day. This may mean that school schedules are not organized by curriculum area any longer, but rather by the resources that different classes require. Another possibility is for teachers to collaboratively plan, coordinate, and schedule the use of the computer lab within the framework of their class schedule for the year. This should be done early in the school year. Schools also may need to expand the number of resources, including more networked computers in different locations, ideally in each classroom.

Staff Development

Special attention needs to be paid to the training of new teachers as they begin integrating network technology into their classrooms and curricula. Teachers will need to become familiar with the technology as well as develop pedagogical and curricular strategies for using it. We have found that common planning time, and collaboration among teachers with different levels of expertise in the use of the network can facilitate the sharing and development of new network-based activities, and the exploration of new software applications for the network. In addition, printed and video-based support materials could help teachers develop activities that are designed to foster both literacy and science learning. It is also possible to enlist technology in providing more staff support. A telecommunication link between teachers and staff developers would make it possible to provide on-line mentoring (via e-mail), facilitate discussion among the teaching staff, and could model effective strategies for on-line interactions.

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Figure 1.

Formative Research Questions

1) How is the network being used by different teachers in different science classes?

2) What impact does the use of the technology have on teachers?

3) What impact do different implementations of the technology have on students’ literacy development and science learning?

Figure 2.

Excerpt from the Questions Test

Lion in the Stars

Stars in the night sky are in groups. These groups of stars are called constellations. Long ago, people thought the constellations looked liked pictures. They saw dogs, horses, and many other things. They gave these pictures names. They thought that one constellation looked like a lion. The people named him Leo.

Do you want to see Leo? Go out at night. Look up in the stars. Maybe you will see him. Look for Leo in the stars.

1. Where are the stars?
2. What are constellations?
3. Who saw the pictures?
4. When can you see Leo?
5. Where can you see Leo?

Figure 3.

Subscales of the ESL CompositionProfile

(Jacobs, Zinkgraf, Wormuth, Hartfiel, & Hughey, 1981)

	Estimated Significance to Effective Communication
Content	30 %
Organization	20 %
Vocabulary	20 %
Language Use	25 %
Mechanics	5 %

Figure 4.

Teachers' Perceptions of the Impact of the Literacy Network Model Program on StudentsCompared to regular science classes, students in the Literacy Network classes...

- were more motivated to learn and participate in class
- spent more time on task
- collaborated more with each other
- used more appropriate science vocabulary
- showed improvements in their descriptive skills

Figure 5.

Teachers' Perceptions of the Impact of the Literacy Network Model Program on Themselves and their Teaching

The use of network technology...

- made it possible to experiment with presenting discussion topics in different ways
- gave them an impulse to learn more about computers
- made it necessary to spend more time to plan and prepare for classes
- provided an opportunity for them to collaborate around issues of logistics and the design of network-based activities

Figure 6.

Problems Teachers Encountered in the Implementation of the Literacy Network Model Program

- scheduling conflicts for the computer lab
- to few computers in the computer lab for large classes
- spatial distance between the computer lab and the science classrooms
- students' lack of computer skills
- technical problems (software, hardware)
- lack of teacher training
- regular lessons are too short for network-based classes

Figure 7: Patterns of Network Use and Performance Increases in the Different Classes.

	Periods Per Week	Types of Applications	Types of Activities	Questions Test Perfm. Increase	Writing Perfm. Increase
CLASS 1	1	75 % Groupwriter 20 % Word Processor 5 % E-mail	Review Questions Learning Log Discussion of Science Topics Tests Social Messages	large	level
CLASS 2	1	99 % Groupwriter 1 % Word Processor	Review Questions	large	missing data
CLASS 3	1	100 % Word Processor	Review Questions Reports	level	level
CLASS 4	1	75 % E-mail 25 % Groupwriter	Question/Answer Activity Review Questions Discussion of Science Topics Social Messages	level	post-test data not comparable to pre-test data
CLASS 5	1	75 % Groupwriter 20 % Word Processor 5 % E-mail	Review Questions Learning Log Discussion of Science Topics Tests Social Messages	large	level
CLASS 6	2	40 % Groupwriter 20 % Word Processor 40 % E-mail	Review Questions Reports Discussion of Science Topics Tests Social Messages	moderate	moderate
CLASS 7	missing data	missing data	missing data	moderate	moderate
CLASS 8	2 - 3	45 % Word Processor 35 % Groupwriter 20 % E-mail	Review Questions Reports Discussion of Science Topics Tests Social Messages	large	moderate