Electronic Communication Tools in the Classroom: Student and Environmental Characteristics as Predictors of Adoption

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Abstract

As the Internet, computer networking, and computer-based communication tools gain a foothold in K-12 classrooms, educators need to understand adoption patterns of these technologies among students. Are some students reaping the benefits of these new tools while others are left behind? Are there characteristics inherent to students that are predictive of success or failure with such tools? Are there characteristics of classrooms or teaching styles that lead to successful use of these tools? These issues are currently being explored as part of the Learning Through Collaborative Visualization (CoVis) Project at Northwestern University. This paper examines factors that contribute to the successful adoption of computer-based communication tools. Our research indicates that what goes on *within* the classroom is at least as important as the previous experiences and traits that the students *bring to* the classroom. Factors that contribute to adoption of these tools include: who a student's teacher is, typing skill, experience with word processors, writing apprehension, skill with each tool, and gender. From these findings, we recommend some strategies for helping improve students' success with computer communication tools.

Introduction

The widespread public discussion of both the Internet and the forthcoming National Information Infrastructure makes it clear that computer networking is to be the next major technology introduced into U.S. classrooms on a large scale. But as educators, researchers, and designers, what reasons do we have to believe that networks will be successfully integrated into classroom culture? Preliminary ventures introducing networks to classrooms have begun to indicate some of the elements that contribute to success and failure of classroom-based networked learning activities (e.g., Riel & Levin, 1990), but we know very little about issues for individual students within the networked classroom. Are some students more likely to adopt the technology than others, even when the group activity is generally considered to be successful? If so, are there differences between these two groups of students? In this paper, we will explore characteristics of students who are successful and unsuccessful adopters of computer networking tools; we will also consider how the environments established by teachers for use of these tools affect adoption. In particular, we will examine student adoption patterns of three tools: electronic mail, Usenet news, and a multimedia collaborative notebook.

Why Computer Networking?

Many previous technologies have failed to have an impact on the classroom. Radio, film, and television are some examples that come to mind. While there are a variety of explanations for

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this, the primary reason these technologies have failed to have an impact is that they did not introduce any significant contribution to the culture and practices of teachers and students. As Cuban (1986) has argued, new technologies must support teachers in reaching their instructional goals and also fit within the organizational constraints of schooling in order for them to be adopted. When new technologies are adopted, they will only have significant impact if they offer new or revised opportunities for restructuring some aspect of the learning environment.

It may be the case that computer networking has a chance to be different from the technologies that preceded it. Because networking technology can greatly extend the communicative reach of teachers, it can help teachers to become more effective professionals (Schwab, Hart-Landsberg, Reder, & Abel, 1992; Bruce & Rubin, 1993; Ruopp, Gal, Drayton, & Pfister, 1994). Because networks offer the promise of two-way communication, they have the potential to surmount the physical boundaries that isolate the classroom from the rest of the world. But networks are not magical—like those previous technologies, they will prove tremendously difficult to implement successfully. If computer networking is to make a difference, it will require significant readjustment of how we view both the curriculum and the practices of today's classrooms. The primary advantage of connecting classrooms to broad-band computer networks such as the Internet is the manner in which it expands the communicative reach of teachers and students. In this sense networks foster collaborative activity between students who are not necessarily located in the same school.

Theory- and Practice-Based Models for Classroom Change

As argued above, computer networking can only have an impact on the classroom if it enables and supports a new view of classroom learning. We believe that the most appropriate learning theory for classrooms that utilize computer networking technologies is constructivism and cognitive apprenticeship as they are embodied in project-based or project-enhanced approaches to science.

Constructivist approaches to education hold that knowledge is not "delivered" to learners but rather must by "constructed" through a process of active engagement with the subject matter. Communication plays a central role in this view of learning, which was largely shaped by the research of Piaget and Vygotsky (for an historical overview of the theory, see Von Glasersfeld, 1989). Vygotsky argued that language and communication are central to the two-way transformational process by which we acquire knowledge about the world. Cognitive apprenticeship (Collins, Brown, & Newman, 1989) holds that students must engage in authentic tasks in order to move towards mastery in any domain. In this model, the teacher acts as a coach, providing scaffolding for students that fades as their skills increase. Cognitive apprenticeship stresses exploration in an environment that exploits both cooperation and competition among students.

