This article presents a system designed to support note taking by students on wirelessly connected PDAs in a classroom. The system leverages the devices’ wireless connectivity to allow students to share their notes in real time and quickly reuse words from their fellow note takers. In addition, presentation material such as PowerPoint slides is also extracted when presented by the instructor, giving students further means for reusing words. We describe the system and report our findings on an initial user study where the system was used for four months during a graduate level course.

There is a tremendous opportunity in using Personal Digital Assistants (PDAs) and wireless networking technology in education and learning (Soloway et al., 2001). For example, PDAs have been used to increase participation in large classrooms (Ratto, Shapiro, Troung, & Griswold, 2003), or enable users to annotate slides remotely (Anderson, Anderson, Hoyer, & Wolfman, 2004). In our ongoing work, we are interested in
supporting note taking because it is a most common activity for students. Unfortunately, text input on PDAs remains a challenge for novice or casual users. Soft-keyboards displayed on the PDA screen, or alternative text entry methods such as Graffiti are slow for text input and hard to learn. Many systems have been designed to improve the speed of text entry (Darrah, Witten, & James, 1990, Masui, 1998, MacKenzie & Soukoreff, 2002).

Instead of developing yet another text entry mechanism, we make note taking more efficient and enjoyable on a PDA by leveraging the connectivity of the devices: the system enables sharing of notes in real-time. At any time, a user can quickly reuse notes or words already entered by fellow note takers with a single tap on the words. The selected word is added to the current note, thus saving time and effort required to enter it (Figure 1).

**Figure 1.** The Shared Text Input system accessed from a PDA. Users can quickly type in notes by reusing words from the slide image (bottom) or from the notes taken by their friends (middle). Users simply tap the desired word to paste it into their notes.
In addition to improving efficiency, circulating what others are writing, makes note taking more lively and increases awareness, adding to the benefits of sharing notes after a meeting (Davis, 1999). To provide more choices and help users get started, the system also sends the images and text of the slides as the instructor projects them. Again, users can quickly tap on the slide image to reuse words from the slide into their notes. Because many users already take notes on laptops, the Shared Text Input system is also accessible from laptop computers (Figure 2). This provides two benefits. First, many more users get a chance to participate in the note taking activity. Second, notes taken on laptops provide a valuable source of words for PDA users since the laptop users can type much faster by using their full-size keyboards.

We bring two main contributions. First, the study shows that sharing text in real time improves the efficiency of taking notes on PDAs. Students can reuse text from the slide image as well as from the shared text entered by other note takers. Secondly, the study shows that many students value the awareness and communication aspects of the system. Many students do not
retype a note already written by a fellow note taker. Many students also use the system as a chat tool to communicate quietly during the lecture, supplementing the information presented by the instructor. However, some students also felt information overload as they try to pay attention to both the lecture and the notes showing up on their PDA.

BACKGROUND

PDA and wireless networking technologies have become immensely successful in recent years. In addition to general use, there are significant opportunities for using them in education and learning. Soloway et al. (2001) made a case for the use of PDAs in K–12 education in schools, promoting the idea of one PDA per student. The opportunity provided by wireless Internet learning devices for K–12 learning and education was further explored by Roschelle and Pea (2002). Several research prototypes have already been deployed, not only involving PDAs but also tablets PCs. Ultimately, all systems try to improve the classroom experience.

In ActiveClass (Ratto et al., 2003), the goal is to augment participation in classroom settings when class size and diversity tend to create passive modes of learning. Students can ask questions from their PDAs and vote on other students’ questions. At any time, the instructor can see the list of questions and choose to address the most popular ones. Unlike our system, ActiveClass does not support shared note taking. In ActiveClass, some students complained that their notes taken on paper could not be synchronized with the questions and answers brought up during the class. By integrating both, our system has the potential to solve that problem.

