COMPUTERS, VIDEO AND OTHER TOOLS IN THE TEACHING OF PROBABILITY AND STATISTICS

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THE ROLE OF ELECTRONIC COMMUNICATION IN STATISTICS EDUCATION

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1. Current problems in statistics education

Many researchers and writers have pointed out that there is a great need to improve methods of statistics education (Bisgaard, 1991; Cobb, 1991; Snee, 1993). Statistical literacy has become a social imperative if we are to share a responsible, thoughtful citizenry. However, often in the classroom students are isolated, working in silent interaction with printed material, or working through "cookbook" computer homework assignments. It is as if in forcing the student to go through certain motions, learning will somehow magically happen. But, as has been pointed out previously (Riel and Levin, 1990), students must be active learners, engaging themselves in the exploration of ideas and communicating those ideas to each other and, at the same time, to themselves. The value of active participation and student collaboration is well known; the problem is in how we structure a learning environment to gain that value.

Today's students also need skills of expression, skills for sharing ideas and information. Seldom does the statistician need only an answer and not need to communicate that answer. It seems apparent that as statistics educators, whether of statisticians or statistically literate citizens, we must be concerned with teaching methods for both creating and communicating statistics information. In foster these communication skills, students must be allowed to practice communicating in the classroom. Indeed, educators are becoming more aware of the importance of social interaction in the classroom (Riel, 1990). There are problems in making these changes, of course; teachers cannot reorganize their classes to meet these goals and still maintain the traditional classroom form. Additionally, current world-wide economic pressures leave teachers with tight budgets, the need to do more with less, often resulting in larger classes and even more difficult communication problems.

Technological advances now make it possible for teachers to consider the possibility and promise of electronic communication through computer networks. This technology can enable teachers to form new

relationships with their students and with other educators around the world, providing much-needed mentoring and support. Networking can also provide an outreach function for nontraditional students, dissolving barriers of geographic location and at least some cultural impediments. Electronic communication allows students to offer each other encouragement, both academic and personal, often resulting in a more positive evaluation of the classroom experience (McCormick and McCormick, 1992).

2. Current forms of electronic communication

Electronic communication today can take several forms, from long distance telephone service to video-conferencing, fax services to slow-scan (freeze-frame) television. All of these systems are designed to deliver data, voice, text, or image from one point to another. While these forms of electronic communication are powerful and hold much promise for educators, the focus here will remain on the most widespread and potent forms for the classroom: electronic mail, computer conferencing and methods of globally-networked "computer-mediated communication".

Many universities, companies, colleges and private individuals are linked together by various international computer networks collectively called the Internet. While it is difficult to estimate the actual numbers comprising this network due to its rapid growth, it is safe to say the Internet is composed of over 5,000 other networks in over 107 countries (Roupp and Pfister, 1993). It is growing from 10 to 15% monthly. The Internet began as ARPANET (Advanced Research Projects Agency Network) in 1969, developed to help university researchers share information. Since then it has grown to include such large networks as NSFNET and NEARNET. In addition, many networks such as BITNET are tied to Internet but are not integral parts of it. An individual user with an account on a computer linked to the Internet gains access to resources not only on that computer, but on any Internet computer that offers public information. There are many such sources; some users have likened the task of getting information on this knowledge-rich network to "drinking from a fire hose" (Gelernter, 1992). The user also has electronic-mail access to all other Internet users, and to users on networks that have connections to the Internet.

E-mail. One of the most useful tools for obtaining information from the network is electronic mail (e-mail). E-mail is essentially a one-to-one or one-to-many form of communication. Besides providing person-to-

person messaging, e-mail is used in electronic discussion groups. In these groups, any message sent to a specific central address is automatically rebroadcast to all members of the mailing list group. These discussions bring people together as a focus group, enabling them to consider common problems, share solutions, and argue issues. EdStat-L is one such forum, dedicated to providing a vehicle through which techniques, tools, ideas and philosophies of statistics education can be shared.

