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Communicating mathematics through the internet: A case study

José Portela
Instituto Politécnico de Viana do Castelo Escola Superior de Educação
Departamento de Matemática, Ciências e Tecnologia
jose.portela@ese.ipvc.pt

Summary

The Internet is enabling new forms of teaching and learning. Connecting, through the Internet teachers to teachers, students to students, students to teachers, and perhaps most important, bringing the world of information inside the classrooms is reshaping the classroom setting, the role of educators, and students' perception concerning what they need to know. This study was intended to describe and analyze how students reacted to instruction delivered through the Internet, and their perceptions concerning the potentiality of the Internet to teach and learn mathematics. The setting for this study was the context of a college classroom, where participants were attending a mathematical communication and technology course. All students and the instructor were located physically in a mathematics computer laboratory in which the course content was presented to the students through the Internet. Data was collected from observations in the mathematics computer laboratory, and from semi-structured interviews using electronic-mail and unstructured open-ended interviews. Findings suggest that students had a deeper involvement in class activities due to the Internet links which created a more meaningful experience for them.

Keywords

Internet, Communicating mathematics, constructivist

Introduction

The constructivist view of learning holds that learning is an active process constructed upon prior knowledge (Bruner, 1990; Piaget, 1965) and is context dependent (Brown, Collins & Duguid, 1989; Resnick, 1987; Vygotsky, 1978). Although not new, constructivism has more relevance in education today because the dawn of the Information Age has rapidly increased the amount of and accessibility to information (Duffy & Jonassen, 1992). Connecting, through the Internet, allows a worldwide university, business, military, and science network (LaQuey, 1993) with immediate communication capabilities for teacher-to-teacher, student-to-student, and student-to-teacher interaction. Perhaps the most important impact is the reshaping of the classroom setting, the role of educators, and student perceptions concerning what they need to know (Harasim, 1996; Harrinson & Stephen, 1996) brought about by opening the classroom to the world through the use of the Internet. Accessing information is now easier than ever. Through the Internet, one can access any document published on-line anywhere

in the world; one can initiate or collaborate in discussions, search for policy archives and educational databases, download space and weather photos, and access on-line libraries. Students, scholars, and professionals are free from geographical and time constraints, thus gaining more equitable access to expertise, information, and tools (Eisenberg & Ely, 1996). With the Internet connection, everyone has access to an enormous body of resources that would be beyond the means of even the most affluent school. Communication online allows teachers, administrators, parents, and students to build bridges and break down walls (Honey & Henriquez, 1996). It provides a social context of learning that has been shown to have positive effects on students' reading, writing, and higher-order thinking skills (Riel, 1990).

In response to expectations and suggestions from the scientific community during the past five years, the Internet is gaining popularity among scholars as an important medium to deliver instructional materials in the academic world (Harrison & Stephen, 1996). Higher education is promoting and extending to students direct access to the Internet (Fetterman, 1996; Harasim, 1996; Liu, 1997; Schutte, 1997). Surveys have confirmed the increasing prevalence of the Internet and other online services in schools. Networks are being established so rapidly and are in such different forms that it is difficult to document their growth.

Although searching for information on the Internet using hypermedia link allows students to bring together various knowledge sources in appropriate and specific contexts, as Spiro, Feltovich, Jacobson, and Coulson (1992) asserted, it is not sufficient just to link everything with everything else; some structure that supports objectives is needed so that learners do not become lost in a confusing labyrinth of incidental or ad hoc connections. Several issues have been raised from the instructor's point of view, including issues concerning media richness, timely responsiveness, interaction with students, and organization of a computer-mediated on-line course (Hiltz, 1995). Some studies report the use of the Internet in K-12 schools (Neal 1995; Rogan, 1995; Center for Applied Special Technology, 1996), the use of the Internet in teacher training (Gallo & Horton, 1994) and the use of the Internet in teaching classes at a distance in higher education (Liu, 1997; Schutte, 1997). However, studies concerning the use of the Internet in higher education classrooms are scarce and none were found in which the instructor used the Internet as a substitute for lectures within close physical proximity to the students enrolled in the course. So I felt the need to study pedagogical aspects using a qualitative research that looks beyond mere test scores, that examines issues pertaining to curriculum and instruction designs, including teaching strategies exploring new issues and variables for experimental studies.

