Collaboration in Wireless Learning Networks

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Abstract

Wireless computing is becoming an integral component of learning environments in higher education and in the world of work, particularly with the increasing number of "laptop universities" and distributed learning communities. However, little research has been conducted on how wireless computing affects learning experiences or learning environments. In light of extensive research revealing the transformative impact of technology on learning, we can assume that mobile and wireless computing could significantly transform how students learn, the content of courses, learning-related practices, classroom dynamics and relationships among students and faculty. These technologies will bring about fundamental changes in the ways that the university creates and disseminates ideas, knowledge and understanding.

Introduction

Computer supported collaborative learning

The study described here has been guided in part by research that has focused on the sociological implications of pervasive communication tools on many aspects of life, including work and education. One such area is Computer Supported Collaborative Learning (CSCL). CSCL is defined as a computer-based network system that supports group work in a common task and provides a shared interface for groups to work with [5]. Collaborative Learning is defined as groups working together for a common purpose [19]. The benefits of collaborative learning are widely recognized [1,4,15]. The Internet and World Wide Web are well suited for hosting CSCL environments [11]. Many CSCL systems designed for group support on projects and communication are currently available [18,16]. Common characteristics include the ability of students to contribute to an existing database of peer work, as well as the option of commenting on the contributions of others. Research has shown that moderated discussions or structured interactions are more effective than un-moderated or undirected interaction [12,14,17]. With the addition of wireless, computing technology comes increased support for the CSCL environment, due to sustained interaction and the resulting creation of closer interpersonal bonds [10,13]. This in turn facilitates a wide sharing of knowledge and the creation of a community of learners sharing common goals [3].

Educational researchers [2,21], argue that students learn best when given the opportunity to learn skills and theories in the context in which they are used, then construct their interpretations of a subject and communicate those understandings to others. Wireless computer-mediated learning environments may support this constructive learning process by helping students find and organize information in context, construct their understandings, and communicate those understandings to others. Wireless computers also support "just-in-time" learning, an adoption by educators of successful industry technique that involves delivery of parts and finished products at precisely the time in which they are needed [20]. Transferred to education, students may receive context –appropriate information or complete a skill-building task, at the most appropriate teachable moment.

The work reported here in part, is a natural extension of our earlier work on the development of computer supported learning environments [7,8,9]. Here we hypothesized that compared with a more traditional approach to classroom teaching, a collaborative learning environment would encourage the use of more social computing among students and group members. Social computing is defined here as the use of social communicative tools such as Email, Instant Messaging, and CHAT. It further encompasses where, when, and with whom this computing occurs. We hypothesized that the social network within groups would become increasingly cohesive as work on the group portal projects became the focus of their classroom experience. This cohesiveness was operationalized as an increase in social communication among group members with a concomitant decrease in communication with members outside their individualized group. The "where" and "when" aspects are defined in terms of whether or not students accessed the network to do their work. Thus, we further hypothesized that

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students needing to collaborate would utilize the availability of the network connections at home and on campus more than the comparison group, and that this behavior would increase over the course of the semester.

For three semesters since this initial research effort, we have continued to gather data from Communication students. This additional data has helped to round out some of the preliminary findings as well as provide fertile ground for follow-up research.

Divided Attention

While technology holds the promise of improving traditional pedagogical approaches in myriad ways, there is the concurrent issue of its potential distraction in toto, or at the very least that students are processing information at increasingly superficial levels while they attempt to juggle tasks, switching attention from one to the other. Both self-report data and classroom observation indicated to us that students were in fact highly distracted by the laptops, and specifically the allure of network access. The simultaneous engagement in collaborative learning activities and *learning* may offset the potential benefits that these environments are intended to promote. Thus, we investigated how learning is effected by multitasking during a typical class lecture in the Communications course we describe below. We hypothesized that, compared to a control group who listened to the exact same lecture but were not allowed to use their laptops during the lecture, students who were able to freely use their computers during class would exhibit poorer memory performance on a subsequent surprise quiz. In addition, we attempt to explore differences in performance by "browsing style" in an attempt to develop a profile of users that might be better or worse at performing multiple tasks simultaneously. In this work we present support for that hypothesis.

