Student Traits and the Use of Computer-Mediated Communication Tools: What Matters and Why?

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Introduction

This paper describes a year-long study of computer-mediated communication (CMC) tool use by high school students. The purpose of this study is to explore a range of variables related to characteristics of students in order to form a better understanding of how to construct learning environments where CMC tool use is an integral part of daily activity. Student characteristics are explored with respect to gender, academic self-concept, parental education, skill and experience with technology, communication apprehension, and social influence. The results of this research have implications for both the design of classroom activities and the design of the CMC tools themselves. This study is intended to be a “stake in the ground” towards a better understanding of the overall design of communication- and technology-rich classrooms.

CMC tools are part of a rising technological tide that began with computers and gained momentum with networks, most notably the Internet. These tools enable communication across time and distance with other networked computer users who have similar tools. Internet connectivity allows students to communicate with a potentially global audience. Students can use these tools to supplement within-classroom activity, through communication with mentors and others or by supporting collaboration. While there are a wide range of CMC tools currently in use, this paper focuses on the use of four particular technologies that are gaining prominence in classroom settings: electronic mail (e-mail), Usenet news groups, collaborative groupware, and videoconferencing. The specific implementation of tools in this study will be described below. Most importantly, this study is of classrooms that represent “next generation” learning environments, where computers and CMC tools are broadly available for students to use, approaching (but not equaling) the ubiquity of computing resources in some research and white collar work environments.

The rapid adoption of these technologies throughout American society has made communication tools such as e-mail essential in the worlds of research and work (Anderson, Bikson, Law & Mitchell, 1995). Accordingly, the world of education has begun to grapple with the task of integrating CMC tools into the classroom, to make sure that students are properly prepared to compete in a world that relies upon the use of technology (Carnevale, Gainer & Schultz, 1990; Secretary's Commission on Achieving Necessary Skills, 1991). Unfortunately, if current trends in school networking are accurate indicators, this will be an uphill battle. Although there were over 5.8 million computers being used in schools as of 1995 (U.S. Congress Office of Technology Assessment, 1995), only 12 percent of schools were connected to some kind of wide-area network like the Internet, and fewer than half of those schools had Internet connectivity to even a single classroom (Heaviside, Farris, Malitz & Carpenter, 1996).

Given the emergent status of school networking, it is no surprise that there is little understanding of how CMC tools are used by students in classrooms. The major body of research on CMC tools has been conducted in laboratory or other controlled experimental settings (e.g., Hollingshead, McGrath & O'Connor, 1993; McGrath, 1993; Walther, 1993). While this work has shed light on CMC tool use, it lacks ecological validity due to impoverished tool and task environments, and there is good reason to doubt that the subjects of these studies (usually college students) provide insight into characteristics of high school or younger students. For the most part, studies of CMC tool use situated in real contexts have been limited to white collar work settings (e.g., Kraut, Fish, Root & Chalfonte, 1990; Sproull & Kiesler, 1986; Sproull & Kiesler, 1992; Steinfield, 1985; Steinfield, 1986). Most studies of CMC tool use in educational settings have focused on the teachers', not students', use of particular tools, most often electronic mail (e.g., Hart-Landsberg, Schwab, Reder & Abel, 1991; McMahon, 1996; Schwab, Hart-Landsberg, Reder & Abel, 1992). The most prominent research on CMC activities that directly involve students is represented by a series of studies by Levin, Riel, and colleagues (e.g., Levin, Waugh, Chung & Miyake, 1992; Levin, 1992; Levin, Kim & Riel, 1989; Levin & Waugh, 1992; Riel, 1989; Riel, 1992; Riel & Levin, 1990). This research yields valuable insights into the proper requirements for activities that employ electronic mail, but is limited by its focus on classrooms where e-mail was the only tool available (making it impossible to determine if student characteristics help determine tool selection), and activities were conducted on special purpose networks where students and teachers had access only to other members of that network. This is a very different situation than that found in the classrooms that participated in this study, where students had direct access to the Internet and a broad range of CMC tools from which to choose. Furthermore, while there are many studies that consider student characteristics with respect to the use of computers, the author is aware of no research that studies student characteristics with respect to computer-mediated communication.[1]

In order to fully explore the factors that are related to student use of CMC tools, it is necessary to study these tools *in use* by students in school. This research setting that enabled this study was established by the Learning Through Collaborative Visualization (CoVis) Project at Northwestern University (Gomez, Fishman & Pea, in press; Pea, 1993). CoVis is an educational networking testbed funded by the National Science Foundation to explore issues of advanced computer and communications technology in practice. In particular, CoVis is exploring ways to enhance, and fundamentally rethink, the way that students learn science using computer-mediated communications and scientific visualization tools (Fishman & D'Amico, 1994; Gordin, Polman & Pea, 1994).

The CoVis Project is founded on the belief that traditional science education, which consists of teaching well-established facts, bears little or no resemblance to the question-centered, collaborative practice of real scientists (e.g., Ruopp, Gal, Drayton & Pfister, 1993). CoVis classrooms are rooted in learning theories that place communication at their center, based on a model of student and teacher engaged in active inquiry, rather than the dominant didactic model of curriculum "delivery" (Pea & Gomez, 1992).

The CoVis educational networking testbed provides an ideal setting for exploring the variety of ways that students employ CMC technologies. The integration of communication tools into these classrooms is complemented with a thoughtful re-evaluation of what it means to "do science" in school. Thus there is a coordinated effort to "co-design" both the learning environment and the communications tools used by student in the CoVis Project. This provides a fertile setting for exploring characteristics of students that relate to CMC tool use.

CMC Tools Explored in This Study

The range of CMC technology available to CoVis students in this study is broad by most organizational standards. This variety of tools provides an opportunity to understand how student characteristics are related to tool use in an environment where students must make choices about how they will communicate. There are four primary computer-mediated communication tools available to students in the CoVis Project: electronic mail (e-mail), Usenet news, circuit-switched desktop videoconferencing (Cruiser), and a networked-based collaborative, multimedia notebook (the Collaboratory Notebook). These four tools were selected for CoVis classrooms because they fill a range of communication needs along several dimensions: asynchronous and synchronous communication, communication with closely defined (known) and loosely defined (unknown)

[1] There are some recent additions to the literature that correct this, (e.g., Center for Applied Special Technology, 1996), but this research did not become available until after the completion of the study described in this paper.

audiences, and communication via several different modalities of media, including text, pictures, and audio/video (see Table 1 for a summary).

	ASYNCHRONOUS		SYNCHRONOUS
MEDIUM	**known audience**	**unknown audience**	**known audience**
text	e-mail	Usenet news	X
text + pictures + hypertext	Collaboratory Notebook	X	X
video + audio	X	X	Cruiser

Table 1. Media, synchronicity, and audience characteristics of CoVis CMC tools.

Electronic Mail

Electronic mail (e-mail) can be thought of as asynchronous text-based communication. All students in the CoVis Project have electronic mail accounts, and can therefore theoretically communicate directly with anybody on the Internet or other connected networks, such as America On-Line or Compuserve. The software used for electronic mail is Eudora, which also allows students to send Macintosh files as attachments to messages. The designers of the CoVis environment believed that e-mail would best be employed for communication between individuals or among small, pre-determined groups of people. Potential uses were expected to include communication of grades or other evaluative material from teacher to student, question asking by students, and general social communication.

Usenet News

"News," as it is commonly referred to, is an asynchronous text-only medium that allows the user to participate in Internet-wide public discussion groups comprised of anybody with access to news reading software and an interest in the topic. There are currently thousands of available news groups, with more being created each day. The advantage of using news is an ability to participate in a broad-ranging discussion or to post questions when one is not sure specifically to whom to direct the query. CoVis students use the Macintosh client software NewsWatcher to read news. The CoVis team envisioned news as being utilized by students to pose questions to the scientific community (using news groups such as sci.environment) or to gain general knowledge of current discussion topics in a range of scientific fields when trying to generate project topics.