E-journal. Network-based electronic serials are periodicals that are primarily "published" on computer networks like the Internet. Several of these function as electronic journals (e-journals). A scholarly e-journal is quite similar to a paper-based journal, containing refereed articles, reviews, and other information. However, the two differ in several ways. The most obvious difference is that an e-journal exists on the network instead of on paper. Readers access journal articles and other information by e-mail request or direct access to the archiving computer. Other differences include the ability of an e-journal to offer databases or other information associated with an article, as well as the ability to interact with and conduct searches on the entire journal archives.

Computer conferencing/Bulletin Board Systems (BBS). In contrast to e-mail, computer bulletin boards and conferencing are methods for sending messages to an area or message database on the network that is shared by others at various locations on the network. All users must access the same network. Some conferencing software is sophisticated, allowing users to search, branch comments into topics and replies, and use a number of other functions. Users generally post information that is later read in sequence by other users accessing the conference. UseNet News is one type of conferencing system used around the world. It is extremely popular, with users debating on over 2,000 subjects, called "newsgroups". The public-domain software also allows local newsgroups or conferences to be set up for classroom or departmental communications.

Methods of direct access. Gopher and World-Wide-Web are two software programs available at no charge that allow the user to use his computer as an information "client", requesting information from any of the several thousand information "servers" on the Internet. Because there are so many public access information servers, many of which are devoted to specific subjects, these programs are needed to help navigate the sea of information available on the network. The programs can employ interfaces that use hypertext, graphics images, sound files, and text. For connecting to public information servers these programs are the current state of the art.

3. Human factors in computer-mediated communication

Regardless of the specific technology employed, computers enable a new form of mediated communication with psychosocial properties that are quite different from those associated with other forms of communication. The computer's impact on communication extends well beyond the convenience of faster and more efficient information transmission (Harrison and Stephen, 1992). Because the system allows the user to delay both receiving and responding to the message to suit his/her schedule, he/she controls the time of communication.

Computer-mediated communication enables collaboration between learners by removing time and distance barriers. Students can help each other in an active collaborative environment and instructors can provide further opportunities for interaction with on-line seminars, group discussions or joint experiments. This type of communication allows for interaction both between students and instructor and among the students themselves that would be impossible in a conventional course.

This mode of communication is also inclusive in that it can incorporate many voices and points of view. This affords every student the opportunity to have an equal chance to participate, independent of status and role differences. The traditional paradigm of lecturing professor/silent student is relaxed; there is no explicit "downward" communication channel. The inherent structure of the network is horizontal (Lewis and Hedegaard, 1993; Roupp, 1993). Conversations may be many-sided and can contain multiple threads of content. These information exchanges are intertwined with the learning and teaching activities that provide much of the subject matter for discussion (Drayton, 1993; Kaye 1992). Conversations are automatically archived so they can later be scanned or referenced. When the use of network communication is frequent, the system provides a real forum, a round-table discussion with many points of view. This gives us the ability to reach beyond the traditional classroom boundaries and, hence, can change both the size and composition of the educational community.

4. Examples and resources: integrating electronic communication and statistics education

Distance education. Electronic communication can be used to supplement traditional courses or provide the primary vehicle for distance education courses. Students engage each other and their instructors in online discussion groups, reading, thinking, then responding. This structure

encourages a much more active learning experience than traditional classroom methods. Distance learning is particularly useful for the disabled student, allowing interaction that might be difficult if not impossible otherwise. Bellman (1992) points out that this type of classroom has few prejudicial elements, and so enables more assertive involvement in the education process by traditionally apprehensive or passive learners.

