Computer mediated teaching: A case-study in discrete mathematics *

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Abstract

Providing distance education students with tutorial assistance is a significant problem for universities such as The University of Southern Queensland where there is a large external student population and some attempt is being made to provide equity of opportunity. Audiographic conferencing is a cost-effective way of providing part of this assistance but certain disciplines present some unique challenges for this technology. This paper describes experiences with audiographic conferencing in a particularly problematic discipline, mathematics. We describe the technology used, its advantages and problems and make suggestions for future technologies.

KEYWORDS: Audiographic conferencing, educational technology

Introduction

Learning by distance education has many advantages for some students. In particular they are able to pursue their chosen course of study with minimal interruption to their life-style especially if study would mean relocation. There are significant disadvantages also and the ability to contact and interact with staff and other students are principal among these.

Distance education students have access to a range of educational aides including; study books, text books, audio and video tapes, CD-ROM and so on, but all these are one-way communication mechanisms—from lecturer to student. There are several two-way communication systems that are available but these are not always suitable. Video conferencing, for example, is used at The University of Southern Queensland (USQ) but at present it is only available between two sites: Toowoomba and Singapore. This technology is also expensive to setup and maintain. Moreover, unless the facilities at both ends of a connection are equivalent then the functionality is reduced significantly. Other such systems require satellite and expensive production facilities and at this stage have not been considered. Students have a high expectation of the quality of such facilities and presentations too (since television and video are so pervasive), but after all we are teachers and lecturers and not highly paid actors nor television producers. Residential schools, where students travel to the USQ campus or lecturers travel to locations suitable for a significant number of students, are another alternative. These are successful but many staff find them very stressful, particularly where they are required to travel overseas and, because of limits on resources, deliver lectures and tutorials on subjects with which they have limited familiarity. Common alternatives to the above two-way communication mechanisms are fax, personal telephone calls and telephone

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tutorials.[1] Lecturers in various disciplines including economics, engineering and mathematics find telephone contact less than satisfactory because it is difficult to communicate concepts relating to graphics and mathematical formulae using audio only. Fax at least allows us to communicate these but turnaround is a problem and the communication is hardly interactive. Telephone tutorials have a host of other problems also but in particular they often degenerate into sessions where the lecturer is asked how to do an assignment or what will be on the examination and so they are often perceived by academics as having little "educational" merit.

Audiographic conferencing (also called audiographic computerised telelearning) allows simultaneous display of graphical images on multiple computer screens at several sites and audio contact between the individuals at the participating sites. These systems normally use two (logical) telephone lines, one for the graphical images and one for the audio communication. A graphics tablet and computer combine to bring the graphical images to all participating sites. To speed operation, complex graphics can be transmitted to all sites prior to a session. Then an instructor is able to load them on request. Less complex graphics can be transmitted during a session. Loud speaker telephones allow communication between all participants. Participants at each site are able to interact using the graphics tablet and effectively control the course of a session although the presenter is always able to over-ride if necessary. Thus the graphics tablet acts like an electronic chalkboard where participants can share ideas and views. Such systems are very cost effective compared with other two-way communication technologies yet audiographic conferencing is still not widely known nor used [EDH87, Cla89]. More primitive versions of the current technology were trialed in high schools in the United States about a decade ago. Teachers and students alike found such systems useful as a "motivational tool" [O'C85].

Such systems have been used in tertiary settings but we are unaware of their use in our discipline (mathematics) at tertiary level or where graphics and symbols, not normally available on a QWERTY keyboard, are necessary. We felt that there was a need to examine this technique and tool, for its usability and its usefulness to enhance the learning experiences of these students. This paper reports a pilot-study of the use of audiographic conferencing for teaching discrete mathematics. The following sections describe the hardware used, our particular problem domain, the experience of the instructor and the students and various issues arising from this experience.

The Hardware

The particular hardware and software used is commercially available as an "Optel Telewriter III". It includes a modem which transmits both voice and data, a computer and screen and a television monitor which are able to present previously prepared visuals and session activity, and a graphics tablet on which all participants can draw or write. Each site has the same equipment but the originator site (where the lecturer is) is able to take control of the graphics tablet when appropriate rather than having it "handed over" from another site.