Collaboratory Notebook

The Collaboratory Notebook is software designed and implemented by the CoVis Project (Edelson & O'Neill, 1994a; Edelson & O'Neill, 1994b; O'Neill & Gomez, 1994) to support scientific inquiry by making it possible for students to record and carry out their project work asynchronously (see Figure 1). 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. In addition, the Notebook is a hypertext authoring tool, allowing users to link pages of text and images together into a coherent structure (for more on hypertext, see Bolter, 1991; Landow, 1992; Landow & Delany, 1991). Although the Collaboratory Notebook has its roots in tools like CSILE (Computer-Supported Intentional Learning Environments; Scardamalia & Bereiter, 1991; Scardamalia, Bereiter, McLean, Swallow & Woodruff, 1989), the Notebook is unique in that it uses link- and page-types that are specially structured to guide students in the tasks of inquiry and project science. CoVis designers intended the Collaboratory

Notebook to be used by students in conducting science projects, especially in tracking progress and reporting project work to teachers and others, including science mentors.

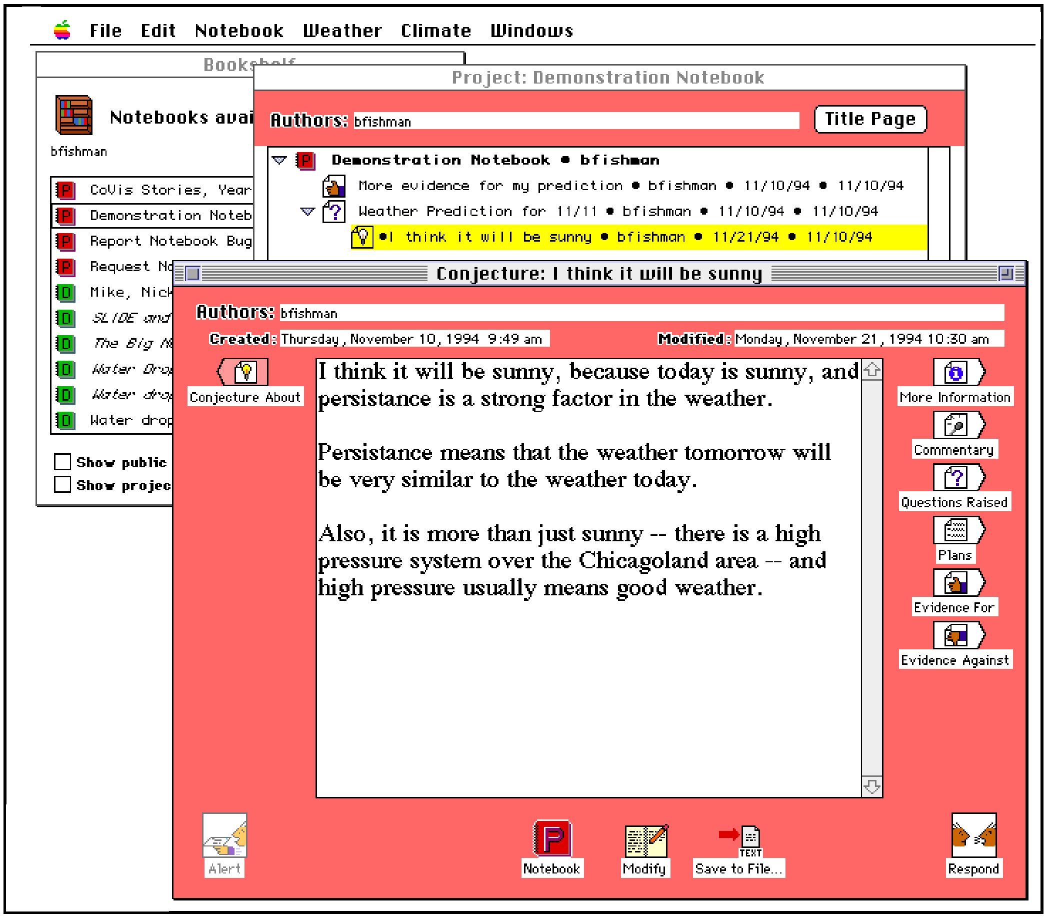

Figure 1. Screen shot of the Collaboratory Notebook application.

Videoconferencing (Cruiser)

Cruiser videoconferencing was the only synchronous CMC technology present in the CoVis classroom, and also the CMC tool with the most complex underlying infrastructure. Desktop videoconferencing allows two or more people to establish a real-time audio and video connection in order to hold meetings where each party can see and hear the other. The Cruiser videoconferencing system, which was developed by Bellcore (Fish, Kraut, Root & Rice, 1993), consists of a separate NTSC monitor, camera, and microphone that is controlled by a Macintosh interface (see Figure 2). Students were able to use this system to contact students in other CoVis schools, CoVis researchers, or scientists who were part of the CoVis network at the University of Illinois at Urbana-Champaign. The system could also be used for “virtual field trips” to the Exploratorium science museum in San Francisco. Cruiser can be thought of as synchronous audio and video.

The network infrastructure that is required for Cruiser is different from that for e-mail, news, and the Collaboratory Notebook. While those three applications require only TCP/IP packet networks, Cruiser also needs a circuit-switched network. This is because each Cruiser “call” required a minimum of 384 KB/s of reserved bandwidth, a demand much greater than can be borne by typical TCP/IP networks (e.g., the Internet). CoVis established these links between Cruiser stations using primary rate ISDN connections. At the time of this study, ISDN was still a new telephone service, and it was just starting to be introduced widely across the United States. Furthermore, Cruiser is not a native Macintosh application, as are the other three CMC tools, but is instead an X-Windows application running in Unix. To launch Cruiser on a classroom computer, students must use an application called Apple MacX, which automatically brings up the Cruiser interface for students to use.

Use of Cruiser is usually supplemented by computer screen sharing, which allows one computer user to see and manipulate the other's screen, and vice-versa. This is accomplished in CoVis through the use of Timbuktu Pro by Farallon Computing. CoVis designers thought that Cruiser would be used by students for a variety of purposes, including discussions to frame projects, project inquiry, and project reporting when meeting participants were not co-located.

Figure 2. Photo of a typical Cruiser set-up.

Methods

Study Setting & Subjects

This research was conducted during the 1994-95 academic year in two high schools participating in the CoVis Project, Lakeside and Edgewater[2], both located in the suburbs of Chicago. The subjects were 280 students in six teachers' classrooms, comprising a total of thirteen class sections. Five of these teachers were in their third year of participation in the CoVis Project, and one teacher was in his first year of participation with CoVis. The teachers in this study taught a mixture of earth science, environmental science, and science technology, and society courses. For this study, only the classes that were directly involved in CoVis were included in the research. These classes were identified as "CoVis classes" because they met in the room designated by each school as the "CoVis classroom" and because the teachers thoughtfully integrated project-based science and CMC technology into the curricula of these courses. Students in this study came from all four grade levels. 144 were in 9th grade, 23 in 10th grade, 38 in 11th grade, and 75 in 12th grade. Subjects are broken down by gender and race in Table 2.

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[2] All names reported in this study are pseudonyms.

	Edgewater	Lakeside	Totals
Male	81	74	155
Female	62	63	125
White	64	113	177
African-American	49	0	49
Hispanic	4	3	7
Asian-American	5	3	8
Other	21	18	39
Total Students	143	137	280

Table 2. Subjects by gender, race, and totals per school (Note: race is self-report, "Other" includes no response).

Each CoVis classroom (one per school shared by three teachers each) was equipped with six Macintosh Quadra 700 computers with 8mb of memory and 16 inch color monitors. All of these computers were connected to the Internet via Ethernet, a high-speed local-area network. The schools' Internet connections were arranged through Northwestern, so a typical student's e-mail address was: jstud@edgewater.covis.nwu.edu. In addition, two computers in each classroom were equipped with Cruiser stations as depicted in Figure 2. In both classrooms, the six computers were arranged in a ring spread out around the edges of the classroom. Aside from the computers, these were typical earth science classrooms, with moveable tables and chairs, and special work surfaces with gas and water hookups. Both schools made computers available outside the classroom, although to varying extents. At Edgewater, there was a computer lab that had 25 CMC-equipped computers and one Cruiser-equipped computer available to students. At Lakeside, there was a single CMC- and Cruiser-equipped computer available outside the classroom, located in a teacher's office adjacent to the classroom.