Method

As part of a grant from Intel Corporation, students in an upper level Computer Science course (hereafter referred to as CS) and a Communications course (hereafter referred to as Comm440) were issued a Dell Laptop (Dell Latitude, CPt), to be used throughout the semester. Across campus a series of wireless transceivers (access points) provided the infrastructure for the Nomad Network. Students were asked to conduct their computing activities through a proxy server so that their information seeking and tool use (Email, discussion board participation, URL visits, etc.) could be monitored throughout the semester. All students were fully informed regarding what their participation would entail, and consent forms were obtained prior to their participation.

In addition to tracking their computing on the network, students were asked to keep journals and complete surveys and questionnaires regarding various aspects of their computing habits. Thus, our data collection efforts include both subjective self-report measures, as well as objective, behavioral data provided by the tracking methods.

Classroom structure

The Comm440 class was designed and structure to emulate the principles of CMC and CMCL environments. The format of the class meeting was a combination of open discussion and lecture. The function of the lecture was to mediate and facilitate discussion and group assignments. Less emphasis was place on traditional methods/roles of teaching and the dissemination of information per se.

For the class a Website was developed which functioned as a portal where students could find specific information about the class, as well as posted contributions by either teaching staff or other students. These posted contributions were information about topics related to the class and/or popular media issues of relevancy and could take the form of comments, references, and URL recommendations.

Students also had access to a class listserv and bulletin board in which their on-line participation was required throughout the semester. The class portal also included web folders for students and groups to store and share information. These folders provided space on the class server designed to provide a central location for students to leave and share documents and objects.

Early in the semester the class was divided into six groups, each responsible for the development and implementation of a web-based portal. One student in each group was arbitrarily designated portal leader, and the design and content decisions related to the project were left entirely to the group. The final project was not due until the end of the semester; presentations were held during the last two days of class meeting.

Unlike the Comm440 class, the context of the CS class was more traditional in format with structured lectures and exams. While not forbidden of course, group work and collaboration were not specifically designed into the goals of the course.

Both classes had equal access to the wireless network connections across campus that afforded students ready use of both campus Email and Internet connection.

Divided attention

As previously mentioned, we were equally interested in what effects the very nature of collaborative activities might have on the learning process. During one lecture, half of the students left the classroom to take part in a lab exercise in a neighboring classroom. The remaining half of the students were exposed to a typical lecture, and encouraged to use their laptops as usual during the lecture. When the lecture ended, these students switched classrooms with the other half of the class, who then went into the lecture hall and heard the identical lecture. The only difference between the two groups was that during the second repetition of the lecture, students were told to close their laptops. Both groups of students were tested immediately following the lecture.

The surprise quiz consisted of 20 questions on the lecture content. Half of the questions were multiple choice (recognition) questions, while the other half were short answer (recall) questions. All students finished the test in approximately ten minutes, after which they were debriefed and thanked for their participation.

The replication study took place two months later. Students who served as controls in the first experiment (Closed laptop condition) participated as experimental subjects in the replication study (Open laptop condition) and vice versa.

Results

Social Computing

At the beginning and end of the semester, we asked students to fill out questionnaires which queried them about what they anticipated would be the primary use of their laptops (in the beginning of the semester), and what they ultimately experienced as the primary function of their computers throughout the semester (at the end of the course). Their open-ended responses were then analyzed via a content analysis software package, CATPAC. The output provided by this analysis is a perceptual map, in which objects are represented by points in a spatial model in such a way that features of the data are revealed in the geometrical relations among points. This differs from simple uni-dimensional scales in that the points are allowed to assume positions within a two-dimensional plane, or three or four-dimensional space.

When interpreting perceptual maps, the fundamental concept involved is that of psychological distance. The axes on the map outputs are arbitrary. By treating psychological distances like physical distances, we are able to create a map of the way people structure similarities or differences among attitudes in a given domain. Short distance represents similarity and larger distances represent disagreement.

Figure 1.

