Multimodal Communication in the Classroom: What does it mean for us?

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ABSTRACT

Experimentation has shown that in-class educational technologies, by permitting anonymous, authored participation, can dramatically alter student communications in the classroom. Now, the appearance of dual pen-and-keyboard computing devices in the university classroom, notably Tablet PCs, motivates thinking critically about how different expressive modalities could improve in-class student problem solving and communication.

This paper describes the use of Ubiquitous Presenter 2.0 in a study to discover the driving issues of multimodality for both in-class technologies and student exercises. This paper sensitizes instructors to the issues of modality and makes specific recommendations for application design. We find that the choice of modality is not merely one of efficiency or naturalness, but is loaded with numerous personal, social, and material considerations. Although use of the pen (over typed text) is generally preferred, we find that choice itself is critical to encouraging student creativity, collaboration, and communication.

Categories and Subject Descriptors

K.3.1 [**Computers and Education**]: Computer Uses in Education

General Terms: Human Factors

Keywords

Educational technology, Tablet PC, active learning, modality

1. INTRODUCTION

The large classroom setting is fraught with challenges for both instructor and student. Educational technology provides unique means for addressing many of these problems. A critical challenge is engendering substantive student participation and instructor feedback, for example with active learning exercises and follow-up discussion. Large class sizes and shyness can discourage volunteerism. If significant participation does occur, it can create data management problems for the instructor.

Experimentation has shown that in-class educational technologies, by permitting anonymous, authored participation, can dramatically alter student communications in the classroom [4]. Shyness is diminished, and students can think through and edit their work before committing their answers. Aggregation, filtering, and partitioning can help with data management. Learning improvements are difficult to measure, yet students and instructors alike cite personal benefits to such technologies.

The appearance of dual pen-and-keyboard computing devices in the university classroom, notably Tablet PCs, motivates thinking critically about how the availability of multiple modalities could impact in-class student problem-solving and communication.[1] Could the introduction of new modalities, by better fitting student thinking and learning styles, engender positive changes in the classroom environment? How should in-class educational technologies be designed to capture such effects? What are the impacts on formulation of active learning exercises?

This paper describes a study of the use of Ubiquitous Presenter 2.0 (UP2)[7], an extension of UW Classroom Presenter (UWCP)[6, 2] that is web-enabled and supports both pen-based and typing-based student submissions. Web support provides student access and control: should the instructor so choose, nearly any computing device can view the instructor's inked slides, in any order, at any time. Student submissions permit students to author solutions to in-class exercises and submit them anonymously to the instructor. Both pen and keyboard inputs are available. (A student with a normal laptop can use the mouse to draw; a student with a keyboardless slate Tablet can use the virtual pop-up keyboard to type.) The instructor can display student submissions for discussion, as well as release the submissions for the students to peruse on their own.

A student initiates a pen submission on the instructor's current slide by clicking a "create ink submission" button below the slide, and a window pops up that permits the student to draw on a copy of the slide. Controls permit choosing the ink color or erasing strokes. A text submission is initiated by clicking the "create text submission" button. Text is entered by typing in a text box below the slide copy to be annotated, and then clicking on the slide to place the text. Additional text boxes (with differently colored

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[1]There are many dimensions to a modality of communication beyond the tool that produces it. Communication may be over any number of media (paper, computer, …), synchronous or asynchronous, ephemeral or archived, mobile or fixed, etc. Here we focus on the differences between pen and keyboard.

dots) can be added, and text can be moved by selecting the appropriate box and then clicking on the desired spot on the slide.

We performed single-lecture studies of two groups, one group working individually, and another in pairs, both with a mixture of Tablets and laptops. We found that each modality indeed affords unique kinds of thinking and expression, but the more surprising result is that the choice of which modality to use is highly articulated across many dimensions, including not only efficiency or naturalness, but also personal and social issues, physical configuration of the space, integration with the computing platform, and other activities taking place at the time. Another surprising result is how the choice of modality affects collaboration, a common element of participatory learning. Another is that a good fit between the problem, modality, and solution method affords creative elaboration on the basic answer. At least for short exercises, we find the pen-based modality is generally preferred, but choice on the whole is embraced.