The Problem

Audiographic conferencing covers (or can cover) all four categories of interaction identified by [KM90] as important to quality distance education, viz:

- learner interaction with the presenter
- learner interaction among persons at a local site
- learner interactions with persons at other sites, and
- vicarious interaction

Because of equipment and staff availability we were restricted to studying interaction between users at two sites. Thus we were only able to offer the first two types of interaction identified

[1] Currently we are also trialing electronic mail, network newsgroups and the World Wide Web.

by [KM90]. This was sufficient to gauge our own perception as well as student reaction to the technology before embarking on a wider, more populated experiment.

Studying mathematics from a distance can be particularly problematic especially for students whose "basic" mathematics knowledge has diminished with time. More than one-half of the students studying discrete mathematics (a basic prerequisite for study in computing at USQ) do so by distance and about two-thirds of these are overseas. Initially 15 students were available from the remote site (the presenter being at the local site) but for various reasons only five students (two females and three males) were available at the time of the session. During a relatively short session (one hour) we covered three topics that were known to be troublesome to on-campus students:

- mathematical induction
- recursion
- partially ordered sets and lattices

The appendix A presents the mathematical concepts covered and shows the essentials of the interaction between the participants during the session.

Observation of the usability of the system was continually monitored at the local site. Student behaviour was monitored at the remote site and in addition we interviewed the students (via telephone) two days after the session to gauge their perception of their experience with the system. The subsequent performance of these students, in this unit, was also available.

The Presenter's Perspective

There were various technical difficulties that we noticed. Firstly, quality of the telecommunications lines is important. Our first attempt to make connection yielded a poor line which was apparently very noisy. Subsequently, any graphics that we drew were illegible at the remote site. As an example even a simple equation such as $n! > 2^n$, written so that it each symbol was about 6cm in height on the video monitor, could not be distinguished. Hanging up, re-dialling and re-connecting did solve the problem but this is an indication of the fragility of the technology. Secondly, the speaker phone caused some problems. Its location, relative to all the pieces of equipment, meant that the presenter's voice seemed to fade in and out. This caused students to guess what was being said. An observation at the remote site was that the guess was based on information shown on the monitor. Simple remedies would include radio microphones, in particular for the presenter, or more sensitive speaker telephones.

Screen resolution presented a major problem. There was no difficulty creating symbols and graphics before the session and having them pre-loaded for later display but there was a problem when we wanted to interactively create new symbols, equations and graphics during a session. To create symbols that were legible at the remote site, we needed to draw them so they were about 6cm in height on the monitor. Also only relatively thick outlines were usable. This significantly reduced the amount of material that could be displayed at any one time.

The particular configuration included two monitors, a graphics screen (PC screen) and a video screen (Sony monitor). Because of the underlying software, there was no way to selectively erase data from the graphics screen so we used it for displaying the problem and then used the video screen for working a problem. The video screen did allow selective erasure but it did not have keyboard access so we could only use drawing pens to display information.

Having two monitors was a problem in itself. For example at times the presenter would point to objects on one display but, unless the appropriate "mode" (graphic or video) had been chosen, the remote site could not see the pointer. There was a need to "physically" change from one mode to the other (graphics to video or vice versa) and this modality became irritating to say the least.

A small response delay was also noted, that is, there was a slight delay between drawing and subsequent display at the other site. This was not severe and should be rectified as line quality and bandwidth improve. But it is something to be aware of, particularly for overseas communications.

Student Reactions

In a follow up to the tutorial we telephoned the students and asked them several questions about their experience. The questions we asked are given in appendix B.

All participants thought the session was useful, especially the visual element which was missing from telephone tutorials. One suggested that such sessions be held every fortnight. They were better able to understand the topics covered than prior to the session and thought the choice of topics was most appropriate. The interaction component was noted as a useful and effective aspect of the tutorial. Participants could see the problem, see the solution and even learned how to write certain symbols correctly and how to lay out a proof, for example.