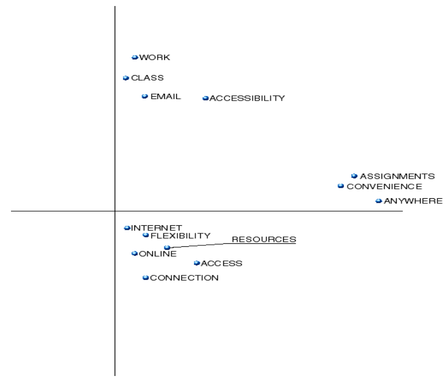
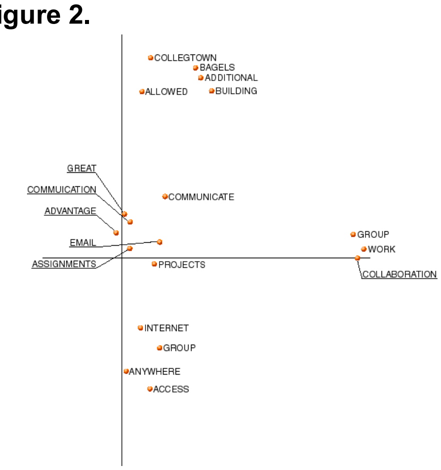


Figure 1 depicts the results of the content analysis performed on responses regarding anticipated advantages of mobile computers. Three distinct clusters, or concepts, emerge. Centrally located above the x-axis, *class, work, email*, and *accessibility* group together. This summarizes the value of mobile computers as a tool for class work. Below, *Internet access, on-line resources, flexibility* and *connection* group together. This cluster is specifically focusing on networked resource availability. Finally, *assignments, convenience*, and *anywhere* cluster on the right. The perceptual map efficiently conveys three unique perceived benefits related to mobile computing. It is significant to note that, at this point in the semester, the Internet as an information and research tool is conceptually central in relationship to perceived advantages associated with mobile computing.

Figure 2.



Comparing these findings to the results of perceived advantages gathered at the end of the semester, the perceptual map, while similar to the results gathered from the beginning of the semester, contains notable differences. Figure 2

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shows the cluster above the x-axis addresses excitement regarding the expansion of the network to College Town Bagels, a popular student haunt located on the fringe of campus. Below that cluster, centrally located on the map, is a cluster containing *great, advantage, communicate, assignments, email,* and *projects.* Most significant is the observation that Internet access, conceptualized as a resource, has become less vital, visually confirmed by its physical location on the perceptual map. Instead, the map depicts social and communication advantages of mobile computers and their use to accomplish class related tasks. The strength mobile computers have in facilitating social relationships within a higher-education context is emphasized. Walther (1992) discusses the ability people have to adapt a medium to fulfill social objectives. It is apparent the students, through the course of the semester, discovered this technology's utility as a social channel, independent from a strictly academic tool.

As indicated earlier, part of our definition of *social computing* included where and when students were engaging in the use of more social forms of computing such as Email, Instant Messaging and Chat. The wireless network allowed students access to these tools in numerous locations on campus, and even a few locations *off* campus toward the *end* of the semester. We looked at the amount of Web-based messaging that occurred as a percentage of the total URLs browsed both on and off the network for each class over time (which we will refer to as "messaging rate")

To analyze these data, we ran a Repeated Measures (or "Longitudinal") Logistic analysis in SAS (using PROC GENMOD). Independent variables were Course, Network, and Time-period; the binary dependent variable was Messaging (i.e., either a URL represented Web-based messaging or it didn't). Partially due to our large sample size (N=457,503), every main effect, two-way interaction and three-way interaction was statistically significant at $\alpha = .05$.

On the whole, Com 440 students were over 3 times as likely (3.16) to be doing Web-based messaging compared to CS 502 students (log estimate=1.1513, $Z=3.99\times10^{15}$, $p<.0001$). Focusing on the *wireless* network reveals a statistically significant *increase* in Web-based messaging for Comm 440 students from Time-period 1 to 2 (2.09%→3.25%) as a percentage of their total URLs, in parallel with a statistically significant *decrease* for CS 502 students (2.16%→ 1.01%). It is unclear whether differences in student populations or course format may have contributed to these reverse patterns. When *not* on the wireless network, patterns of Web-based messaging were quite similar between the Comm 440 and CS 502 groups, with both increasing slightly percentage-wise from Time-period 1 to 2 (5.85%→6.34% and 1.93%→2.10% respectively).