The purpose evolved naturally to fill a void in the literature and sought to answer questions left unanswered: to describe the instructor's rationale for using the Internet as a vehicle to deliver and learn mathematics, and to describe how mathematics graduate students reacted to the instruction delivered through the Internet. The research questions follow:

1. What was the instructor's rationale for using the Internet as a vehicle to deliver and learn mathematics?

2. How do students react to instruction delivered through the Internet?

3. Do students perceive the potential of the Internet as a vehicle to deliver and learn mathematics?

Methodology

The renewed interest in constructivism and anthropological studies and its methods of research are now recognized as relevant and useful for education. Lincoln and Guba (1985) argued that within naturalistic inquiry, the case study method is the best choice for reporting classroom observations. My interest was to allow the reader to experience being both inside (through exact quotes, transcriptions of documents) and outside (through observations) the student's frame of reference. Using a case study methodology I was primarily concerned with the process, rather than with outcomes or products. The interest was in understanding how students were making sense of their experiences. The primary instrument for data collection and analysis was myself, the researcher. Data were mediated through the researcher, rather than through inventories, questionnaires, or other instruments. Observations of ordinary activities and records of behavior took place in a natural setting, the classroom.

The setting for this study was a college classroom in a large university in the Southwest United States. The university decided to increase the quality and number of computers available to students. The class observations took place in a computer laboratory (see Appendix A), housed in the Mathematics Department. The laboratory was equipped with 20 UNIX terminals with quick connection to the Internet. The participants in this study were one instructor and nineteen graduate students. Eight of the students were U. S. -born and eleven were international students. These students were working towards their master's or doctoral degrees. One student dropped the course near the end of the semester. The international students came from Bulgaria, Canada, China, Germany, India, South Korea, Turkey, and Vietnam. The students met with the instructor, face-to-face, for three consecutive hours every Wednesday, during the Fall of 1996 in a mathematics computer laboratory.

The syllabus, the directions, the course content, the class activities, and the required course homework were available to the students through computers connected to the Internet using the World Wide Web as a hypertext interface. Students were able to interact with the published lessons and to link to remote sites. The instructor, using a special UNIX instruction, released the lessons on the Internet about five minutes before each class began. The primary emphasis of the course was the application of computer technology to facilitate the communication of mathematics. The syllabus included the study of the following topics: the UNIX operating system; using electronic mail; using MapleV, a calculus

package, to solve mathematical problems; using a mathematics editor, LaTeX, to produce complex mathematical essays; using search-engines, to seek for information on the Internet; creating a Web-page, to display academic and personal information. The role of the instructor was to facilitate the understanding of new concepts and help students with topics and problems they encountered, such as mathematics content problems or computer-related problems. The content of each published lesson prompted students to read the text, to search for information related to the subject presented, to use the available computer tools to accomplish assignments, and to turn in a final product by the end of that specific session.

Data were collected from observations made in the mathematics computer laboratory, through semistructured interviews using electronic-mail, and using open-ended interviews. Electronic-mail messages and the electronic-mail semi-structured interview, exchanged between the researcher and participants, were recorded as computer files, taking advantage of the saving capability of the software used (NetScape Navigator Gold 3. 01™). The conversation with the instructor was recorded using a tape recorder. During the period of the investigation participants were assigned the production of a home-page which included their personal and academic preferences. The instructor's home-page and the participants' home-page were captured as sources of evidence and considered in the same manner as information derived from interviews or observations (Erlandson et al., 1993).

Analysis

Summarized transcripts from personal interviews and e-mail interviews were examined for discrete statements and behaviors. All interview reconstructions were shared with the participants for clarification. The multiple data sources, peer debriefing, member checking, reflective journaling, and methodological notes provided triangulation. Coding of the data collected provided a means for locating the primary sources of information serving as an audit trail (Lincoln & Guba, 1985).

Using NetScape Navigator Gold 3. 01™

To categorize data, a process called "index cards" developed by Lincoln and Guba (1985), was followed. In this study the index cards were substituted by cells in a matrix using a software with hypertext capabilities. The software, NetScape Navigator Gold 3. 01™, which is distributed free for educational purposes, was found to be suitable to develop the analysis process.

First, the text to be analyzed was pasted on a new NetScape Navigator Gold 3. 01™ blank document. Second a unit (a sentence or a paragraph) from the text was highlighted and copied to the clipboard. The third step was to designate the highlighted unit as a "target" with a command found on the menu of the software. The software automatically creates a name for this target (part of the highlighted sentence). The fourth step consisted of pasting the sentence in a matrix cell (see Figure 1). The fifth

step consisted of highlighting the sentence pasted in the matrix cell and inserting a link to connect the sentence pasted in the matrix cell to the previous created target. The software automatically prompts target names already created. By clicking the desired target name, the link was established. This process allows the researcher to keep track of the context for the units. With this process each unit, by simply clicking on it, will be connected to the original text, which gives the possibility of checking for situational factors (who, what, when, where). The units were pasted in the cells with the intention of creating yet-to-be-named categories (Lincoln & Guba, 1985). This first unit represents the first entry in the first yet-to-be-named category.