Pebbles (Myers, 2001) allows students to annotate presentation slides in real time by inking on their PDAs, augmenting opportunities for students to ask questions by directly leaving comments or questions on the projected slide. Students cannot take personal notes and notes are not persistent but rather ephemeral traces of ink used for real-time annotation of slides. In our system, the notes are persistent and available to students during and after the class.
Livenotes (Kam, Tarshish, Glaser, Iles, & Canny, 2002) is essentially a shared whiteboard application that uses wireless communication and pen-based computing to allow a real-time conversation within a small group of students. Students record handwritten notes on their respective tablets, such that the same notes appear in real time on the tablets of their group members who are also running the software.

Classroom Presenter (Anderson et al., 2004) focuses on providing the instructor with tools to annotate his or her slides in real-time from a Tablet-PC. The instructor can draw the attention of students on specific points and better explain concepts not originally shown on the prepared material by scribbling diagrams and adding text. This system does not support shared note taking or annotations by students.

With NotePals (Davis et al., 1999), students take their notes in digital ink on a PDA, and the notes are combined automatically into a shared document after the class. This system spreads note taking responsibility across the group, and group members need only PDAs during their meetings. However, NotePals only allows note sharing after the class and it is not possible to reuse material from others during the class.

Debbie (Berque, Brinkman, Geringer, & Maynor, 2002) allows the students and instructor in a pen-based electronic classroom to share written information during class. The instructor can draw freehand sketches directly on the surface of the instructor-station’s video-tablet or electronic whiteboard. Each student can write freehand on his or her display to make private annotations to the instructor’s material. The instructor can import portions of a student’s workspace for viewing and discussion by the entire class. The instructor can also ask the students to sketch answers to problems that are related to the topic discussed. Because of this, class sessions tend to unfold as highly interactive activities.

StuPad (Truong, Abowd, Gregory, & Brotherton, 1999) focuses on allowing students to add personal annotations on top of the slides being presented by the instructor. The underlying capture system is eClass (formerly Classroom 2000). One motivation of StuPad is to reduce the need for students to copy off notes already displayed by the instructor, so that students can better concentrate on the lecture. However, personal annotations are introduced so that students can still take notes for individual processing.
SYSTEM IMPLEMENTATION AND TECHNOLOGY

Technology Overview

Our note taking system is implemented in a client server mode. The client, implemented as a Java applet, enables students to enter notes from either a PocketPC PDA or a laptop. The server, implemented using Java servlets served by Tomcat from Apache, enables the distribution of instructor’s slides to the students and sharing of notes among students. Notes are stored by the server in a MySQL database for later retrieval. The client applets connect to the server with a socket, allowing the server to push new notes to clients. This synchronous communication makes sure that words can be reused as soon as other users make them available, making the system more useful than if the user had to manually refresh the list by pulling new notes from the server.

In addition to the server and java applets, a real-time slide extractor module has been implemented in Visual Basic as a DLL add-on for Microsoft PowerPoint and installed on the instructor’s laptop. When the instructor opens a PowerPoint file and presents it, the DLL receives an event from PowerPoint and is able to extract the JPEG image of the slide. More importantly, the DLL can query the PowerPoint Object Model to extract all textual elements and their location on the slide. When a user taps or clicks on a slide image, the system is retrieves the word located underneath. The DLL sends the image, the words and their bounding boxes to the server through a standard HTTP POST call.

Experiment Settings

We deployed the system at the Naval Postgraduate School in Monterey, CA in a class of 20 students during a four-month period from March to June 2003. Fifteen students chose to participate in our. In the experiment, the classroom had 802.11b WIFI coverage available to all students using the PDAs and laptops. The instructor presented his slides using PowerPoint from a laptop also connected to the network with WIFI.
All of the 15 students who volunteered to participate in the experiment were loaned HP-iPAQs equipped with 802.11b wireless cards for the duration of the experiment. Within three weeks of starting the experiment, five users had switched back to using their own laptop instead of the PDAs. Some students said that they had switched because they could not keep the PDA after the experiment. However, these students still accessed the Note Taking system from their laptop. Others users used their laptops but discontinued using our system because notes were not stored locally and they did not have access to the Internet from their home. All of the users accessed the system through a Java applet running in their web-browsers, as shown in Figures 1 and 2. Based on students’ feedback, we modified the laptop version, rearranging the control and making them larger, as shown in Figure 2. Many students also complained that only sentences could be reused from the slide image, not individual words. We modified the module that extracts text from PowerPoint by extracting individual words instead of individual lines of text.