Automated Data Gathering on CMC Tool Use

CMC tool use is the primary dependent measure in this work. Because CMC technologies are by definition computer-based, it was relatively easy to gather data on their use. Each of the four CMC tools used in CoVis—electronic mail, Usenet news groups, the Collaboratory Notebook, and Cruiser videoconferencing—generated a log of its use by students and teachers in CoVis classrooms. These logs could then be analyzed to generate usage statistics for individual subjects. The phrase "amount of use" in this study refers to the number of messages sent by students using each of the four CMC tools.

In the case of electronic mail, records were kept of all messages that were sent or received through the CoVis mail server (a computer running Unix housed at Northwestern). All CoVis participants had e-mail accounts on these machines. A logging program written by CoVis staff removed the header from each message and converted the names of the sender and recipient for anonymity. These names were replaced with codes that could later be translated to match with individual CoVis student identifiers. It was determined that messages sent would be used for this study, and not messages received, since that figure represents conscious tool use on the part of the student. Although most students received far more messages than they sent (an artifact of the ability to send mail to more than one recipient), they did not exercise any control over the receipt of mail. A single message sent to multiple recipients was counted as one message sent.

For Usenet news groups, a logging program was created by the CoVis staff that intercepted all postings to the CoVis news server (a second Unix computer at Northwestern) and saved them to a separate directory. These postings were then analyzed in order to generate counts for individual students. Anonymity was not required in this logging or analysis process, because Usenet news postings are by definition intended to be public. Due to technical limitations, it was not possible to record the number of Usenet news groups read by students. Therefore, the number used in this research represents the number of messages posted by students.

The Collaboratory Notebook uses a centralized Oracle database (also on a Unix computer at Northwestern). This database stores all Notebook pages created by students, the basic message unit of the Collaboratory Notebook. Data gathering tools were constructed that generated reports of Notebook page creation from the Oracle database.

Cruiser videoconferencing was one exception to the detailed data that can be gathered for the other three CMC tools. Cruiser did not require the use of individual user names or identifiers in order to place calls. Therefore, although it is possible to know how many Cruiser calls were placed during the school year from system logs, calls could not be assigned to specific individuals. However, Cruiser calls turned out to be such unique events in CoVis classrooms that it was possible to know approximately when this tool was used and for what purposes.

Surveys of Beliefs, Attitudes, and Experience

Survey instruments were designed to gather data on student experience with computers and CMC tools and student beliefs and attitudes towards both CMC tools and school. These surveys were a mixture of instruments designed and used by other researchers in related studies, and instruments that were designed specifically for this study or adapted from other studies.

Surveys were administered to CoVis students at three different times during the school year. In the early Fall, a survey was administered that consisted primarily of demographic questions. In the Winter (after Thanksgiving), a second survey was administered that consisted completely of questions about attitudes towards CMC tools and their use. This survey was administered at this time of the year (and not in the early Fall) in order to allow time for each of the tools to be introduced, but not quite enough time for their use to stabilize. A third and final survey was administered in the late Spring, to serve as a longitudinal measure of student beliefs and attitudes towards CMC tools.

In all cases, survey administration was proctored by members of the CoVis research staff, and completed during students' regular class time. Because of concern that students may not be familiar with all CMC tools discussed in the survey, or may have different ways of referring to these tools, CoVis researchers made a brief presentation about CMC tools immediately preceding each survey administration. This presentation was prepared and scripted by the author of this study, and was intended to provide a common vocabulary for talking about CMC tools in the survey.

Academic Self-Concept and Attitudes Towards School

In order to explore the relationship between CMC tool use and a student's academic self-concept or attitudes towards school, two brief survey instruments were used. A series of questions on students' attitudes toward their classroom teacher, the curriculum, and school in general was adapted from an Australian study that investigated the link between academic performance and attitudes towards school (Marjoribanks, 1992). Questions dealing with a student's academic self-concept were taken from the National Assessment of Education Progress

(NAEP) survey on computer experience (Martinez & Mead, 1988). In both cases, all questions were answered on a seven-point Likert scale.

Prior Experience and Skill with Computers and CMC Tools

The NAEP study demonstrated a positive relationship between prior experience with computers and computer competency (Martinez & Mead, 1988). To explore whether this relationship extends to CMC tools, the questions from the NAEP study were used to survey student experience with computers. Computer experience was broken into component skills such as word processing, spreadsheets, e-mail, etc., in a manner similar to that of an earlier study of computer experience (Koohang, 1989). A single question on keyboarding skill, thought to be a prerequisite to CMC tool use, was taken from Schmitz and Fulk (1991). All responses were asked in Likert form on a five-point scale.

A student's comfort, or level of expertise, with a communication tool was another factor predicted to have an influence on whether or not that tool was used or perceived to be useful. Therefore a short survey was designed to ask students to rate their expertise with each tool on a scale of 1-5, with 5 indicating that a student was "very experienced" and 1 indicating that a student had "no experience" with the CMC tool in question.

Communication Apprehension

Communication apprehension was predicted to negatively influence student use of and attitudes toward particular communications tools, depending on the type or amount of communication apprehension exhibited. Oral communication apprehension was measured with an instrument developed by McCroskey (1977) called the Personal Report of Communication Apprehension (PRCA). Students who exhibited a high degree of oral communication apprehension were predicted to make less use of audio and video communication tools like Cruiser videoconferencing. Also, oral communication apprehension was predicted to have no effect on use of text-based tools like electronic mail.

Written communication apprehension, measured with an instrument developed by Daly and Miller (1975), was expected to predict low use of text-based communication tools, like electronic mail or Usenet news. However, as was the case with oral communication apprehension, written communication apprehension was not predicted to inhibit use of speech- or visually-based tools such as Cruiser. It was possible for a student to exhibit both high written and oral communication apprehension, and in prior studies, these two factors have been demonstrated to be highly correlated. For both written and oral communication apprehension, low scores are considered to be better (or to indicate lower apprehension) than high scores.

Parents' Educational Attainment

Parents' level of education was shown to be positively related to computer skills as measured by the NAEP (Martinez & Mead, 1988). This study used the survey items from the NAEP to determine the parental education of the CoVis population. The primary distinction made in this data was between parents with some college education and parents without any college education. These questions were asked for both male and female parents, and the answers were considered as the sum of both parents' educational attainment.

Social Influence

The extent to which one's peers or superiors impact tool use behavior and attitudes has been called social influence (Fulk, 1993; Fulk, Schmitz & Steinfield, 1990). Past studies have demonstrated a strong link between social influence and CMC tool use in white collar organizations, but whether this effect will extend into the classroom is an open question. Social influence is a complex interaction of personalities, and it is correspondingly the most complex characteristic of students to measure.

In order to study social influence, it was necessary to create a survey instrument that would help identify "influence groups" among the student population. This instrument asked students to assign a rating of between 1 and 5 to indicate how frequently they communicated with the person named in the survey, with 5 being the most frequent. Each name also had a box that the subject could check to indicate "never communicate." Because it was too laborious to complete a survey of this nature for all 280 subjects in the CoVis population, it was necessary to assemble a smaller set of names as a sub-sample of the entire population.

To construct this survey, a subset of the student population was first identified by a stratified random sampling procedure. Before the administration of the second survey after Thanksgiving, "high" and "low" users of CMC tools were identified from the logs of CMC tool use up to that date, corresponding to the upper and lower quartile of tool use. The names of four students from each of the six teachers were randomly selected from these "high" and "low" groups, resulting in an initial sample of n=24 students. These 24 students participated in a very brief interview where they were asked a single question:

> Who are the people that you communicate with the most? Please list ten people that you communicate with most frequently, using any means, and list them in order, from most frequently to less frequently. Communication in this case means either conversations or messages that you begin or send or conversations or messages that others begin or send to you.