Classrooms that utilize computer networking are most appropriately configured as project-based learning environments (Ruopp, Gal, Drayton, & Pfister, 1993). In such environments, students conducting in-depth projects can make a variety of uses of networks. They can access a broad array of on-line discussions and reference materials. They can share data they collect with other students across the globe, and use the data others have collected for their own investigations (Newman, Goldman, Brienne, Jackson, & Magzamen, 1989). They can exchange newsletters they write with students at other schools, thus providing an audience other than the teacher in their classroom (Riel & Levin, 1990; Bruce & Rubin, 1993). Finally, they can be mentored by experts over a distance (Songer, 1993). Classrooms built around this mix of technology and pedagogy have also been referred to as distributed multimedia learning environments (DMLE) (Pea and Gomez, 1992).

A classroom rooted in constructivism and cognitive apprenticeship, where students can engage in inquiry-based explorations, is ideally matched to the benefits offered by computer

networking. In this best case scenario, a network can be used to bridge a gap between two "communities of practice" (Lave & Wenger, 1991). By community of practice we mean the set of meanings, beliefs, and practices shared by a group of people working toward common goals. For example, the members of the Atmospheric Sciences community share a set of beliefs about the proper way to do research, the nature of scientific knowledge, and the variety of practices that are employed for communication (these range from electronic mail to annual meetings). Students are also members of a community of practice—the community of schooling. Practices here include grading, homework, studying many different topics in the course of a day, writing papers, *etc.* We argue that learning about a field should be tantamount to learning the practices of that field. Therefore, when students conduct inquiries about scientific questions, and communicate with scientists about this process, they create a bridge between their respective communities of practice. Students in this setting operate as legitimate peripheral participants (Lave & Wenger, 1991) on their way to an enhanced understanding of scientific culture and practice.

What Counts As Successful Use?

In our framework, a successful student is one who learns to use communications tools to enter into bridging relationships across communities of practice. However, we recognize that this is a goal that requires a great deal of work both in curriculum development and in coordination of mentoring relationships between students and scientists. As an important first step to this more advanced level of communication, we recognize that students must simply *use* the technology. In this paper we will focus on measures of use as a first approximation of successful adoption.

The CoVis Classroom

The Learning Through Collaborative Visualization (CoVis) Project (Pea, 1993) is a high-bandwidth networking testbed exploring the educational applications of both asynchronous (e.g., e-mail, news) and synchronous (e.g., audio and video conferencing) computer networking tools.[2] By introducing these tools, as well as a pedagogy based on collaborative, project-based inquiry, to high school science classes, the CoVis Project is working to transform both communications tools and the curriculum. As a networking testbed, CoVis is poised to offer new insights into the structures necessary to support educational collaboration among students and others who are not co-located. As an example of a next-generation DMLE, the CoVis classroom is equipped with a wide variety of electronic communication tools. In this paper, we address student adoption of the following three tools:

Electronic mail (e-mail) can be thought of as asynchronous text-based communication. All students in the CoVis Project have their own electronic mail accounts, and has the ability to communicate directly with anybody on the Internet or other connected networks (such as America Online or CompuServe). The software used for electronic mail is Eudora, which also allows students to send Macintosh files as attachments to messages.

Usenet news, or "news," as it is commonly called, is an asynchronous text-only medium that allows the user to participate in Internet-wide discussion groups open to anyone with access to news reading software and an interest in the topic. There are currently thousands of available topics, with more being created daily. News provides the opportunity to participate in a broad-ranging discussions, or more importantly, to post questions on a topic without directing them to a specific individual. CoVis students use the Macintosh client software NewsWatcher to read news.