2. BACKGROUND AND RELATED WORK

Much work has explored the issues of increasing access and communication in the classroom – often by providing new modes of communication. Systems such as UWCP [6], and DyKnow[3] support ink-enabled instructor lectures. Both systems allow students to interact with the instructor electronically (UWCP with ink, DyKnow with ink or typed text). Clicker systems[5, 8] allow students with small hand-held devices to vote on an answer to a multiple choice style question and summarized results can be displayed for the class. Livenotes[1] is small group collaborative system where students create and exchange notes with either ink or typed text.

In this paper, we seek to understand how multimodality (or its lack) in such tools can affect their use, the resulting communications, and how students and instructors perceive the process and the results.

3. METHODOLOGY

Our research questions directed us towards an *exploratory* study. In particular, we sought to generate and capture previously unobserved phenomena regarding student problem-solving and communication in the classroom setting, permitting us to enumerate a set of issues and what they imply for the modern classroom. By contrast, we were not trying to determine whether any given modality was efficacious or whether one modality was better than another. Such a study does not demand strong controls over experimental variables. Indeed, greater variety in the setting helps generate more unique phenomena, which can open up entirely new lines of questioning for later in-depth study.

Consequently, we chose to conduct two one-hour "mock" lectures with rather different configurations of the setting. In one class, the students (10 CS undergraduates and 1 CS instructor) worked individually using either a Tablet PC or laptop, and were thusly instructed to use either the pen or keyboard interface. This design exposed issues in using one modality over another. A limited UP2 was used here (text only) and Tablet students used UWCP's student ink submission feature; this difference appears immaterial to our results. Due to device failures during lecture, a few students switched both their device and modality mid-class. In the second class, students worked mostly in pairs sitting at a table, and could solve and submit problems using their choice of pen or keyboard. One pair of CS undergrads used a single Tablet with attached keyboard, one pair used a laptop with an external mouse as an added option, and a lone CS instructor used a Tablet with keyboard. This second class design exposed issues of choice.

Both lectures were conducted by the author most experienced with active learning exercises using UP and UWCP (Simon)[2]. Both lectures used essentially the same prepared slide set, which consisted of a series of brief active learning exercises of varying styles. The content of the exercises was evenly divided between computer science and general problems. The first problem (not counted in the forgoing statistics) was a general problem that helped familiarize students with UP2's operation. The slides were compiled into and displayed from a UWCP deck, as well as made available from the UP2 server as web pages for display on the students' devices.

Both sessions were videotaped. In the class of individual students, one camera captured the whole room, while another roved, capturing individual student work. In the class of paired students, a dedicated camera was used for each group, and clip-on microphones were used to capture audio of each pair's discussions. At the end of each class, an open-ended collective interview was conducted to help us understand the phenomena we had observed and get general opinions and feedback. In a couple of instances, we also followed up with specific e-mail inquiries.

4. OBSERVATIONS: TEXT VERSUS INK FOR DIFFERENT PROBLEM TYPES

Several of the problem types we assigned in our mock classes exposed important issues of modality. We discuss them first here, and then look at issues that largely cut across the problem types.

4.1 Selection problems

Often instructors ask questions that are expressly limited to a range of answers − perhaps to guide discussion or instruction, or to limit the amount of time spent on an exercise. Several forms of selection-oriented problems were given including binary "yes/no" answers (where that exact text was included on the presented slide), a text-based multiple-choice question with an additional free-form explanation question (see Figure 1A) and a similar multiple-choice question utilizing pictures (see Figure 1B).

With the simple yes/no question, all ink interface users simply circled either yes or no. In contrast, students using text improvised numerous ways to unambiguously select the answer. Many students typed either the word "yes" or "no" and positioned that next to the yes or no on the slide. Others used positioning and alternate text ("X" or "***" or "____") to indicate their selection.