Students were prompted to think of anyone, with the only caveat being that the people they name be participants in the CoVis Project, although they did not need to be in the same class. These interviews yielded 240 names, although there was a lot of duplication among students' lists.

From these lists of names, a survey was created that included the names of the original subjects, plus four names from the lists generated by their interviews, the top and bottom two from each list of ten. This created a list that originally included 96 names, but was reduced to 82 because of duplication. The names of all six CoVis teachers were included in the final listing, since they were identified by students during the interviews. Due to attrition during the school year, the final longitudinal measure of social influence was smaller than the initial list, n=79 (73 students and 6 teachers).

Using the data generated by the survey, a "social influence factor" was calculated for each of the 79 respondents to the social influence survey. Actually, a series of social influence factors was calculated, one for each of the CMC tools. The social influence factor, therefore, represents social influence with respect to a particular CMC tool. This made it possible to investigate the extent to which one student influences another student's use of electronic mail as something separate from that student's use of Usenet news. In addition, a social influence factor was calculated for overall tool use.

An example of the calculation of the social influence factor with respect to electronic mail is shown in Table 3. In row "a" of this example, Judy has assigned Eddie a "communication frequency" score of 3, and Robbie a score of 2. Marlene has a score of 0, indicating that Judy does not communicate with her at all. We also see that Judy has sent a total of 3 e-mail messages in the time period pertaining to this survey, Eddie has sent 5 messages, Robbie 15 messages, and Marlene 2 messages. The number of messages sent by each person with whom Judy communicated is multiplied by the communication rating Judy gave that person, and the sum of those products is divided by the number of people with whom Judy communicated ((5*3)+(15*2)+(2*0)/3) = 15). The amount of social influence on Judy (the "social influence factor") with respect to e-mail is therefore calculated to be 15.

	subject	influence factor	# mail messages	Judy	Eddie	Robbie	Marlene
a.	**Judy**	15	3	•	3	2	0
b.	**Eddie**	25	5	5	•	4	0
c.	**Robbie**	10	15	2	4	•	2
d.	**Marlene**	16	2	1	3	2	•

Table 3. Sample social influence data and calculated "influence factor."

Finally, to test for a social influence effect, subjects' social influence scores for each tool were checked for correlation to the use of that tool. A significant and positive correlation between social influence scores and tool use indicated the presence of a social influence effect on tool use. To examine the relationship between student and teacher in terms of influence, the social influence factors were computed and checked for correlation to CMC tool use both with and without the presence of the teacher data. This test is similar to those conducted by Fulk, Schmitz, and Steinfeld (1990) in exploring the relationships between supervisors and members of a work group.

Observations & Focus Groups

Each of the classrooms involved in this study was visited on a regular basis by members of the CoVis research team, including the author. CoVis researchers sometimes provided technical assistance to teachers, sometimes discussed curricular issues, sometimes conducted classroom activities in conjunction with the teacher, and sometimes simply observed classroom activities and student behavior. These visits had a broad range of objectives, but all served to provide members of the research team with a qualitative understanding of the nature of classroom practice and CMC tool use. In almost all cases, the researchers had an opportunity to watch students interacting with each other, their teacher, and the CMC tools. Furthermore, the researchers could discuss with students what they were doing as they engaged in various kinds of activities. These data were used to help interpret other forms of data gathered in this research, particularly the log data.

Two focus groups, one with students from each high school, were conducted at the conclusion of the school year. The objective of these groups was to gather data on student perspectives, in their own words, towards learning and using the CMC tools. These groups were thus intended as a qualitative supplement to the quantitative data generated by surveys and automated data gathering. The format and structure of these focus groups was adapted from research in marketing, where this form of research is widely used (e.g., Bellenger, Bernhardt & Goldstucker, 1976; Calder, 1977; Tynan & Drayton, 1988). Subjects for focus groups were recruited from a random sample of CoVis students at each high school. From this sample, phone recruitment was conducted by the author, resulting in groups composed of four students from each high school. Each group meeting lasted for roughly 90 minutes.

Results

During the 1994-95 academic year, CMC tools were widely used by students in CoVis classrooms. Table 4 reports the quarterly and total use of each CMC tool by students (the total for Cruiser also includes calls placed by teachers) as recorded by the automated logging facilities for each tool. The use of these tools was not evenly distributed among students, but rather was skewed positive (with the exception of Notebook use, which was normally distributed). The number of students who created very few messages with these CMC tools was much larger than the number of students who created a lot of messages.

It is immediately apparent from these data that e-mail was used far more than any other tool. The number of e-mail messages sent during the school year was nearly an order of magnitude greater than either the number of news articles posted or Notebook pages created, and two orders of magnitude greater than the number of Cruiser calls placed.

Quarter	Mail Messages Sent	News Articles Posted	Notebook Pages Created	Cruiser Calls Placed
Q1	3102	214	0	10
Q2	3541	747	982	14
Q3	2088	222	105	8
Q4	1719	234	27	0
Total	**10450**	**1417**	**1114**	**32**

Table 4. Student CMC tool use (Note: Cruiser use includes calls placed by teachers.)

Among all CoVis students, the mean number of e-mail messages sent during the school year was 38.9 (*SD*=56.4, *n*=275, *SE*=3.36), with a range of 0 to 327 messages. The mean number of news articles posted during the school year was 2.7 (*SD*=6.6, *n*=280, *SE*=0.39), with a range of 0 to 71 articles. The mean number of Notebook pages created by students during the school year was 7.6 (*SD*=7.6, *n*=145, *SE*=0.45), with a range of 0 to 41 pages.

There were a total of 32 Cruiser calls placed from CoVis classrooms during the year. Because the data logging mechanism for Cruiser did not track individual users, it is not possible to report the mean number of calls placed by students (and observational records indicate that most of the calls placed were by teachers, although students were present). In fact, the low use of Cruiser in general makes it less meaningful to discuss use of Cruiser in the same context as the use of the other three tools. For that reason, results relating to actual classroom use will exclude Cruiser, focusing on the other three CMC tools. Possible explanations for this lack of Cruiser use will be explored in the discussion below.

Compared to the expectations one might have for CMC tool use in white collar environments, a mean of 38.9 e-mail messages sent by students over the entire school year might seem low. This comparison, however, is inappropriate for several reasons. First, in white collar environments, users typically sit in front of their *own* computers for eight hours a day, with unrestricted access to the CMC tools. In classrooms, students must *share* computers with as many as six other students, and only have access to those computers for approximately forty-five minutes a day. Second, the nature of classroom tasks (described in more detail in the sections below) often places students in project teams or groups. Within these groups, individuals assume “specializations.” One student will take responsibility for analyzing data, another for writing reports, and another for communicating with mentors and the teacher via CMC tools. These specializations in part explain the wide range in the use of e-mail by students. Many students sent no or very few messages, while a small group of students, the “communication specialists,” sent a lot of messages. Furthermore, these highly skewed patterns of CMC tool use by students in classrooms are echoed by later research conducted on the use of CMC tools by teenagers at home in the Pittsburgh HomeNet study (Kraut, Scherlis, Mukhopadhyay, Manning & Kiesler, 1996).

Academic Self-Concept and Attitudes Towards School

Academic self-concept is measured in this study as the extent to which students consider themselves “A” students, “B” students, and so on (see Table 5 for an overview of the distribution). There were significant relationships between this rating of academic efficacy and CMC tool use for e-mail, the Collaboratory Notebook, and overall tool use. No reliable relationship existed between perceived grades and use of Usenet news (see Table 6 for a summary of correlations).

perceived grades	*n*	percent
mostly A	19	7.28
half A and half B	63	24.1
mostly B	81	31.0
half B and half C	50	19.2
mostly C	29	11.1
half C and half D	13	4.98
mostly D	4	1.53
mostly below D	2	0.766

Table 5. Students' academic self-concept.