The *Collaboratory Notebook* is software designed and implemented by the CoVis Project (Edelson & O'Neill, 1994; O'Neill & Gomez, 1994) to support scientific inquiry by making it possible for students to record and carry out their project work asynchronously. This is essentially a text-based asynchronous computer conferencing system, although it has multimedia capabilities for the display of attached pictures or other Macintosh documents. The Collaboratory Notebook is

[2]More information about the CoVis Project is available on the world wide web at URL http://www.covis.nwu.edu/.

unique in that it uses link- and page-types that are specially structured to guide students in the tasks of project-based science inquiry.

Methods

Subjects

Preliminary research for this study was conducted during the 1993-94 school year in two Chicago-area high schools. During this preliminary year, 275 students participated in CoVis classes (125 females, 150 males). 89 of these students were first-years, 38 sophomores, 48 juniors, and 100 seniors.

The primary research reported in this study was conducted during the 1994-95 school year still underway. During this year, 272 students participated in this research (123 females, 149 males). 138 of this year's students were first-years, 22 sophomores, 38 juniors, and 74 seniors. During both years, students took classes with one of six teachers (three at each high school). There were a total of twelve sections of Earth Science (taught by Mr. Waterford, Ms. Hadden, Mr. Lowell, and Mr. Bernstein[3]), one section of Environmental Science (taught by Ms. Chidsey), and one section of Science, Technology, and Society (taught by Mr. Gerrold).

Instruments and Procedures

The data reported in this paper were gathered with a series of survey instruments referred to collectively as the Student Profile and Communication Surveys. The surveys were completed during class time, and were administered by graduate research assistants. During the preliminary year, the surveys were administered three times—first in the fall, after all the communications tools had been introduced, then in the winter, and finally at the close of the school year. During the current year, the surveys were administered in the first semester, after all the communications tools had been introduced. A second round of surveys addressing the same questions will be administered in April, as the school year draws to a close.

The Student Profile surveys were designed to provide basic information about each student's socio-economic and family background, attitudes towards school, attitudes towards group work, beliefs about science, and beliefs about and experience with computers. Computer experience was represented both as overall computer experience and as sub-components that included word-processing experience, graphics experience, and gaming experience. We expected that students with more computer experience might have an easier time learning to use communication tools, and thus use them more. As a subset of computer experience that involves similar skills (i.e. text creation and formatting), we expected that word-processing experience might be even more predictive then overall computer experience. It was predicted that keyboarding skills could affect students' adoption and use of text-based communications technologies, so one question in the experience-with-technology survey asked students to report their keyboarding skills. We expected that typing skill would be positively correlated with use of these text-based communication tools. It seemed possible that students' attitudes toward school could affect their use of these tools in this environment, so this possibility was explored. Previous research has indicated gender may affect student's adoption of computer tools (Bowers, 1988), so this information was obtained from the schools.

The Communication Surveys were designed to provide information about each student's attitudes toward particular modes of communications as well as communication tools. Communication apprehension was predicted to influence student use of and attitudes toward particular communications tools, depending on the type or amount of communication apprehension exhibited. Oral communication apprehension, measured with an instrument developed by McCroskey (1977) called the Personal Report of Communication Apprehension (PRCA), was not

[3]Names are pseudonyms.

predicted to affect the use of text-based tools reported here. High written communication apprehension, on the other hand, was expected to correlate with low use of text-based communication tools, such as e-mail, Usenet news, and the CoVis Collaboratory Notebook. This factor was measured with an instrument called the Writing Apprehension Test (WAT), developed by Daly and Miller (1975). A short series of questions was added to the current year's survey asking students to rate their expertise with each tool, since it was expected that a student's comfort, or level of expertise, with a communication tool will be related to whether or not that tool is used by that student.

During the preliminary year, student use of communication tools was estimated by students' self-report at each survey administration. In the current year, automatic procedures were implemented to more precisely log students' use of communication tools. In the case of electronic mail, basic information about each message sent from or received by a student's account was logged (the date and time, sender, receiver, and length of message). E-mail addresses in these logs were automatically changed to unique CoVis identifiers for confidentiality, and all recipients of mail from CoVis students were informed that logging was being carried out in the background. Student news postings, which are by their nature public documents, were collected into files by news group, and then tallied by student. Logs detailing student use of the Collaboratory Notebook were maintained in the software's underlying database. For the current analyses, logs of students' use of the electronic tools through the first 15 weeks of the school year are considered, since that corresponds to the time when the surveys were administered.