Before starting a notes session, users are presented with a list of all registered users. Individuals can choose with whom they want to share notes. This feature was requested by several users prior to deployment. It allows users to work in study group and not share their notes with all connected students.

Taking Notes

To enter a note, the user simply types in the desired text in the text box located at the top and clicks either the “perso,” “chat,” or “public” button. Clicking “perso” creates a personal note that no other user will be able to see, even after the class. “Chat” creates a note like in a standard chat application, with the text prefixed with the username. Only users selected on the logging screen will receive the chat note. “Public” works like “chat” except that the username is not added.

As mentioned previously, a unique characteristic of our system is that users can reuse a word from the slide image or the shared text area with a single tap. The system automatically inserts this word into the note at the current insertion point. This is similar to doing a copy and paste, but is much faster and well-suited to stylus input.
To help users select words from the scaled-down version of the slide, the system zooms in on the word located under the stylus as the user moves the stylus. When the user finds the correct word, he/she lifts the stylus and this word is added to the note.

**Note Retrieval After the Class**

An important aspect of note taking is retrieving the notes after the class. This is supported by a set of Java Server Pages (JSPs) that allow students to visualize their notes and the notes taken by their friends from a standard Web browser (Figure 3). After users choose a date, the system generates a web page displaying the list of notes ordered by time and grouped around slides. For each group, this user’s notes are displayed in bold, notes from others in normal font, chat messages are easily identified with the username in front, and personal notes are displayed in italic. By clicking on the slide image, users can get the higher resolution version.

![Figure 3](image)

**Figure 3.** Students can retrieve their notes after the class from a standard Web browser. Notes are sorted by time and grouped by slide.
FINDINGS

This section summarizes the results of our experiment wherein 15 users used the system over a period of 9 weeks.

Log Analysis

The database contained 1,044 slides, captured during 33 classes. Of the 15 registered students, 8 actively used the system to take notes and 7 never entered any notes.

Three users only used the system for two days and we chose to remove them from the subsequent numbers presented here. The remaining five students used the system for more than 6 classes, with a maximum of 10. These active users took 400 notes in total. Ten percent (10%) of these notes contained words reused either from the shared area or from the slide image. Words were equally reused from the slide or the shared notes.

Focus Group

The analysis coming from the database does not tell us about the user experience. Also, not reusing words does not mean they were useless: students could have read them without clicking on them. To better understand these points, we conducted a focus group with five students at the end of the experiment. Two students were PDA users and three used laptops.

Two students expressed privacy concerns: they were not comfortable with sharing all their notes, even with their buddies selected at the beginning of the session. One of the students said that she was anxious while writing her notes because she knew they would be shared. Interestingly, she did not think about using the “Perso” button.

We also asked students for feedback about reusing words from the slide versus the shared text area. All students liked reusing text from the slide image by simply clicking on it. They liked it better than reusing words from the shared notes. As they were about to take a note, they knew what words
to expect on the slide because it was the same being projected in the class. On the other hand, it was harder for them to locate words from the shared area. In this regard, laptop users suggested we implement a word completion technique that would suggest words from the shared text area as they type in their notes. A similar approach could also be implemented on the soft-keyboard on PDAs. Interestingly, many students said that it was not necessary to reuse words from the shared area because these notes could be accessed later anyway.