CMC tool	r_s	*p*	*n*
All Tools	.388	$<.01$	139
e-mail	.352	$<.01$	139
news	.128	$>.10$	139
Notebook	.345	$<.01$	139

Table 6. Relationship between academic self-concept and CMC tool use.

Attitudes toward school include the extent to which a student enjoys spending time in school, how important doing well in school is to a student, and whether or not the student enjoys school work. This was measured with an attitudes survey designed by Marjoribanks (1992). There were no reliable relationships found between attitudes towards school and CMC tool use.

Computer Experience and Skill

Computer experience and skill are assessed by a number of sub-measures. These include literal experience with computers, including a variety of common software applications, ability to type, and experience with each of the CMC tools used in this study. Other factors include whether the student has either a computer or a video game at home. All of these items were measured by self-report in surveys.

Overall experience with computers (Cronbach's α=.82) is significantly related to the amount students use CMC tools, although all of the sub-components of computer experience are not necessarily related to CMC tool use. These sub-components were experience with word processors, spreadsheets, e-mail, games, the World Wide Web and Gopher, file transfer, on-line chat, and MUDs. Each of these was measured on a scale of one to five where "1" equals "I have never done this" and "5" equals "I am an expert at this." It is also worth noting that the strength of this relationship increased during the school year (see Table 7 for a summary of the correlations). It was expected that overall experience with computers would increase during the year, and this was the case, $t(194)=7.859$, $p \leq .0001$. Mean computer experience among CoVis students in the fall was 21.66 and in the spring had increased to 24.26.

skill with:	**all tools**			**e-mail**			**news**			**Notebook**		
experience	***r***	***p***	***n***	***r***	***p***	***n***	***r***	***p***	***n***	***r***	***p***	***n***
overall (FALL)	.223	<.05	101	.213	<.05	101	.214	<.05	101	.045	>.10	101
overall (SPRING)	.343	<.01	101	.328	<.01	101	.264	<.01	101	.288	<.01	101

Table 7. Relationship between computer experience and CMC tool use. Note: Data for individual tools comes from spring surveys.

There was a strong relationship between self-reported skill with the CMC tools and students' actual use of the CMC tools. It is interesting to note that skill with e-mail is related to use of all three tools, and skill with news is related to use of all but the Notebook. Skill with the Notebook, on the other hand, is related only to use of the Notebook (see Table 8 for a summary of the correlations). This relationship between skill with e-mail and news and the use of all CMC tools makes some sense, as the basic skills needed to use e-mail and news are common to most text-based tools. The Collaboratory Notebook, on the other hand, has a unique interface that uses metaphors and operations not found in either news or e-mail. Thus it is not surprising that expertise with the Notebook does not produce directly transferable results in the use of tools other than the Notebook.

	all tool use			**e-mail use**			**news use**			**Notebook use**		
	r	***p***	***n***	***r***	***p***	***n***	***r***	***p***	***n***	***r***	***p***	***n***
Overall Skill	.366	<.01	115	.369	<.01	115	.329	<.01	115	.157	>.10	115
Skill with e-mail	.337	<.01	115	.362	<.01	115	.313	<.01	115	.114	>.10	115
Skill with news	.198	<.05	115	.171	<.05	115	.310	<.01	115	-.01	>.10	115
Skill with Notebook	.263	<.01	115	.199	<.01	115	.066	>.10	115	.346	<.01	115

Table 8. Relationship between skill with CMC tools and CMC tool use.

One place where students might be expected to gain experience with computers is in the home. Thus students were asked whether they had a computer in their home, and also whether they had a video game in their home (of the stand-alone type, such as Nintendo or Atari). Computer ownership was related to overall CMC tool use. The majority of CoVis students had a computer in their home (78.5%). Students who owned a computer created more messages than those who did not (see Table 9 for summaries of *t*-tests, means, and descriptive statistics). A similar effect was found for use of e-mail and use of the Collaboratory Notebook. Computer ownership was not, however, related to use of Usenet news.

	t-tests			*DO own home computer*			*do NOT own home computer*		
tool	***t***	***p***	***df***	***M***	***SD***	***n***	***M***	***SD***	***n***
all tools	2.40	<.01	256	51.49	64.8	203	28.98	47.55	55
e-mail	2.40	<.01	259	43.86	59.13	205	23.39	46.01	56
news	0.75	>.10	205	2.73	5.79	205	2.13	3.29	56
Notebook	2.89	<.005	137	8.79	8.31	103	4.58	4.42	36

Table 9. Summary of *t*-tests showing relationship of home computer ownership and CMC tool use.

Many CoVis students also owned a video game (73.9%). Video game ownership does not appear to be related to use of CMC tools. The mean number of messages created using *all* tools during the school year by students who owned video games was 47.65 (SD=62.34, n=120). The mean number of messages created by students who did not own video games was 44.00 (SD=61.97, n=68). These means are not significantly different, $t(256)=0.41$, $p>.10$.

Typing ability, which can be thought of as a gateway skill for using CMC tools, was not significantly related to the use of CMC tools for CoVis students. Typing ability did, however, improve among CoVis students during the school year, most likely as a result of the use of CMC tools and word processors in CoVis classrooms. The mean self-reported ability to type in the fall was 2.75 (SD=0.75, n=260). The mean self-reported ability to type in the spring was 2.93 (SD=0.73, n=223). These means are significantly different, $t(204)=-3.634$, $p<.0002$.

Gender and Parents' Level of Education

Two demographic factors were assessed in this research: gender and parents' level of education. The parents of CoVis students achieved relatively high levels of educational attainment. Taking the education of both the mother and father into account, 67% of the CoVis population's parents were both graduated from college, and for 46% of CoVis students, at least one parent has a post-graduate degree. Only 3.23% of the population reported that both of their parents ended their education with a high school diploma, and 2.82% reported that one or both parents did not finish high school.

The data suggest that there is a relationship between parental level of education and CMC tool use (see Table 10 for a summary of the correlations). The number of Notebook pages created is strongly related to parental education. The number of e-mail messages sent and overall tool use are also related to parental education, but the use of Usenet news is not.

CMC tool	***r***	***p***	***n***
all tools	.237	<.02	128
e-mail	.226	<.05	128
news	.073	>.10	128
Notebook	.291	<.01	128

Table 10. Relationship between parental education and CMC tool use.

Gender is related to the use of only one CMC tool, Usenet news, as boys posted more than girls. The mean number of news articles posted by boys during the entire year was 3.46 (*SD*=8.09, *n*=155). The mean number of news articles posted by girls was 1.82 (*SD*=3.77, *n*=125). These means are significantly different, $t(278)=2.07$, $p<.05$.

Gender is not significantly related to the use of e-mail ($t(273)=0.95$, $p>.10$), the Collaboratory Notebook ($t(143)=0.78$, $p>.10$), or overall CMC tool use ($t(267)=1.02$, $p>.10$) (see Table 11 for descriptive statistics).

gender	CMC tool	mean # of messages	*SD*	*n*
boys	all CMC tools	50.14	70.37	148
	e-mail	41.81	64.23	152
	news	3.46	8.09	155
	Notebook	7.15	7.87	75
girls	all CMC tools	42.40	49.16	121
	e-mail	35.28	44.79	123
	news	1.82	3.77	125
	Notebook	8.13	7.34	70

Table 11. Descriptive statistics on CMC tool use by gender of student

Communication Apprehension

Two kinds of communication apprehension were considered in this study: oral, or spoken trait apprehension, and written apprehension. CoVis student scores on both oral and written trait apprehension measures were consistent with those found in earlier studies (e.g., McCroskey, 1977). Student scores were distributed normally on both scales, and the scales were significantly correlated to each other, $r=.331$, $p<.01$, $n=237$. (The lower a student's score, the higher their communication apprehension.)