Results and Discussion

Preliminary Year

The 1993-94 data on self-report of the use of e-mail and news were analyzed to uncover trends for further exploration in the 1994-95 year. These data showed several interesting trends. First, it was encouraging to find gender, academic self-concept, and communication apprehension did not appear to be significant predictors of student adoption. The factors we did find to be significant were students' previous experience with technology, the extent of technology access in their school, and who their teacher was. Not surprisingly, a very small number of students (4%) had considerably more experience with computer technology than their peers, and this was reflected in the number of e-mail messages they sent and received as compared to everybody else ($\bar{x}$ 8.2 vs. $\bar{x}$ 5.6 (self-report of messages per week), $t(7)=2.5$, $p<.04$). The most salient difference between our two schools was technology access: both schools have six computers in the CoVis classroom, but where one school has lab facilities with 25 stations outside the classroom, the other has one computer in the teachers' office. This correlated with the greater usage of e-mail by students at the first school ($\bar{x}$ 7.0 vs. $\bar{x}$ 4.9 (self-report messages per week); in the Fall $t(112)=3.22$, $p<.002$; in the Winter $t(91)=2.24$, $p<.03$; in the Spring, $t(177)=2.79$, $p<.01$). Interestingly, there was no significant difference between the two schools in use of Usenet news. This may be due to the fact that students at the first school did not use Usenet news outside of class, as many of them were observed to do with e-mail. Finally, the most significant factor relating to students' use of e-mail was who their teacher was ($\bar{x}$ 8.5 in one class vs. $\bar{x}$ 2.5 in another (self-report of messages per week); in the Fall $F(5,108)=3.78$, $p<.01$; in the Winter, $F(5, 304)=1.98$, $p<.10$; in the Spring $F(5, 645)=4.53$, $p<.001$). Teacher was also the most significant factor correlated with use of news.

The self-report data of tool use on which these analyses are based present numerous problems in reliability and precision. Estimating one's own use of a tool retrospectively is extremely difficult for anyone, and some of the students may have (purposefully or not) inflated their use of the tools in our surveys. In self-report surveys, one can only reasonably ask for rough estimates, which makes it difficult to detect small differences between groups of students, and to

understand what accounts for the greatest variance. These problems led us to implement automatic logging procedures for the current year.

1994-95 School Year

The data we are collecting this year enable us to more reliably and precisely explore how students' characteristics affect their initial adoption of electronic communication tools. Accordingly, our analysis of this year's group of students will be used to confirm or disconfirm the significance of the various factors explored in the previous year, as well as to determine what factors account for the greatest amount of variance in use. We will consider the use of the CoVis Collaboratory Notebook, Usenet news, and electronic mail in turn.

Teachers

In explaining differences that exist in communication tool usage between students in different classrooms, it is important to first form an understanding of the qualitative contrasts between the teachers in whose classrooms student work takes place. The most important differences with respect to the issues addressed in this paper are individual teachers' approaches to project science and how each introduces and integrates communication tools into their classroom activities. An overall view of teachers' personal use of communication tools as they compare to their students' use of communication tools is in Table 1.

Mr. Waterford teaches Earth Science. He began the school year with a teacher-directed project and tool introduction activities. After that, the remainder of the school year has been almost completely student-directed, so much so that Mr. Waterford does not lecture or assign homework. Projects in his class involve extended inquiry and data collection and analysis. His students are encouraged to use communication tools like news and e-mail to locate data and communicate with outside mentors. Mr. Waterford sometimes uses e-mail to communicate with his students about assignments and grading, and students sometimes turn in their work via e-mail. By Mr. Waterford's choice, students are not introduced to the Collaboratory Notebook and thus do not learn to use it. Mr. Waterford has been teaching for over twenty years.

Ms. Hadden teaches Earth Science. She uses a mixture of teacher-defined projects and student-defined projects. A good portion of class time is spent in lecture and lab to provide base content information to her students. Ms. Hadden uses both e-mail and news, and like Mr. Waterford, uses outside mentors with her students. By her choice, her students do not use the Collaboratory Notebook. Ms. Hadden is a fifth year teacher.