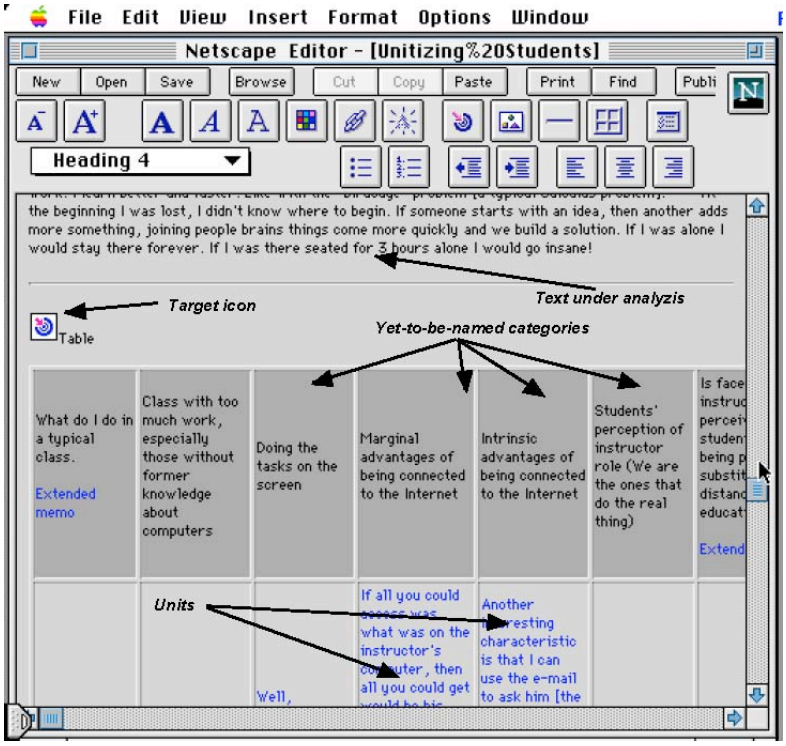

Figure 1. Snapshot of a computer screen displaying a NetScape Navigator Gold 3. 01™ file. The window displays part of the text under analysis, a target icon, and units pasted on cells of the matrix.

The process proceeded by selecting the second unit, reading it, and noting its contents. By making a determination on tacit or intuitive grounds whether this second unit is a "look /feel-alike" (Lincoln & Guba, 1985) with the first unit, the second unit was pasted under the first. Next, proceed to the third unit and repeat the process. If the second unit is not similar to the first, the second unit will be the first entry in the second yet-to-be-named category, which was placed in the next column of the matrix.

After some units had been processed it was found that some units neither were fitting any of the provisionally established categories nor seemed to form a new category. Other units were also

recognized as possibly irrelevant to the developing set. These units were placed into a miscellaneous column; they were retained for later review (Lincoln & Guba, 1985).

Once the units were organized in the matrix, it was felt that a printout would be a better visual help to check for the "look/feel-alike" criteria. The changes on the printout (moving units from one column to another or to the miscellaneous column) were transferred to the matrix in the computer. As the process continued new categories emerged rapidly at first, but the rate of emergence diminished after a number of units have been processed. After the "look/feel-alike" categories accumulated about five or six units, it was felt the need to write memos, which lead to the delineation of category properties and devising of a covering rule (Lincoln & Guba, 1985). These memos were created below the matrix; using the linking capabilities of the software, chosen sentences were linked to the original context.

The records of raw data (observation and interview notes), data reduction and analysis products (3x5 cards, computer files, peer debriefing notes), data reconstruction and synthesis products (grounded theory and data analysis sheets, reports), process notes (journal), information regarding an instrument developed (analysis procedure using HTML code) were kept and available for audit. Triangulation was used to ensure the veracity of the relationships. At this moment, a research peer and a professor unfamiliar with the study assisted in a negative case analysis (Erlandson et al., 1993). Member checking was continuous throughout the interviews. To do so, the researcher sent an electronic-mail message to each respondent which included the fully transcribed text of the interview with a request for their comments and revisions.

The context

The setting for this study was a college classroom in a large university in the southwest United States. The course is recommended as part of the requirements for all mathematics graduate students. The instructor used the Internet to publish the course content and simultaneously was available in face-to-face meetings to provide personal assistance. The students could access the course content as well as other sites using the Internet connection (see Figure 2).