There was no difference in the mean amount of oral communication apprehension exhibited by boys ($M=57.44$, $SD=18.32$, $n=131$) or girls ($M=58.93$, $SD=18.47$, $n=106$), $t(229)=-.0414$, $p>.10$. However, girls did exhibit more written communication apprehension ($M=46.7$, $SD=15.08$, $n=110$) than boys ($M=52.17$, $SD=13.76$, $n=135$), $t(223)=2.931$, $p<.01$.

There is a significant relationship between written communication apprehension (Cronbach's $\alpha=.91$) and the use of Usenet news, and marginal relationships between written communication apprehension and the Collaboratory Notebook and overall CMC tool use (see Table 12 for a summary of the correlations). There is not, however, a relationship between written communication apprehension and the use of e-mail. The order of the strength of these relationships is not surprising, given the nature of each of the tools. E-mail, which was not related to written apprehension, is the most private of the CMC tools. The Notebook, which was marginally related to written apprehension, is semi-private, enabling communication among groups of students. Usenet news, which was highly related to written apprehension, is also the most public of the CMC tools. Oral communication apprehension (Cronbach's α=.88) was not significantly related to the use of the CMC tools.

CMC tool	*r*	*p*	*n*
all tools	-.171	<.10	129
e-mail	-.147	>.10	129
news	-.217	<.05	129
Notebook	-.171	<.10	129

Table 12. Relationship between written communication apprehension and CMC tool use.

Social Influence

The social influence effect was calculated two ways: once with teachers included in the model (to highlight the relationship between teachers' tool use and students' tool use), and once with teachers left out of the model (so that the effect of students' tool use on their peers is highlighted). The data indicate that social influence has a stronger relationship to CMC tool use early in the school year than late in the school year (see Table 13 for a summary of the correlations). Furthermore, the social influence effect is stronger when teachers are included in the model. This is not surprising, because it might be expected that students would be less familiar with tools early in the school year, and therefore be more easily influenced by what their teachers or peers do with CMC tools. Later in the year, as students become more familiar with the CMC tools, they would begin to make their own decisions.

	all CMC tools			e-mail			news			Notebook		
	r	*p*	*n*	*r*	*p*	*n*	*r*	*p*	*n*	*r*	*p*	*n*
fall (teachers)	.361	<.01	73	.296	<.02	73	.174	>.10	73	.590	<.01	45
fall (no teachers)	.153	>.10	73	.073	>.10	73	.177	>.10	73	.302	<.10	45
spring (teachers)	.328	<.01	73	.154	>.10	73	.141	>.10	73	.336	<.05	45
spring (no teachers)	.128	>.10	73	.046	>.10	73	.143	>.10	73	.140	>.10	45

Table 13. Relationship between social influence and CMC tool use.

Summary of Effects Related to Characteristics of the Students

The following student characteristics were found to be significantly related to the use of CMC tools: academic self-concept, the extent to which a person identifies with being artistic or musical, experience with computers, skill with CMC tools, computer ownership, parental education, writing apprehension, and social influence. The strength of these effects vary somewhat when considering different CMC tools, and they also vary when time is taken into account (fall versus spring).

In order to understand which of the factors discussed in the preceding sections uniquely explain variation in overall student use of CMC tools, a multiple regression analysis was conducted using factors that showed significant simple correlations to CMC tool use. In the resulting model, the multiple R^2 accounts for 23.7% of the variance in total CMC tool use. Total skill with CMC tools is the most potent of the five factors that remained in the working model, while parents' education, overall experience with computers, access to computers (differences between schools), and academic self-concept all remain significant in the combined model (see Table 14).

factor	*B*	*SE B*	β	*p*
skill with all CMC tools	6.54	1.89	3.46	<.001
parents' education	7.27	2.40	3.03	<.01
overall experience with computers	2.04	0.75	2.70	<.01
access to computers	-19.55	8.61	-2.27	<.05
academic self-concept	6.45	3.81	1.70	<.10

Table 14. Regression model for overall use of CMC tools explained by student characteristics. Note: R^2=23.7%.

It should be noted that social influence was not tested for its fit with the multiple regression model in Table 14 because that factor's simple correlation to CMC tool use is based on a smaller dataset generated by the social influence sample.

Discussion

A central motivation for this research is that students need to improve both their communication skills and their familiarity with technology in order to be prepared for the workplaces of today and tomorrow. When the U.S. government commissioned the report on necessary workplace skills (SCANS, 1991), computer mediated communication (CMC) was only starting to emerge in the workplace, and, in the process, to revolutionize the way people work and communicate (Sproull & Kiesler, 1992). CMC tools today provide a unique bridge between the classroom and the world beyond. When CMC tools are integrated into classroom practice effectively, they do more than just connect students to the rest of the world—they help them build the communication and technology skills they need in order to thrive after graduation.

Today, the Internet and CMC tools like electronic mail are vital components of the work place. But what about the "learning place?" For all but a very few K-12 classrooms, CMC tools are something that students and teachers hear about but never get to use. When these technologies finally do reach the classroom, how will their impact be felt?

This study takes as a basic assumption that these technologies *will* become part of everyday classroom life. This prediction is supported by evidence of the rapid growth of networking technology in the nation's public schools (Heaviside et al., 1996). What is less certain is what will happen when CMC tools meet classroom culture. Will students benefit equally from this new technology? How can we foster positive change using these tools? How must the technology be adapted or updated to meet the special demands of the classroom?

The Classroom Is Not An Office

In considering ways that the frequency and manner of CMC tool use by CoVis students deviates from the reader's expectations based upon prior experience with CMC tools in white collar or academic settings, it must be stressed that the classroom is not an office. This statement is meant to call attention to the fact that the CMC tools used in the CoVis classroom (with the notable exception of the Collaboratory Notebook), all originated in white collar research and business settings. Each of these tools was designed with a set of assumptions about work that are violated by the classroom setting.

For example: whereas there is often a 1:1 ratio of people to computers in white collar settings, the ratio in the classroom is normally 5:1 during any single class period and closer to 30:1 over the course of an entire school day. This puts the notion of "personal computer" in a new light. People in white collar settings often personalize their computers, to make them both more enjoyable to use and more efficient. The shared nature of the classroom computer requires that it be kept generic to meet the varied needs of users, and thus unable to perfectly meet the particular needs of any single user.

Most employees in white collar settings work in a single location, have a phone number where they can be reached, and can usually decide how best to structure their work schedule. Students, on the other hand, move from classroom to classroom during the day (as many as nine different locations, not including the lunch room), are unreachable except in emergencies, and are told to focus on particular subjects during particular hours (and explicitly *not* to think about those subjects during other hours). Furthermore, because of relatively frequent interruptions by field trips, teacher in-service, or all-school assemblies, it is unusual for a class to actually be held for five days in a row. The implications of this highly constraining schedule mean that the ways CMC tools are used by students will be very different from the ways they are used in white collar settings. The most obvious consequence is that the frequency of use is greatly reduced. In CoVis classrooms, the number of e-mail messages the typical student sends during an entire year is equivalent to the number of messages many white collar employees send during just a few weeks. Another factor contributing to this relatively low frequency of use is the novelty of CMC tools in general in the classroom environment. As teachers become more comfortable with different ways of integrating CMC tools into their students' everyday activities, we will undoubtedly see *some* increase in frequency of tool use. Even so, it is unlikely to ever reach the level of use in white collar settings.

Explaining Differences in Student Use of CMC Tools

The factors that explain differences in CMC tool use fall into two basic categories: those that can be compensated for in the short term with proper intervention and design, and those that cannot be directly compensated for, but are still useful for understanding how different students might react to the introduction of CMC tools. The factors that fall into the first category are experience with computers, social influence with respect to CMC tools, and communication apprehension. Factors in the second category include students' academic self concept, parental education, and gender. None of these factors explain a tremendous amount of variance in student CMC tool use by itself. Rather, CMC tool use is related to a large number of small factors. It is the combination of these factors that explains why some students used CMC tools more than others.