Ms. Chidsey teaches Environmental Science. She uses a range of teacher-defined projects with her students, and student-directed projects towards the end of the school year (not included in this study). The hallmark of her projects is a strong connection to students' everyday lives. Ms. Chidsey has her students use all three communication tools in her class. She encourages her students to contact outside sources for project data. Her students use news to request information and data for their projects from outside sources. Much basic content information for Ms. Chidsey's class is provided through short lectures, labs, and readings that are discussed in class. Ms. Chidsey is in her fourth year of teaching. Previously she was an environmental engineer and chemist.

Mr. Lowell teaches Earth Science. He uses a mix of teacher- and student- defined projects supported by lectures, labs, and worksheets. Projects are defined very flexibly in Mr. Lowell's class. The teacher defines broad areas for inquiry, with the students define specific project topics. Although he does not discourage students from seeking outside mentors, Mr. Lowell does not support such efforts directly. Mr. Lowell uses all three communication tools in his classroom, although the Collaboratory Notebook is not integral to his assessment practices. Mr. Lowell has been teaching for nineteen years.

Mr. Bernstein teaches Earth Science. He uses a mix of teacher- and student-defined projects in his class. To a greater extent than the other teachers, he uses lecture, worksheets, and labs to provide basic content, with projects used primarily to explore individual interests in more depth. He is a heavy user of both e-mail and news, and uses them to communicate with his students a great deal. The Collaboratory Notebook is central to his assessment practices for student projects, as all students are required to keep a journal using the Notebook. Mr. Bernstein is a first-year teacher. Previously he worked as a field geologist.

Mr. Gerrold teaches Science, Technology, and Society. Projects in his classroom are almost entirely teacher-directed. Student projects deal with the role of technology in their lives. Projects in Mr. Gerrold's class do not utilize mentors, although students sometimes interview people outside the class as a form of data collection. Mr. Gerrold himself does not make much use of e-mail or news for communication with his students. He has chosen not to use the Collaboratory Notebook yet in the current school year, although he did use it in year one. Unlike the other teachers, he introduces communication tools one by one over the course of the entire school year. Mr. Gerrold is in his fourteenth year of teaching. Previously he was a mechanical engineer.

Teacher and Class	Collaboratory Notebook Pages ($\bar{X}$ for students)	Usenet News posts ($\bar{X}$ for students)	Electronic Mail messages sent ($\bar{X}$ for students)
Mr. Waterford	0	6	823
Mr. Waterford's students (n=63)	0	2.0	17.9
Ms. Hadden	5	0	393
Ms. Hadden's students (n=41)	0	0.1	12.3
Ms. Chidsey	29	0	307
Ms. Chidsey's students (n=28)	4.1	1.6	23.5
Mr. Lowell	44	0	707
Mr. Lowell's students (n=77)	4.2	1.8	13.8
Mr. Bernstein	199	3	1028
Mr. Bernstein's students (n=41)	14.4	0.4	30.3
Mr. Gerrold	1	0	167
Mr. Gerrold's students (n=22)	0	1.1	23.3
Mean among teachers (n=6)	46	1.5	571
Mean among students (n=272)	3.8	1.3	18.8

Table 1. Teacher Tool Use Compared to Means of Student Tool Use

CoVis Collaboratory Notebook

The amount that students use the CoVis Collaboratory Notebook is significantly related to several factors. As in the previous year, who a student's teacher is very significantly related to the number of entries they generate in the Notebook ($F(2, 143)=56.08$, $p<.0001$; the number of Notebook pages created by each student ranges from 0 to 39). In addition, as students' self-reported skill with the Notebook increases, so does their use ($r=.355$, $p<.01$); as their academic-self concept increases, so does their use ($r=.273$, $p<.01$); students with greater writing apprehension create fewer pages ($r=-.206$, $p<.05$); while students with greater keyboarding skills created more pages ($r=.200$, $p<.05$). Gender and computer experience were not significantly correlated to use of the Collaboratory Notebook.