There are several successful examples of electronic communication and distance learning today. The Appalachian Community Service Network (ACSN) combines broadcasting, satellite, cable television and telephone technologies to provide instructional programming to Appalachia, a rural part of the United States that faces some of the same problems as many emerging nations (Van Deerlin, 1980). The Global Schoolhouse Project, sponsored by the U.S. National Science Foundation, uses live two-way interactive video on the Internet to reach classrooms in California, Virginia, Tennessee and the United Kingdom. This allows students to extend their learning experiences far beyond the traditional classroom by allowing them to interact and collaborate with their peers regardless of geographic location. In Montana, the Big Sky Telegraph Project uses a combination of network technologies to reach over 116 one-room rural schools. The system uses packet-radio broadcasting (wireless network communication) to transmit audio, text, and animated color graphics over a 50 mile range (Utsumi and Villarroel, 1992).

There are also dangers to consider in distance education projects, however. The social changes that this technology brings into our lives and classrooms must be carefully considered. Fundamental changes in human behavior, regardless of the setting or the goal, are difficult to achieve. For distance education to work, much more may be needed than simply technical infrastructure, especially when the distance is between cultures. In online communication, since words are the only information available, the opportunity for multicultural miscommunication is ever present. Shades of meaning and style of communication become even more important since visual and auditory cues are absent (Shapard, 1990). Debate may seem like an attack to some participants, or advice may sound like arrogance. Although students and instructors may not be experts in the social interpretations of online communications, it is safe to say that human decency is always in style. However, online communications may require more of it, or more thought about how not to violate it, than other forms of communications that contain more nonverbal information.

Collaborative learning opportunity. The structure of computer-networked communication allows great opportunity for collaborative

learning. The network may be used to perform online experiments, perhaps linking geographically-distant classrooms for joint experiments. The multitude of information already on the Internet can be used in a "data hunt" in which student groups access the network to find datasets related to their interests, retrieve and analyze the data, reporting back results (or problems) via the network. Other groups on the network may be surveyed by a class, or called upon for information by student groups. "Experts" or "clients" may visit the class online for an "electronic consultation", explaining an industry application of methodology, or describing a problem. Such visits might even be scheduled live, so students could interactively ask questions or posit solutions with the visitor.

In exploring and experimenting with networked collaborative learning, it is important to keep in mind that the philosophy of "if you build it, they will come" is a recipe for failure. One of the most important factors for success for computer conferencing in the classroom is a commitment to leadership that supports the activity (Canning and Swift, 1992). Indeed, Reil and Levin (1990) point out that the goal must be shared by the group, access must be easy and equally available to all and someone must act as the facilitator or leader. If the students fail to see the practicality of using the network, or if they are not explicitly encouraged to use it, they will not use it.

Nuts and bolts. Perhaps more mundane, the use of the network in improving the classroom infrastructure, such as student feedback or test and quiz results, can be quite helpful to both student and instructor. In the Statistics Instructional Computing Laboratory (SICL) at North Carolina State University, a "public" area is set aside on the network for instructors to put electronic copies of exams or quizzes from previous years, as well as results of exams and quizzes given during the semester. Other materials may appear there, such as special datasets for the students to experiment with, or pointers to other information on the network. Some instructors encourage group interaction via classroom bulletin boards, posting homework assignment errata or helpful examples similar to homework assignments. Other instructors use the "ghost" login facility, whereby any student logging in under the name "ghost" can send an anonymous message to the instructor. The intent of this facility is to encourage honest feedback, suggestions, and commentary on the course. This is a popular feature that has resulted in instructors receiving some thoughtful criticism and suggestions. Finally, all locally-written help manuals for the computer system and software packages in SICL are available through the lab's online help system. All of this material, from computer-command

descriptions to notes on multiple regression, may be searched by keyword or accessed sequentially via the menu system.