Two students complained about information overload when the shared text area became too crowded. Despite the slide image displayed on their PDAs being small, they had no problem with it because it was the same slide being projected in the classroom. In a previous version of the system, the server filtered the notes before distributing them to connected users, in essence keeping only keywords. Students quickly turned down this idea: they really saw value in seeing the whole sentences written by their friends. This feedback clearly indicates that students found the shared notes useful even when they don’t reuse specific words.

We also asked permission to look at the notes themselves. One of the students had entered URLs in his notes. When asked about it, the student said that he often looked for additional references during the class and shared his search results with his friends. However, he complained about the lack of feedback: he did not know whether or not his friends liked this recommendation.

Although reusing words from the slide or the shared text area was useful, students still had to enter most of their notes using the soft-keyboard on the PDAs. Most of these PDA users were frustrated. For a while, one student tested a foldable keyboard plugged into his PDA. But this solution turned out to be frustrating as well: he would have to lean forward all the time in order to see his note on the small display.

Many students also complained about networking problems. Besides variability in the wireless coverage within the classroom, students told us that the PDAs would automatically disconnect and switch off to save power. Unfortunately, the socket connection did not resume when students turned on the device. This engineering problem forced users to refresh the applet in Pocket Internet Explorer to start a new session. In doing so, they also lost the content of the shared area (but not the notes previously created).
Generally, although distributing the application using an applet was a simple solution, it also prevents the system from storing the notes locally. This is especially important in case of network failures but also if students want to read their notes from the PDA while disconnected. Students who had switched back to using their laptops cited this lack of local storage as an important issue.

**Instructor’s Feedback**

The instructor was very pleased with the experiment. The slide-extracting tool never failed and allowed him to make last-minute modifications before the class without having to copy the modified PowerPoint file onto the external Web server.

Also, because slides are only captured if displayed for more than 4 seconds, he could quickly jump through slides or not show the entire presentation during a class. This feature turned out to be useful when he could not cover all of what had been prepared.

**CONCLUSIONS AND FUTURE WORK**

This initial experiment shows that reusing text from a slide or from other users in real-time is useful to students taking notes on PDA. Although we had initially focussed the system on PDA users only, laptop users also liked seeing what others had typed.

Some of the users reported problems with information overload in the shared text area. A solution would be to filter out similar notes but not filtering out small words from each note: students want to see the complete notes. Presenting the slide image of the current slide was very useful and did not cause information overload. All users, including laptop users, found reusing text from the slide to be easy and very useful.

PDA users liked reusing words with a single-tap operation, but they were frustrated with the soft-keyboard for new words they had to enter, which according to our data still occurred for about 90% of their notes. A natural
solution seems to use ink recognition on the PDA. Another approach is to leave ink as ink (Denoue, Chiu, & Fuse, 2003), yet provide ways for users to seamlessly share text or ink across devices.

In addition to gathering and analyzing further classroom data, there are several additional opportunities for subsequent investigations. First of all, following up on the use of GSS technology at HICSS conferences (Valacich & Dennis, 2001) and other workshops (Shirky, 2002), there is the question of how sharing notes can add value to workshop and conference settings. These kinds of technologies offer new ways in which to conduct background communication using a broader variety of devices and drawing upon both slides and previous communication to facilitate creating input. The technology thus offers increased opportunities for participation from the audience point of view, which, in turn is likely to enhance the amount of knowledge resulting from the meeting experience.

A second interesting opportunity relates to archival of notes and slides. Selected workshops often try to transcribe discussions that take place after a paper has been delivered. Our system and others provide an alternative means for capturing such discussion in digital form. This experience can then be reflected back to the classroom setting. How valuable are notes to students in the days after they have attended the lecture (Abowd, 1999)? What role do the notes play in preparing for a final examination or project? Do the notes still have value after the course is completed? What would be the impact of making such notes available to new students taking the course?

Finally, if it becomes easier to create notes, it is likely that more notes will be taken. If that is the case, how well will students be able to extract the information they need from those notes? Can summarization techniques be applied to make it easier for students to find what they are looking for in this new abundant resource of notes they, or others, have taken?

References


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