To determine what factors uniquely account for the amount of variance in Collaboratory Notebook use, we built a regression model with these variables: teachers (coded as dummy variables), keyboarding skill, and skill and comfort with the Collaboratory Notebook. This regression equation accounts for almost 50% of the variance in use of the Collaboratory Notebook. Table 2 shows reliable coefficients in the equation. Only the Bernstein component of the teacher variable, keyboarding skill, and skill with the Collaboratory Notebook accounted for reliable variance; academic self-concept and writing apprehension did not account for any reliable variance.

Factor	Coefficient	Probability
Mr. Bernstein's class	9.27	$p \leq .0001$
Keyboarding skill (scale 1-4)	1.98	$p < .001$
Skill and comfort with the Collaboratory Notebook (scale 1-5)	1.05	$p < .01$

Table 2: Significant Factors in Regression Model for Collaboratory Notebook Use (R^2=49%)

The Collaboratory Notebook has been introduced and used thus far in only three of the six teachers' classes. We built separate regression models using keyboarding skill as a factor for each of these teachers' classes, and found that more variance was accounted for among Mr. Bernstein's students. For Mr. Bernstein, the regression model accounted for 16% of the variance, and the coefficient of keyboarding skill was 4.04 ($p<.01$); for Mr. Lowell, the model accounted for 4% of the variance, and the keyboarding coefficient was 1.22 ($p<.05$); and for Ms. Chidsey, keyboarding did not account for any variance (coefficient=0.18, $p>.8$). The mean number of notebook pages for each of these groups is shown in Table 3.

How well do you type?	Ms. Chidsey's students (n=28)	Mr. Lowell's students (n=77)	Mr. Bernstein's students (n=41)	Overall means
"badly" (n=8)	3.0	4.6	7.5	3.7
"not too well" (n=35)	2.0	2.5	11.0	2.1
"well" (n=70)	5.1	5.7	14.7	4.0
"very well" (n=24)	3.8	4.6	19.4	7.1
Overall means	4.1	4.2	14.4	3.8

Table 3: Mean Collaboratory Notebook Pages by Teacher and Typing Skill

It was somewhat surprising that keyboarding skill did not account for significant variance among all three teachers' students. We hypothesized that a threshold might exist beyond which keyboarding skill is related to the number of Notebook pages created by students. We found support for this hypothesis by separating students who were in the top 50th percentile of Notebook users (number of Notebook pages created > 6) and found a significant positive relationship between keyboarding skill and creation of notebook pages ($r=.262$, $p<.05$). For Notebook users in the lower 50th percentile (number of Notebook pages created ≤ 6) there was no significant correlation between keyboarding skill and page creation. Differences in the amount of variance accounted for by teacher are therefore explained by differences in the range of Notebook pages created by their students.

The differences among teachers and amount of comfort and skill with the Collaboratory Notebook are less difficult to explain. Teachers who introduce their students to the tool, and structure use of the tool into classroom activity, will inevitably see more use by their students of the tool. Ms. Chidsey, Mr. Lowell, and Mr. Bernstein all familiarized their students with the Collaboratory Notebook, but Mr. Bernstein structured use of the Notebook more centrally into classroom activities. In other teachers' classes, students had access to the Collaboratory Notebook, but had not learned how to use it. In addition, students who feel more confident with a tool such as the Notebook are more likely to use that tool, which in turn may increase their confidence all the more.

Usenet News

Students in the CoVis population are able to read and post messages to Usenet newsgroups on a variety of topics, from science to politics. In order to measure students' active participation in news discussions, we tracked the number of posts made by each student. The total number of posts by students in the first 15 weeks of the school year was not very high—67% of 272 students for whom data is available had not posted any messages, 15% had posted just one message, and the remaining students ranged from 2 posts to 43 posts. The mean number of posts was 1.3. Within this population, several interesting results emerge. First, boys post more messages to Usenet news than girls ($\bar{x}$ 1.8 vs. $\bar{x}$ 0.7 ($t(270)=2.48$, $p<.02$)). News usage was also marginally correlated to membership in different teachers' classes ($F(5, 266)=2.15$, $p=.06$). Two student characteristics were positively correlated with news postings: skill and comfort with Usenet news ($r=.317$, $p<.01$), and experience with word processing ($r=.222$, $p<.05$). Writing apprehension was marginally correlated with news postings. In this case, students who are more writing apprehensive tended to make fewer news postings ($r=-.126$, $p\leq1.0$).