Experience with Computers

The factors that accounted for the greatest amount of variance in student CMC tool use were those factors related to experience with computers. These include students' self-reported experience with various kinds of computer software, computer ownership, and self-reported skill with CMC tools. This result could be interpreted as an indication that people who are more comfortable with CMC tools are more likely to use them, which is sensible. These results also suggest that there may be some transferability of experience using one kind of computer tool (i.e., word processing programs) to new applications, such as CMC tools. Computer ownership is correlated with computer experience, again indicating that access to computers is one of the best ways to increase students' comfort and skill with them, and in turn their use of them.

While there are some school systems participating in special research projects that can provide computers for every student's home (e.g., McMahon, 1993; McMahon & Duffy, 1993), this is not usually a feasible option. Therefore, the design implication of the importance of student experience with computers and CMC tools is to emphasize training with CMC tools early in the school year. These results do not indicate how such training should be implemented. However, a training methodology consistent with the overall approach to pedagogy in the CoVis Project would suggest that it might be best to integrate it with ongoing classroom activity, rather than making it a separate activity.

In discussing the importance of student experience with computers, it is interesting to note the *un*-importance of experience with video games. Neither video game ownership nor experience with computer games was significantly related to student use of CMC tools. While the reasons for this are not clear, it does contradict popular rhetoric that "vid kids" are in some way preparing themselves for a high-technology future. To be properly prepared to participate in an inter-networked society, it seems that experience with a broader range of computer applications is necessary.

Social Influence

When CMC researchers set out to explore the impact of social influence on tool use in the past, they sought to explain uses of CMC tools that could be adequately explained by so-called "rational choice models" of tool selection (e.g., Fulk et al., 1990). To do this, they posited a social influence effect, which stated that the extent to which someone will use electronic mail (or other CMC tools) could be predicted by the use of those tools by relevant co-workers or supervisors. Evidence for this effect was found in a white collar organization (Steinfield, 1986) and a government agency (Schmitz, 1987). In this study, social influence was measured as the relationship between how often a student used particular CMC tools, and the product of the "communicative distance" ratings a student assigned to people with whom he or she communicated and the amount those people used particular CMC tools. As was the case in the study conducted by Fulk et al. (1990), the social influence effect among "co-workers" in the classroom was analyzed by constructing a sample that included only students. The influence of "supervisors" was analyzed by constructing a sample that included both the students and the six teachers.

The results of these analyses were striking in two ways. First, the presence of a "social influence effect" was felt more strongly among students in the fall than in the spring. Second, the models that included teachers resulted in a much stronger relationship between social influence and CMC tool use than the models that included only students. This would seem to indicate that teachers' CMC tool use exerted a stronger influence over students than the use of CMC tools by their peers. Furthermore, the influence that teachers' CMC tool use had over their students' CMC tool use appeared to decrease over time.

The influence that teachers' tool use has on students' tool use can be explained by Bandura and Walters' (1963) social learning theory, in which learners acquire new behaviors by observing a model. In this case, teachers model their tool use behaviors for students. Furthermore, this kind of learning does not require the subject to actually perform the behavior at the time it is observed, or even to receive direct reinforcement for it (Bandura, 1971). Thus, the teacher may be unaware of the modeling he or she provides for students.

The decrease of the strength of the social influence effect over time can be explained as an artifact of increasing student familiarity with the CMC tools. As students gained comfort and facility with the various CMC tools, they developed their own opinions about how and when to use each tool, based upon their experiences. As a result, the influence that their teachers and peers had on their tool use decreased over time.

The design implication of the social influence effect on CMC tool use is to make teachers more aware that the way they use CMC tools will strongly influence what their students do with CMC tools. Thus if a teacher wants the Collaboratory Notebook to become instrumental for their students' projects, it is important for the teacher to make the Notebook instrumental to the way he or she does his or her work with respect to projects. The same applies to e-mail and news. Teachers must demonstrate to students not just that they also use the tools, but *how* they use them for the greatest benefit. Teachers must explicitly model tool use behavior for students.

Communication Apprehension

It was hypothesized that written and oral communication apprehension would be related to CMC tool use by media type. For example, students who exhibit high oral communication apprehension would be less likely to use audio and video media like Cruiser videoconferencing. Students who exhibit high written communication apprehension would be less likely to use text-based media like e-mail, and news.

As it happened, Cruiser use was so low in this study (see below) that it was not possible to examine the relationship between its use and oral communication apprehension. As expected, oral communication apprehension was not related to use of the text-based CMC tools: e-mail, news, and the Collaboratory Notebook. None of these three tools employed the kind of oral communication that would be problematic for someone who exhibited high oral communication apprehension.

Written communication apprehension was significantly related to the use of news and the Notebook, but not to use of e-mail. This result makes sense when the audience characteristics of these three tools are taken into account. E-mail is essentially a personal and private medium. Most e-mail messages are sent from one individual to another individual. News and the Notebook, however, are public and group-oriented systems, respectively. It is easy to understand why students who exhibited high written communication apprehension might have been reluctant to post messages using Usenet news. In one teacher's class, for example, students were actively dissuaded from posting, in large part because the teacher was uncomfortable using news. The Notebook is a slightly less public forum. Notebook pages are accessible only to other group members and to a student's teacher. Accordingly, the relationship between written communication apprehension and creation of Notebook pages was weaker than the relationship between written apprehension and news posting.

Communication apprehension is an aptitude that cannot be changed by teachers, but there are measures in the design of the communication environment that can be taken to help make students more comfortable communicating using the various CMC tools. For example, one hypothesized design recommendation is that local Usenet news groups be constructed for students to use until they become comfortable with the conventions of news posting. Activities that encourage "lurking" in news groups, the practice of reading articles without posting any articles, can be used to help students understand the different types of discourse that comprise conversations in these specialized spaces. In the case of the Notebook, greater encouragement and feedback might be of value. Researchers at MIT (Papert, 1980) found that students who were reluctant to write because of fear of committing errors could benefit from the introduction of word processors. The primary change in the new environment was that students realized that they could edit their work easily, and teachers encouraged frequent revision. In a similar fashion, students who view writing in the Collaboratory Notebook as the equivalent of turning in assignments to the teacher would benefit from active reinforcement of the evolutionary nature of Notebook entries.

Academic Self-Concept

Students' self-perception of their performance in school was as a straightforward self-report of the types of grades the student normally receives. Academic self-concept measured by grades was found to be positively related to CMC tool use, but it is not clear that there are any design recommendations to be made relating to issues of students' academic self-concept. Teachers, however, can be sensitive to students' academic self-perceptions in order to identify those students who may need extra attention in order to become successful users of CMC tools.

Parental Education and Gender

Gender and level of parental education were two demographic factors studied in this research. While parental education was found to be generally related to student CMC tool use, gender was only related to the use of Usenet news, which was used more my boys than by girls.

While some studies have reported a relationship between parental education and educational access for students (e.g., Bielby, 1981), access to CMC tools did not seem to be at issue in this study. Students whose parents had limited educational backgrounds were evenly distributed among schools and classrooms. Furthermore, computer and video game ownership, which could be considered indicators of status, were not significantly correlated with levels of parental education. What is behind the relationship between this factor and CMC tool use? One possibility is that parents' general orientation to academic achievement was reflected in their children's behaviors. The student's own academic self-concept may be an indicator of this. The factors of parental education and student academic self-concept (grades) are significantly related to each other (r=.236, p<.02), lending support to this conjecture.

Why was gender related to use of Usenet news, but not to use of the other CMC tools? The most logical explanation lies in the nature of the different CMC tools. While the Notebook and e-mail are designed primarily to support private conversation, Usenet news was designed explicitly to support conversation in a public forum. Furthermore, that public forum does not always feature the most welcoming type of discourse. Conversations in news groups are sometimes rude and are known for frequent "flaming" <Lea, 1992 #367; Sproull, 1986 #441>. (for more on flaming see Lea, O'Shea, Fung & Spears, 1992; Sproull & Kiesler, 1986). Such an environment might not appeal as much to girls as it does to boys. This is supported by the evidence of higher written communication apprehension among girls than boys. This increased communication apprehension would in turn lead to greater reluctance to post articles to Usenet news groups.