The main problems noted by participants related to the technical difficulties already discussed. Other aspects included the relatively small amount of information that could be displayed at any one time and the problem of involving participants in the exercises. Only two (both males) of the five actually used the equipment. One female felt that the males dominated and controlled the use of the equipment but there was also some nervousness and reluctance by others to get involved in the interaction. This reluctance was mainly attributed to the discrete mathematics, however, and not the use of the technology. These students were concerned about looking foolish both to their peers and to the lecturer—a not uncommon problem in normal face-to-face tutorials. Those that did control the equipment knew that they did but did so because they felt "someone had to do it". The time for the tutorial was too short because participants needed time to get used to the equipment. In particular, the graphics tablet took some assimilation time, but the screens themselves were also problematic simply because they were new and novel. There was no indication that the technology hindered the session, though—some visual being better than none at all and the discussion would have been almost impossible without it.

Conclusions

Technical difficulties aside, we felt that the use of this technology, to provide an enhanced telephone tutorial, was successful. We were genuinely able to discuss problems that students had with particular topics without the usual "what is on the examination" type questions that frequently accompany telephone tutorials.[2] Many of the problems noted by students were not dissimilar to problems encountered by on-campus students, which gives the impression that the session was indeed a "virtual classroom". [3]

We thought it interesting that no participants felt uneasy about not being able to see the presenter, or that the presenter could not see them. Indeed, it would be very useful to see the students because we could then make some attempt to rectify the participation problems and perhaps to ease the minds of those students who were worried about their mathematical skills.

The Future

Currently USQ is trialing a newer version of this technology called the "SMART 2000". It has already been used in a unit on market analysis, there are plans to use it in engineering units, and nursing has also indicated interest. Initial reaction to the new technology is that it is more usable and more functional but its use is yet to gain wide acceptance.

We are also planning to trial video conferencing since such technology is becoming available at a range of sites and also provides a face-to-face component not present in the audio-conferencing situation.

[2]Many staff do not conduct telephone tutorials for just this reason.

[3]All participating students passed the unit and two received grades of "credit". This is not to imply that all students who participate in such sessions will pass, it is just a fact.

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A Examples of Discrete Mathematics

Mathematical Induction

Prove by induction that $k^2 > 2k + 1$ for $k \geq 3$.

Consider the basic step: $3^2 = 9$ and $2 \times 3 + 1 = 7$ and $9 > 7$ which is T.

Consider the inductive step: Assume $n^2 > 2n + 1$ and show $(n + 1)^2 > 2(n + 1) + 1$.

$(n+1)^2$	$=$	$n^2 + 2n + 1$		lecturer
	$>$	$2n + 1 + 2n + 1$		students
	$>$	$2n + 1 + 1 + 1$	(since $n \geq 3$)	students
	$=$	$2(n + 1) + 1$		lecturer

Recursion

Find an iterative solution for the recurrence relation $s_n = -s_{n-1} + 2s_{n-2}$ where $s_0 = 4$ and $s_1 = 1$.

Firstly, do you understand the problem? (Yes.)[4]

A solution is of the form $s_n = x^n$. Do you know why this is a solution or why we choose this solution? (Some discussion emanates.)

Substitute this solution in the equation to get $x^n = -x^{n-1} + 2x^{n-2}$. How do we proceed from here?

(multiply through by x^{2-n} to get $x^2 = -x + 2$ or $x^2 + x - 2 = 0$.)

This factorises to give $x = -2, 1$ as possible solutions.

And the general solution to the original equation is?

($s_n = c_1(-2)^n + c_2(1)^n$)

The c_i are constants—how do you determine them? Can you do it? (Not sure, but will try.)

($s_0 = 4 = c_1(-2)^0 + c_2(1)^0$)

gives $4 = c_1 + c_2$

($s_1 = 1 = c_1(-2)^1 + c_2(1)^1$)

gives $1 = -2c_1 + c_2$ and we can easily solve these to get the c_i.

[4] Information in parenthesis represents student responses.

Posets and Lattices

Consider a set $A = \{1, 2, 3, 6\}$ and a relation "divides". Is this a poset and/or a lattice? How do you tell?

At this stage time had virtually run out so only discussion ensued. Questions mainly concerned the definitions of lattices and posets and the concepts of greatest lower bounds and least upper bounds.

B Questions for Students

- Was the session useful?
- What did you find most useful?
- What were the main problems?
- Did you think the technology hindered or helped the session?
- Did you feel in "control" of the session?
- Did others in the group take too much control?
- Were you reluctant to interact? If yes, was it the technology or the topic, discrete mathematics?
- Did you have any other comments?
- Did you actually use the system or just watch?