To determine what factors account for variance in the number of posts to news, we built a regression model with these factors: writing apprehension, gender, word processing experience, and skill and comfort with news reading software. This model, which accounts for 16% of the variance in student posts to Usenet news, is shown in Table 4:

Factor	Coefficient	Probability
Writing Apprehension (scale 20-100)	-0.04	p<.01
Gender (weighted toward male)	1.00	p<.02
Word processing experience (scale 1-5)	0.51	p≤.01
Skill and comfort with the Usenet news software (scale 1-5)	0.97	p<.0001

Table 4: Regression Model for Usenet News Posting (R^2=16%)

It is interesting that writing apprehension is a significant coefficient in this regression equation. Usenet news is a much more public venue than the Collaboratory Notebook or electronic mail. In news, the potential readership of messages posted is millions, whereas access to Collaboratory Notebook pages is limited to the CoVis community (specifically teachers, researchers, and sometimes other students), and e-mail messages are limited to their individual addressees. Our news client software, NewsWatcher, in fact, asks users "Are you sure you want to post [this message]? This program posts news to thousands of machines throughout the civilized world. Please be sure you know what you are doing," before sending messages to the server for distribution. The mean number of news posts by students in the top quartile of writing apprehension was 0.8, while students with the lowest apprehension posted an average of 2.4 messages.

Gender was a significant predictor of posts to Usenet news. The importance of gender to use of this tool, when it does not appear to play a role for other tools in our classrooms, certainly warrants further attention. We can make some suppositions as to the source of this difference, but they must necessarily be tentative. Perhaps the public nature and/or tone of Usenet news discussions engaged males more than females. Perhaps some of the most prevalent uses by males do not interest females as much. A content analysis of news postings might reveal such trends.

Based on the results from our preliminary year, we expected that experience with computers might be predictive of communication tool usage. Our surveys separated experience with a range of computer-based technologies, so that we might determine which experiences are most important. For Usenet news, experience with many computer technologies, such as games and spreadsheets, were not important. But experience with word processors was important. It could be that the similar task of composing texts on a computer was important in making students more

comfortable with this tool. It is also interesting that typing skill was not able to account for significant variance in Usenet news postings. One explanation for this might be that word processing experience and typing skill are in fact different measures of the same underlying set of skills, since typing is a necessary component of word processing.

Electronic Mail

The most heavily used communication tool in CoVis is electronic mail. As with Usenet news, we measure students' active participation in electronic mail dialogues by the number of messages they send. The mean number of messages over the 15 week period was 19, and the median was 9 messages sent. The number of e-mail messages sent ranged from 0 to 279 (n=272). The lowest quartile of students had sent fewer than 4 messages in 15 weeks, but the highest quartile had sent more than 20 messages.

Electronic mail use is significantly related to several factors. A student's teacher once again plays a role ($F(266,5)=2.32$, $p<.05$). Experience with word processors is positively related to use of e-mail ($F(256,4)=5.7$, $p<.001$), as is students' self-report of skill and comfort with electronic mail ($F(261,5)=2.43$, $p<.05$). Gender, academic self-concept, and writing apprehension were not significantly correlated to e-mail use.

A regression model was built that accounts for 18% of the variance in e-mail use, including the following variables: skill and comfort with e-mail, teachers (coded as dummy variables), and experience with word processors (see Table 5). As with the other tools, we expected skill with e-mail to account for variance in use. Only the Bernstein component of the teacher variable accounted for reliable variance. Mr. Bernstein is a new teacher who is excited about using e-mail in his work (he sent over 1000 messages himself during the 15 week period, more than any other teacher (see Table 1)), and he encourages his students to send him e-mail. Experience with word processors also accounts for a percentage of the variance. Thus, previous work with word processors appears to have positive effects on use of both e-mail and Usenet news.