In summary, difference in course format between the CS and Comm440 courses, as well as the differential impact of being on the wireless network versus not being on it, appear to explain some of the differences observed in the prevalence and patterns of Web-based messaging within and between the two student groups. This last analysis, however, suggests that characteristics of the students themselves (i.e. individual differences) can also have a significant impact on the presence of social computing in mobile computing context.

Information Seeking

In this analysis we include comparisons between the CS and Comm440 class on how they found useful URL's. Within the Comm440 class we have also analyzed the number of URL's recommended and subsequently "hit" by other students over time. While these analyses certainly contain a social element, and thus might have been incorporated in the proceeding section (social navigation), we felt the intent of the behavior was sufficiently different, or at least the primary purpose was to relay sources of information, albeit via some social venue.

Several survey questions we gave to students in both the Computer Science course and the Communications course queried students about how they discovered URLs that, once visited, were determined to be useful to them. As part of another study on social navigation, a subsection of the results are relevant here also. Interestingly, Communication students reported finding most of their best URLs as a result of *social* methods of relaying and exchanging data, namely Email, discussion boards, Instant Messaging, and chat clients. Computer Science students indicated that the URLs they found most useful were discovered primarily by *non-social* means, such as search engines, and other Web sites they visited. A chi square analysis of this data revealed these self-reported modes of information exchange were significantly different.

Within the Comm 440 class we looked at discussion board threads and listserv for explicit recommendations of URLs posted by students and their subsequent "hits" by others in the class. The findings are represented in Table 1.

Table 1.

Time	Number Recommended	Number of Hits
1	27	3849
2	11	963
3	5	85
4	6	0
5	0	0
Note: Time blocks represent 22 days.		

At the outset of the semester, students used this set of communication tools frequently. The discussion board and listserv functioned well for 'umbrella' type communication, conveying content of interest to the entire class. When comparing the number of URLs hit before and after recommendation, a significant relationship was found (M= 50.55, SD= 276.85), t (30)= 2.59, p= .015. This is clear evidence that when students posted a URL of interest to either the discussion board or listserv, other students in the social network of the class followed and explored the referred URL.

Indirect evidence from email traffic patterns suggests that the decline in URL recommendations may have occurred as a result of increased group cohesiveness. Although the portal projects were assigned at the beginning of the semester, class observations indicate groups did not begin serious work on them until past the second half of the semester. As the semester progressed, and as communication between students became increasingly task oriented, the tools designed for larger audiences were replaced with more personal, individual communication tools, namely email and independent discussion boards. Three of the six portal groups implemented discussion boards into their portal design.

Email communication was analyzed across all groups over time using a 2 (Time) X 2(Within group, Outside group) repeated measures ANOVA. What emerged from this data was a significant main effect of Time F(1,27) = 5.629,p<.05, and a near significant interaction effect between Time and message type (within or outside the group) F(1,27)=3.714, p<.065). Interestingly, emails among group members from time 1 to time 2 did not change, but emails to and from other members of the class decreased dramatically

That communication outside their groups dropped off was not surprising. What was somewhat counterintuitive was that within the groups emails did not change over time. We decided to run another analyses to see if we could discern some explanation for this. In the second analysis we analyzed only emails from group leaders to other members of their group and to members outside their group. Though no effect was significant due to the very small N (5), the opposite pattern emerged. Emails to members within their group increased sharply, nearly doubling between time 1 and time 2, while communication with members of the class outside their group decreased to nearly none.