In the case of parental education, there is little that the teacher or school can do to intervene. As in the case of academic self-concept, it may be possible to provide extra attention for students who require it, if their parents' educational level is known by the teacher. Gender issues, however, might be dealt with in similar fashion as issues relating to communication apprehension, since they appear to be related to each other. Design of "safe spaces" for girls to practice using news until they are comfortable with the medium might be helpful. As was the case with academic self-concept, however, helping to make teachers aware of both of these factors can help to identify students who might need extra support with particular CMC tools early in the school year.

What Happened to Cruiser?

The data on the use of Cruiser videoconferencing indicates that, compared with other CMC tools, Cruiser was hardly used at all. Given the overall high richness and usefulness ratings that this tool received from students, to what might we attribute the apparent failure of Cruiser to be used in CoVis classrooms? The most probable explanation is a combination of difficulty of use and critical mass theory (Markus, 1987). In fact, critical mass is the explanation used by the developers of Cruiser to explain both that system's success at Bellcore and the failure of a similar videoconferencing system called MTS (Kraut, Cool, Rice & Fish, 1994).

In a survey item asking students to assess their own skill level with various CMC tools, Cruiser was ranked lowest. This is likely the result of a combination of lack of opportunity for use, and the difficulty of using the Cruiser interface. While the other tools (e-mail, news, and

Notebook) operated following the normal assumptions of the Macintosh computer, Cruiser was an X-Windows application running in an emulated environment on the Macintosh. This made its controls and operating assumptions unfamiliar to novice users. Furthermore, the infrastructure used to place Cruiser calls was unreliable, resulting in almost as many failed attempts as successful calls. This was also true for CoVis researchers at Northwestern, who placed many more calls than either teachers or students.

Markus' (1987) critical mass theory may also explain why Cruiser was not used. Markus asserts that there are only two stable states in the adoption of media: "all or nothing" (Markus, 1987, p. 500). Either the tool will achieve near-universal access, or it will not be used at all. To re-state this principle in terms more suitable to the CoVis classroom: in order for a medium to be successful, it must enable its users to communicate with relevant audiences. In the case of e-mail and news, near-universal access exists, they are the most common communication tools used by people on the Internet (Krol, 1992). The Collaboratory Notebook was not used outside of CoVis classrooms, but the only people students needed to reach using the Notebook were within CoVis classrooms; therefore universal access for relevant parties exists for the Notebook. Cruiser, however, was only available in CoVis classrooms, at Northwestern, at the Exploratorium in San Francisco, and at the University of Illinois Department of Atmospheric Sciences. Although CoVis researchers believed these to be places CoVis students would want to "visit" using Cruiser, the range of people at these locations did not meet the "relevant others" requirement of critical mass theory. In the words of one focus group participant, "There was no one on the other side—there was no one to talk to using video."

The clear design implication of Cruiser's failure to be used by CoVis students is that critical mass issues need to be considered by designers from the outset. The "if we build it they will come" approach to technology diffusion did not translate successfully into the classroom context. The structure of the classroom does not allow for open or idle experimentation with new technologies unless they quickly come to serve an instrumental role for the user. Future attempts must be wary of this, and ensure that critical mass issues are accounted for with respect to new technologies *before* they are introduced into the classroom.

Areas for Further Consideration

Message Reading Behaviors

The choice of measuring messages *sent* as opposed to messages *read* was made in this study for two reasons: first, logging technology to capture message receipt was not available for all CMC tools; second, the receipt of messages is not the result of direct student action, and there is no straightforward way to know when a message is actually read as opposed to just discarded. Much e-mail, for instance, may be considered "junk mail." By this measure, students who have never launched Eudora would appear to receive as much mail as students who anxiously check their mailbox every day. Therefore, to study message receiving behaviors would require a more active form of observation than logging provides. Doing so, however, might provide new insight into the role that certain CMC technologies play in the classroom. Usenet news, for instance, may be far more useful as a browsing medium than a message creation medium. Students might be using Usenet news as a reference source, or a way to vicariously learn about current issues in a particular topic by "lurking" without actually posting. A more refined understanding of these activities would provide more insight into the role CMC tools can play as part of more passive classroom communication activities.

Measure of Message Units

A potential shortcoming of this study is the equivalent treatment of e-mail messages, news postings, Collaboratory Notebook pages, and Cruiser calls. In fact, it could be argued that the semantic content of an e-mail message may be substantially different than the content of a

Collaboratory Notebook page or a Cruiser conversation. For this reason, it may be unrealistic to compare the raw numbers of messages sent using each medium as was done in this study. As with the issue of message reading behaviors discussed above, treatment of message content as opposed to message count would require a radically different methodology, and in essence be a different study. The methodology of message counting employed in this research was deemed appropriate for as a *first level* attempt to understand the networked communication patterns of high school students, and more in depth study of communication behavior is reserved for future work.

The World Wide Web

Due to the timing of this study, the World Wide Web was excluded as a CMC tool. Although the Web was just starting to be used in CoVis classrooms at the initiation of this study, the technology at that time limited its use to that of an "electronic library." There was no way for students to interact with materials on the Web in the sense of a two-way communications medium. Therefore, although the Web was becoming a useful research tool at the time this study began, it was ruled out as a CMC tool from the student perspective. Since that time, Web technologies have evolved to include greater amounts of interactivity, including forms, scripts, and most recently, the advent of full programming languages like Java (Gosling & McGilton, 1995). As a result, it is now possible to duplicate the functionality of Usenet news and the Collaboratory Notebook (and to some extent, e-mail), within World Wide Web browsers such as Netscape Navigator and Microsoft Internet Explorer. Furthermore, students participating in focus groups at the end of the school year consistently named the Web as the most useful tool available to them. Some students described a process where they would begin by using the Web to identify possible sources of information, and then switch to e-mail to communicate with them directly. Use of the Web in classroom settings provides fertile ground for further research.

Conclusions and Inferred Design Guidelines

The intended outcome of this study is a set of guidelines that designers can use in the development of CMC-enhanced learning environments. It is important to recall that designers, in this context, include more than the people who program and create CMC tools. In this context, teachers are also designers. They design the activities that introduce and employ CMC tools, and they help the end-users (students) form their initial impression of the tools and how they are to be used. Researchers also play a design role in these settings, frequently acting as intermediaries who bring innovations such as CMC tools to the classroom, as was the case in the present study. The findings of this study lead to a number of hypothesized design recommendations for future implementations of CMC-enhanced learning environments.

Teachers influence students' use of CMC tools through their own behaviors with CMC tools. Data on the presence of a social influence effect with respect to CMC tool use indicates that teachers exercise the most influence over student CMC tool use behaviors in the early part of the school year. This suggests that teachers need to be aware of their own attitudes towards and use of CMC tools, and particularly how they communicate these to students through behavior. Explicit modeling of desired behaviors is recommended.

The data also indicate that increased experience with general computer applications, as well as skill level with particular CMC tools, is a strong predictor of CMC tool use. Accordingly, teachers and schools need to focus on developing training programs for the CMC tools. Furthermore, CMC-enhanced classrooms are not solely about the use of CMC tools. By increasing students' familiarity with general computer applications such as word processors and graphics packages, an increase in the use and integration of CMC tools is also likely to occur.

Students who exhibit a high degree of written communication apprehension are less likely to make use of CMC tools that address public forums, such as Usenet news. To help communication apprehensive students become acclimated to these environments, it is recommended that "safe spaces," in the form of local news groups, be established to give students practice with the medium. This might enable apprehensive students to eventually benefit from CMC tools such as Usenet news.

Finally, teachers can be made aware of certain student characteristics that are related to successful use of CMC tools. These include academic self-concept, parents' level of education, and gender. Foreknowledge of the effect of these factors on CMC tool use will allow teachers to give special attention to students where it is most needed.

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