Factor	Coefficient	Probability
Skill and comfort with e-mail (scale 1-5)	10.9	$p \leq .0001$
Mr. Bernstein's class	12.1	$p<.05$
Experience with word processors (scale 1-5)	3.6	$p<.05$

Table 5: Significant Factors in Regression Model for Electronic Mail Use (R^2=18%)

Contrary to the findings from our preliminary year, differences in technology access between our two school settings appear to have no affect on the adoption of these communications tools (for Usenet news, $t(270)=.04$, $p>.10$; for e-mail, $t(270)=.78$, $p>.10$; for the Collaboratory Notebook, $F(266,4)=.20$, $p>.10$). Having six computers in the classroom and another in an outside lab seems to be sufficient for the levels of use we are currently seeing. For higher levels of use outside class time, availability of more computers in lab facilities could obviously prove important.

In summary, these results support our suspicion that students' self-report of tool use in the preliminary year may have been less than complete—we found several more factors to be related to tool adoption with this year's electronically logged usage. Regression analysis determined the relative importance of these factors in accounting for differences in students' tool adoption. Students' level of comfort and skill with each of the technologies accounted for variance in use of that technology. Prior word processing experience accounted for variance in use of electronic mail and of Usenet news, but not the Collaboratory Notebook. Writing apprehension and gender accounted for some variance in adoption of Usenet news, but not adoption of the other tools. Keyboarding skill accounted for some variance in use of the Collaboratory Notebook, but not the other tools. And finally, simply having Mr. Bernstein as a teacher accounted for variance in students' use of the Collaboratory Notebook and electronic mail.

Conclusion: Design Implications for Classrooms

Our exploration of the data suggests that what goes on *within* the classroom is at least as important as the previous experiences and traits that students *bring to* the classroom. The actions and attitudes of teachers are clearly important among the factors determining the extent to which students adopt networking tools. Following Cuban's (1986) advice, we must recognize that the teacher is also a designer of any technology placed into the classroom. The structure of the learning environment and the activities conducted in that environment play a large role in individual students' adoption of tools. Further qualitative and observational research in classrooms is required if we are to gain a deeper understanding of how and when specific teachers' practices encourage productive uses of communication tools. However, the data presented here has implications that educators can apply immediately to improve tool adoption by students.

Since students' level of comfort and perceived skill with each new tool affects their use of that tool, teachers should provide training and activities with tools that will ensure early successes. The level of confidence such success provides students may encourage enough use to further boost skill, in a mutually reinforcing manner.

We were not surprised to find that typing skill and word processing experience were gate keeping attributes for use of communication tools. While most of the students in our study were able to produce the minimum number of Notebook pages required for classwork, those with better typing skills were able to create the most pages, allowing them to make richer use of the communication tools. Similarly, experience with word processors was an advantage for students in using e-mail and Usenet news. Educators will need to make allowances for this, as "keyboarding" and on-screen layout and composition become increasingly important areas of literacy for students.

Teachers should be aware that writing apprehension may limit the use of more "public" forms of electronic communication, such as Usenet news, especially among girls. They can encourage the common practice of "lurking," or observing Usenet discussions for a period, before posting their own messages. By familiarizing themselves with the norms of a discussion group, students may reduce the apprehension they feel toward an initially unseen and unknown audience. Teachers can also encourage students to participate in "safer" discussion groups. In CoVis, we achieve this by establishing local news groups that are available only to students and teachers in the project .

Finally, our finding that gender may affect adoption of some networking technologies can serve as an important reminder to educators that electronic networking technologies are just the latest area where boys and girls may have differential success, at least initially. We do not consider these findings to be definitive—further investigation is needed to determine the extent and important causes of gender differences in Usenet news adoption—but educators would do well to attend to possible gender biases in the meantime.

As computer networks proliferate in our schools (and our society), it becomes increasingly important for us to understand not only how these tools can be used, but also how students can be supported in using the tools. An important first step in this process is to determine what factors in the learning environment can be manipulated in order to increase the chances of student success. As the CoVis testbed moves forward, we will work to continue to expand our understanding of these issues.

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