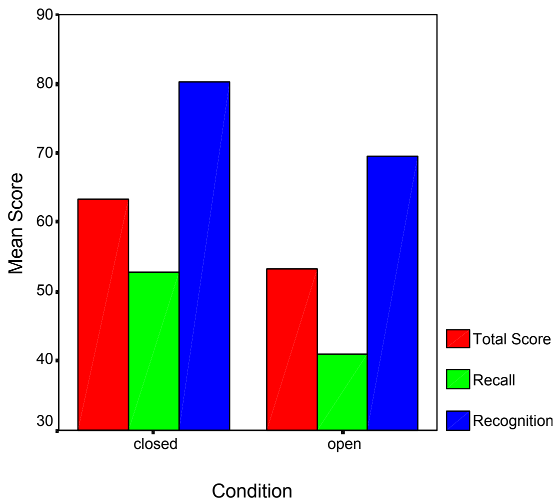
It appears that their role as group leaders was best served by the social communicative benefits of email (e.g., being able to copy the entire group the same message). Again, though these trends are only suggestive, the patterns that emerge indicate that tool use was differentially affected by the context within the group, namely the role one assumes or is assigned.

Multitasking in the classroom

The surprise quizes were corrected and given three scores; a total score which included the percent correct out of the total number of questions, a recall score and a recognition score, which were the proportion correct out of the total of ten like questions. The data are first reported for the initial study, and then the replication study.

The initial data were first analyzed using a one-way ANOVA with condition entered as a between subjects variable. The results of this analysis revealed a significant effect of condition on total and recall test score measures, with students in the open laptop condition performing significantly poorer than those in the closed laptop condition (F (1,43) = 4.42, p. <.04; F(1,43) = 5.00, p.<.03, respectively). Differences between the two groups on recognition scores approached significance, F (1,43) = 3.45, p.< .07. Figure 3 graphically represents the differences between these two conditions.

Figure 3.



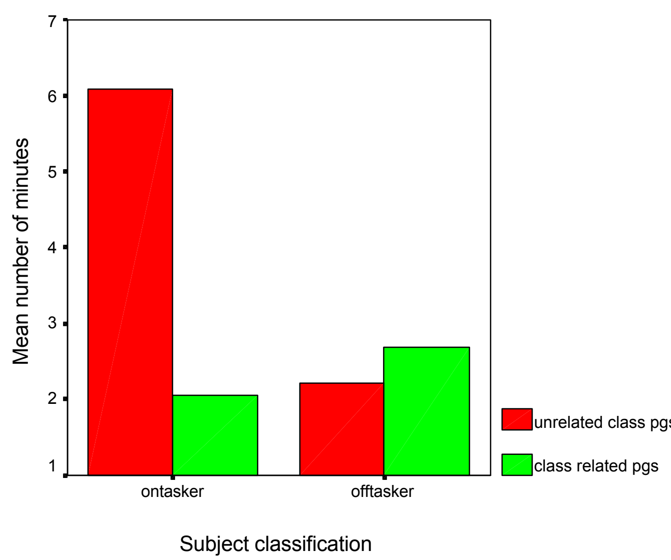
The replication data were scored and analyzed in exactly the same manner. Again, the results of this analysis revealed a significant effect of condition on total and recall test scores in the same direction (F (1,20) = 10.70, p< .004; F (1,20) = 6.13. p< .02 respectively). Again the difference between the open and closed laptop conditions neared significance on recognition scores, F (1,20) = 2.80, p< .11. Finally, we were interested in whether the content of what student's were browsing during the lectures impacted their performance on the subsequent memory test. We were able to extract their on-line browsing behavior for those class periods and code them according to whether the content was class related or unrelated depending on the lecture content. From this log data we were also able to calculate the amount of time spent on class related and unrelated pages, the overall amount of time spent on-line, the amount of time spent per page, etc. Here, we are obviously only interested in those students serving in the open laptop condition.

We first calculated the proportion of time each student spent on class related and unrelated sites. This was simply their overall times spent online during those class periods divided by the amount of time spent browsing related and unrelated pages. When these totals were correlated with later test scores, an interesting, and again, counterintuitive relationship emerged; for recall scores, the more time spent browsing class related pages resulted in lower recall scores (r = -.516, p. < 02), and conversely, when students spent more time browsing class unrelated pages they did better on recall questions (r = .510, p. <.03).