Mentoring and electronic community. One of the most important facets of electronic communication is the ability to create communities, not by a common geographic location, but by a commonality of ideas. The electronic discussion groups on the Internet are well suited to this task. Statistics educators may find a congenial community in EdStat-L, the discussion group for statistics education. The purpose of the group is to provide a forum for comments, techniques and philosophies of teaching statistics. The group's stated goal is to bring together every teacher, student, researcher, and specialist interested in improving statistical instruction. The group's communications range widely, sometimes debating the issue of what academic groups are the proper teachers of statistics, sometimes discussing different ways of looking at (and explaining) certain statistical concepts, and sometimes just "chatting" with each other, all in a highly interactive, informal coffee-house style. This facility can also be used as a way for experienced teachers (mentors) to pass down advice, teaching anecdotes and the wisdom of experience to younger, beginning teachers. For many isolated statisticians and statistics educators, the network can be a place to find a much-needed community.

More formal interaction with the international statistics education community is also available on the network: The Journal of Statistics Education (JSE) is a new, rigorously-refereed electronic journal on post-secondary statistics education. JSE publishes high-quality articles on a variety of topics related to the teaching of statistics. The electronic medium enables readers to download datasets and teaching materials, search interactively the entire archived journal, access articles immediately as they become available, or participate in the parallel electronic discussion forum JSE-Talk, a forum devoted exclusively to discussion of issues concerning the JSE readership.

The JSE Information Service, an adjunct to the JSE, is a growing electronic archive of information, software and discussions related to statistics and statistics education. In addition to the JSE itself, the Information Service includes the JSE Guidelines for Authors and Call for Papers, and fully indexed and searchable archives of several electronic discussion groups related to statistics or statistics education. Also available through the service are software related to statistics or statistics education, information and programs to help users find and use other network resources, the national archive of SAS macros and programs, and information about other services of interest elsewhere on the Internet.

5. Future possibilities in electronic communications

Though it is generally dangerous and unfruitful to try to predict the technological future, there do seem to be some developments in electronic communications that are inevitable.

The most obvious development to come is that of the network itself. More and more of us will become connected to the network, and hence connected to each other. The major problems in network communication today have to do with the incompatibilities existing between the current plethora of networks and software and hardware companies. The many networks, service companies and lack of standard communication protocols belie the fact that we are not in a communications revolution, but an evolution. The situation is similar to the growth of other products and services that had a large impact on society, such as telephone service, the automobile industry, or cigarette manufacture. These industries all went through natural stages of growth: early innovation and experimentation, proliferation of brands and product standards, and finally stable growth resulting in a small number of standards or product types, a relatively small number of companies, and rapid spread through the culture. In the beginning days of telephone service, it was sometimes necessary for subscribers to belong to different telephone companies-users had to be on the same network in order to communicate. This is not far from the situation today in computer networked communication, and it seems probable that the evolution will continue.

Videoconferencing is another technology that is still expanding into the education field, allowing teachers to reach students in geographically-dispersed locations. As technology has advanced, videoconferencing has moved from concept to executive privilege and is now becoming a practical communications tool. With further advances in technology this form of communication will no longer require large boardroom-sized facilities but will be usable from a desktop computer on the electronic network (Gill, 1993).

Virtual reality may become important to us as educators. Virtual reality has been described as "a three dimensional participatory multi-sensory computer-based environment that occurs in real time" (Randall, 1992). This technology makes possible in the fields of distance communication and education, something new called telepresence, a paradoxical term that might be defined as having or sensing one's presence at a remote or even virtual location. Techniques in education such as visualization and simulation could certainly be affected, given this power to create virtual learning environments. Virtual reality combined with the global network could give us the ability to form workgroups whose

members are geographically-distant, but able to communicate within the virtual networked reality, a version of "cyberspace" (Reingold, 1991). Using this technology, students and teachers could physically interact with objective, graphical databases, perform rotations of graphic images by hand and work together in virtual simulations of experiments. Whether the technology will be able to transcend social barriers and deliver the many promises made for it now provides fuel for hot debate in today's popular press.