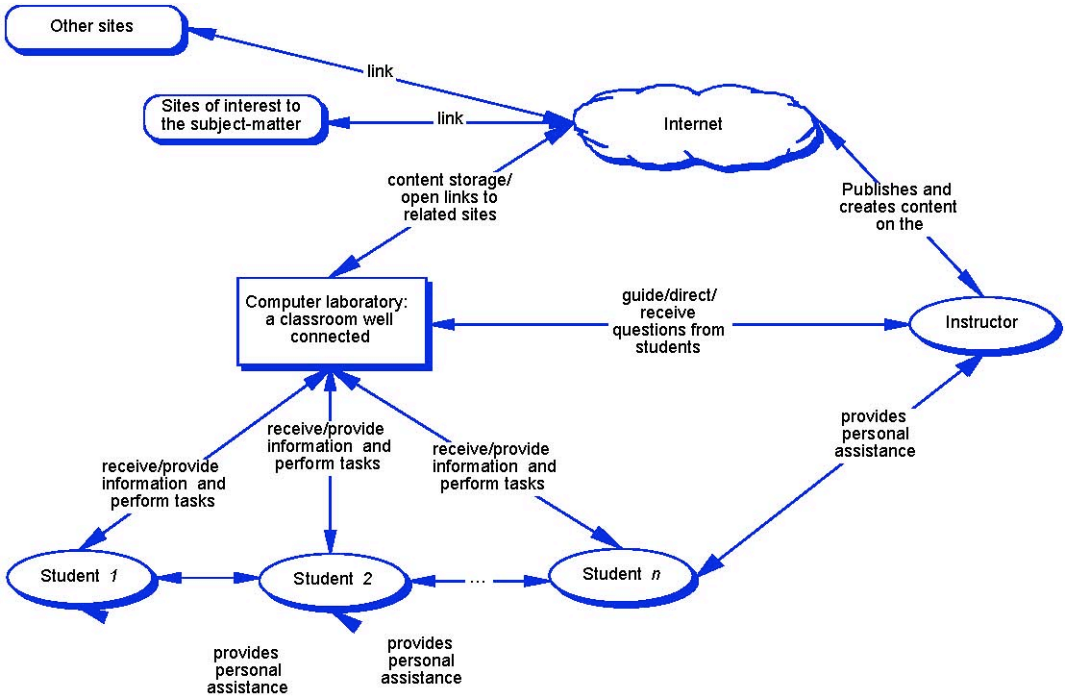

Figure 2. The instructor used the Internet to publish the course content. The instructor was always available to provide personal assistance in face-to-face meetings. Students could access the course content and also other sites at any time.

Lessons to Be Learned From the Outcomes

The reader should carefully note that these lessons are "not generalizations, but 'working hypotheses' that relate to an understanding of the site" (Lincoln & Guba, 1985, p. 362).

Following are displayed 4 tables that summarize the outcomes of this study.

Table 1. Reconstruction of the Instructor's Formal Interview

Question	Description
What was the instructor's rationale for using the Internet as a vehicle to deliver and learn mathematics?	The instructor's goal for the course focused on the students' ability to communicate mathematics using computer technology to prepare them not only during their graduate studies, but also for their future professional careers.
	To use computers effectively; students need to be active participants in the learning process or the computer will function as a distractor to the learning process. Information technology allows teachers to change their teaching style from the lecture method to a more student-interactive mode.
	Teachers need appropriate preparation to design and direct courses using the Internet to meet the challenge of working with a diverse student population.
	Face-to-face meetings (close physical proximity) have advantages: the instructor is apt to troubleshoot, and the students learn better from each other.

Table 2. Reconstruction of Students' Reactions to Use of the Internet as a Vehicle to Deliver Mathematics Instruction

Questions that supported the interviews	Description
How do students react to instruction delivered through the Internet?	Without the connection to the Internet the class would be uninteresting and limited by the instructor's choice of materials.
	Working with the computers was considered the "real thing", but face-to-face interaction was determined to be fundamental.
	The Mathematical Communication and Technology course was not as complex as first impressions suggested.
	Using computers connected to the Internet can also be a drawback.

Table 3. Reconstruction of Students' Responses to the Potential Use of the Internet.

Questions that supported the interviews	Description
Do students perceive the potential of the Internet as a vehicle to deliver and learn mathematics?	Advantages of being connected to the Internet in the classroom included the students' ability to: (a) e-mail the instructor at any time; (b) concentrate on the subject matter instead of taking notes; (c) look back at the work from previous classes and access it at any time from any place; (d) work at their own pace; (e) participate in classroom interactions; (f) learn by doing; (g) receive individual help from the instructor without holding the whole class back; and (h) access sites right-on-the-spot which are related to the assignments.