In other research [6], we found a significant relationship between browsing efficiency and class performance. Thus, we thought that the above results might reflect some inherent differences in browsing "styles". To explore this relationship further, we classified students as primarily "ontaskers" or "offtaskers" if the proportion of their time spent online was at least 50% on or off task. Thus, a person who spent 65% of the class period browsing class related pages he would be classified as an "ontasker". If, on the other hand a student spent only 48% of their time on class related pages, she was classified as an "offtasker". In so doing, we could investigate differences between these two groups when engaged in both class related and unrelated activities.

The mean number of minutes spent on class related and unrelated pages were calculated for each student by divided the number of related and unrelated pages by the number of minutes spent on each kind of page. An ANOVA yielded a significant main effect of task classification for the mean number of minutes spent on class unrelated pages F(1,14) =11.17, p<.005). Students classified as "ontaskers" spent significantly more time on class unrelated pages than "offtaskers". When students that spent the majority of their time *on* task, went *off* task they spent an inordinate amount of time on those class unrelated pages. Those students that spent the majority of their time off task during the entire lecture spent an equivalent amount of time on class related and unrelated pages. (See Figure 4).

Figure 4.



As it turns out, "ontaskers' did worse on all three measures of performance, and significantly so on their total scores F (1.17) = 4.85, p.<04). Figure 7 graphically depicts these differences. Thus, it appears that the negative correlation between the proportion of time spent on class related sites and

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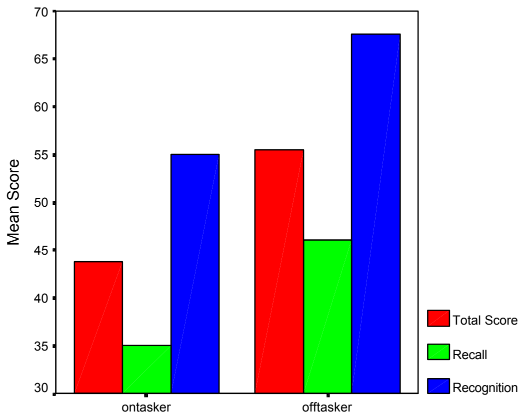
performance is mediated by ones ability monitor or balance their browsing behaviors.

Figure 5.



Discussion

The work reported here represents an overview of computing behavior observed, tracked, and studied over the course of almost two years. Several variables mediated tool use and changes in computing behavior; these include community dynamics, time, and individual characteristics of the user. We think, taken as a whole, a couple of important themes emerge. The essence of these themes can inform curriculum change to better implement technologies in learning environments.

First, computing behavior is, and will be, influenced by classroom structure. As we saw here, students in the Comm 440 class used their laptops primarily as social communication tools, both in the relaying of information, and asynchronous communication. As the structure within that class transitioned from the "class community" to the "group community", their subsequent communications reflected that change, as evidenced by the decrease in emails to members outside their immediate work group.

This change in behavior reflects yet a larger principle or theme; computing behavior is dynamic, and will evolve to accommodate the changing needs and demands of the conditions or situation it occurs in. Relatedly, there is at least preliminary evidence reported here, that computing behavior differs as a function of individual characteristics such as discipline. In other work we have done, other individual differences such as ethnicity, gender, experience, and personality variables have also indicated differential effects [9]. Thus, blanket statements and practices will likely not promote effective uses of technologies in the classroom. We need to more fully explore these variables systematically, in order to understand their mediating effects on various outcomes.

The data here suggest that there may also be cognitive dispositions, which may be endogenous to the individual user, the situation, or both. When browsing behavior was quantified and/or individuals were characterized in terms of their browsing behavior, certain stylistic features emerged. In separate investigations, shorter, staccato-like browsing did not produce the debilitating effects on performance that longer, more sustained browsing resulted in. We think this is an important finding that has widespread applied implications for using the Internet to supplement learning and setting boundaries for tool use in the classroom. This finding is also relevant for basic theoretical research in the areas of cognitive science, perceptual and personality psychology, and education psychology.

Computing behavior then, like any behavior, does not occur in a vacuum. Systematic investigation of the antecedents and consequences of these behaviors is imperative if we ever hope to develop meaningful curriculum that integrates technologies in ways that facilitate the learning experience.

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