Another development that seems certain is that we will need to become even more information literate. This entails "the ability to realize that information is needed, and to locate, evaluate and use effectively the needed information" (Wegner, 1992). The sea of information available on the networks will affect the life of each of us, whether student, teacher, or citizen. In order to survive and prosper in the intellectual climate of the future we will have to rely on each other for training, assistance, and encouragement in the task of lifelong learning.

6. The prospect of a truly global network

Although the Internet is growing at a furious rate, and hundreds of thousands of users are now connected, the great majority of the traffic on the network comes from North America. There is no reason to doubt that other developed countries will soon be as thoroughly connected to the network. However, it is easy to forget that we are not the whole group because the only voices we can hear on the network are our own. The Lesser Developed Countries (LDCs) are sparsely connected to the Internet and they may encounter severe political, financial and social difficulties in achieving the connection. It is important to note that poor or remote locations, even in developed countries, will have similar difficulties in becoming connected to the network.

By learning the basics of how the technology can be used for advancing education, we will be better prepared to advise our colleagues or lead our classes to pioneer the future of networked education. The technological solutions are simple and relatively inexpensive. As a result of continuing improvement in computer and communication technology, a meaningful network can be built using low-cost appropriate technology. The two technical solutions described here are elegantly simple, inexpensive and widely used.

Grassroots networking by telephone: FidoNet. FidoNet is a wide-area network that uses modems on the direct-dial telephone network. There are

over 13,000 nodes on this user-run network, making it even larger than the popular and well known BITNET network. While hobbyists predominate on FidoNet in North America, about half of the public FidoNet systems in Europe are run by small- to medium-scale businesses. In Africa, the network is heavily used by non-governmental organizations and poorly-funded academic institutions. Within North America, there is growing use within the primary and secondary school systems. FidoNet is structured so that any node can communicate with any other node without the aid or consent of technical or political groups at any level (Bush, 1992). FidoNet communication is limited to e-mail or broadcasts similar to electronic discussion groups. While messages may take days to reach their destination, the network makes it possible to communicate with some remote locations where no other form of communication exists. A computer, modem, the FidoNet software and access to a telephone line are the necessary components of the network.

Packet radio and low earth orbit satellites. The power of packet radio as used in the Montana's Big Sky Telegraph project to reach remote areas can be vastly increased when coupled with satellite technology. For example, VITA's (Volunteers in Technical Assistance) satellite or "orbiting mail-box" will cover every spot on the earth twice a day. The satellite orbits at an altitude of 800 km. When it passes over a ground station, the station uplinks or transmits messages to the satellite and the satellite similarly downlinks or transmits messages or files to the ground station. The solar powered ground stations, which are relatively cheap, then broadcast the digitized messages on a radio frequency to computers in the local area that are "tuned in" to the packet-radio broadcast (Ronkin, 1991).

7. Conclusion

As educators, we need to work to improve the techniques we use. We need to involve our students with their learning and foster better communication skills. We need to reach out to students who need education, but have been left out of the traditional classroom. The promise of electronic communication offers great opportunities for distance education, imaginative collaborative learning projects, and help in making information easily accessible. In addition to technology for classroom projects, there is a wealth of information and services on the network for statistics educators themselves, such as the EdStat-L discussion group and the electronic Journal of Statistics Education.

We must guard against letting technology change the underlying values

of education, remembering the proverb, "When all you have is a hammer, everything looks like a nail". The overweening desire for technology can blind us to problems, perhaps making us forget our reasons for looking to technology in the first place, which is to improve our students' and our own learning. It takes more than technology alone to truly make a difference. Connecting everyone to the global network will have no positive effect by itself; our own imagination and effort is the real empowering force. However, it is important to know that technical solutions do exist, and that these solutions can have a large impact for little cost.

Armed with both knowledge and imagination, we can look to the future to take what is useful from the technological world in making the classroom a better place, engaging our students in their own learning. We can use the medium to reach out to others, and learn from others in ways that were before unimaginable.

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