Suggestions for Further Research

Figuring out what the Internet in classroom contexts is good for certainly fits with the assertion by Kerr (1996, p. 227): ". . we view the future through a rear-view mirror--a pastiche of expectations, images, and judgments that derives from our past experiences with similar media, but which may not be adequate to the capabilities and distinctive feature of new information technology forms. " Because we are experiencing the emergence of new applications of information technology, the only answer the researcher found was to raise additional questions.

This investigation gave birth to several issues that were not included in the scope of this study. The first involves the importance given by students to having the lessons published on the Internet so they could go back to reread material not well understood. Is this phenomenon similar or not to the use of a textbook? Books also have this feature; books can be carried to any place, therefore why do students

give so much value to this use of the Internet? Another issue to consider is the transferability of this methodology of instruction to other levels of education. How does the use of the Internet for teaching and learning at the graduate level apply to other levels of education? Would we get similar responses from a class of elementary pre-service students as reported in this study? A third topic is related to the nature of the discipline. How are the classes conveyed through the Internet dependent on the nature of the discipline? Would this technique work just as successfully in an English class, or in a science class? A fourth topic concerns the performance of the computers and students' learning. How is the performance of the computers (how they are used in specific teaching and learning situations) contributing to the success of students' learning? Would a different platform provide the same ease of access as did the computers in this study? A fifth issue to consider for future research is related to the quality of materials published on the Internet. How do the students judge the quality of the information available on the Internet and how does this impact what they learn? What impact does the use of an evaluation standard have on the information the students use from the Internet? A sixth issue regards time management when "surfing the Net. " How do they self monitor their time so they can complete their assignments by the stated deadlines? How does the unrestricted access to the Internet impact different personalities or academic abilities of students?

Further Remarks

Learning does not occur in isolation; the context of learning, related to the student, the instructor, and the situation in which the learning takes place, influences learning (Hativa & Lesgold, 1996). The major theme of Vygotsky's (1978) theoretical framework was that social interaction plays a fundamental role in the development of cognition. As Vygotsky (1978) insisted, psychological development cannot and should not be seen as proceeding only within individuals. Instead, it is fundamentally and necessarily a social phenomenon, one that must involve at least two parties. Education is thus to be thought of as a social phenomenon, a process of growth and change for all involved (Rubtsov & Margolis, 1996). According to Rubtsov and Margolis (1996), computers offer special and powerful new ways for learners and instructors to engage in activity together. Computers are not merely a convenient device for conveying information, but a new cultural tool which may facilitate instruction and learning.

In this case study was reported a class using the Internet for teaching and learning shifting the focus from knowledge transmission to knowledge building (Vygotsky, 1978). The students were actively engaged in constructing their own knowledge, performing activities that called for understanding, connecting, gathering, and selecting information, generating and testing hypotheses, and generating inferences (Salomon & Perkins, 1996). Students had opportunities to explore new information, to interact and collaborate with other students. The instructor did not remove himself from the educational process; his role had shifted from being the deliverer of instruction to being the creator of learning experiences for the students. He acted as an academic guide, enabling distributed access to experts, archival resources, authentic environments, and shared investigations. One of his goals was

to help students learn to communicate mathematics clearly using the tools available on the computers. This was combined with a concerted effort to bring the students off the computer and involve them in discussions to build a sense of community.

The students were the ones who were actively constructing their own knowledge, with the appropriate support from the instructor and from different resources, such as partners, on-line information, and textbooks. According to Vygotsky (1978), the range of skills that can be developed with adult guidance or peer collaboration exceeds what can be attained alone. Close physical proximity with the instructor and other students was imperative for the success of those involved in the course. Their venue was the world but their home base was the instructor and their classmates. Contact with an instructor and peers and the sense of community was regularly observed in the mathematical communication and technology course, allowing the researcher to conclude that the well-connected classroom will still be the paramount center for learning.

Students used their own knowledge and the information they gathered on the Internet to generate solutions to the problems. The solutions to the problems presented in class were dynamic because they evolved as the students gained more and more knowledge. In fact the computers became the tools for enhancing problem solving, critical thinking, and communication skills. We are on the verge of an explosion of the use of the Internet in educational settings. This case study presented one example of the power of the Internet as it can be incorporated into the classroom.

The context of this case study was very peculiar, the participants were unique with notable cultural and individual background diversity, the instructor demonstrated strong beliefs about the method of instruction used, and the case was singular. Despite great variation, some aspects of what occurred were quite generic, and they may apply cross-culturally and across human history to all teaching situations. There was an instructor, students, subject-matter, presentations, evaluation, homework, debate, all occurring inside a classroom. The transferability is left to the judgment of the reader.

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