Figure 1A shows two student works where selection among a number of items was required. While the majority of ink users circled their answer, 8 out of 10 text submissions used their explanation to also indicate their selection, most often naming the selection at the beginning of the sentence or paragraph. The remaining text submissions identified their choice by placing their sentence answering "why" next to the selection.
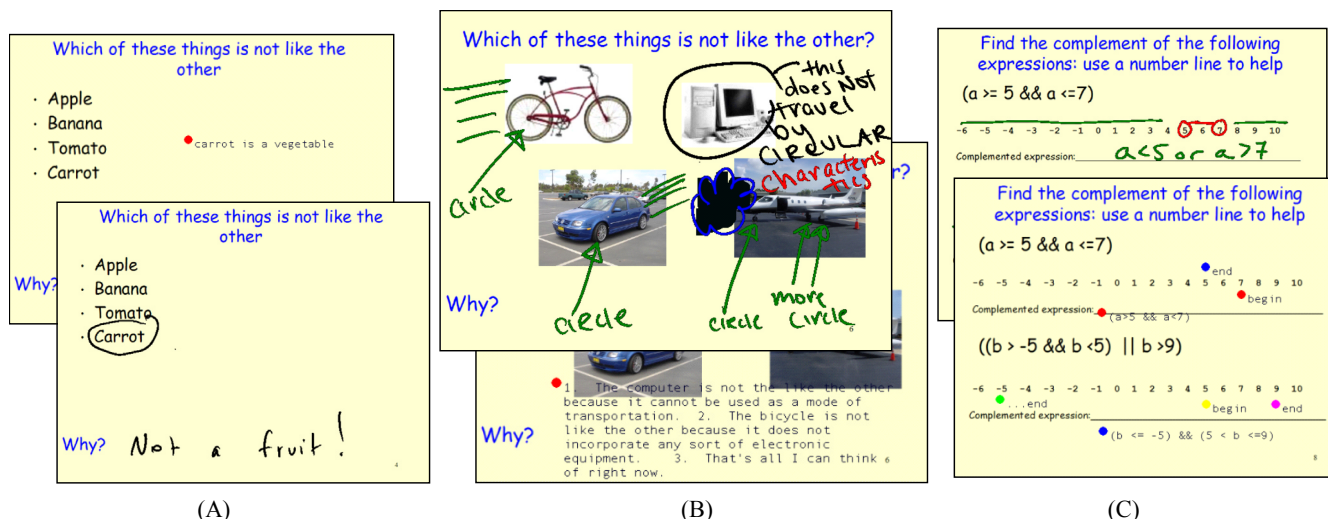
**Figure 1: Ink versus Text: (A) Issues of selection,
(B) Selection where modality hinders recognition of more complex answers,
(C) Modifying a prepared background**

Figure 1B shows selection among pictures where, again, all ink users circled their choice. Students using text sometimes put their answer on top of the picture to select it, since they lacked space around it. Two students used a two-part approach, putting the text "this one" next to a picture and then typing a second text entry after the "Why?" prompt.

A feature seen with these questions (and others), is that students often elaborate on the minimally required answer. Such elaboration was not explicitly encouraged, but was utilized in review and discussion. Pedagogically, such elaboration is desirable, in that it exposes and explores the richness of the problems, increasing learning and enabling the students to guide instructor discussion. Figure 1B highlights the differences in the ways that students using ink or text elaborate. The students using ink drew lines to make additional selections, drew lines between them, decorated them with text, etc. The students using text wrote a paragraph, numbering their multiple answers to keep them distinct.

To summarize, the students using text were inventing language(s) for selection, split between a gestural pointing language and repeating the selected answer in their text. All were successful in communicating their intent.

From an instructional point of view, the ink and text response types are different. Ink makes it relatively easy to identify different answers and elaborations at a glance, helping instructors to quickly review student work in class for possible projection and further discussion. On a 10 inch Tablet screen, the default preview size is 1.1 by 0.8 inches in the filmstrip mode – the majority of screen real estate is devoted to the current slide (which the instructor can annotate with ink). At this dimension (or even at twice that size, which is supported by UWCP's slide-at-a-time preview feature), text is hard to read. Identifying text elaborations is not hard, but understanding them entails a careful reading.

4.2 Modifying a prepared diagram

Instructors sometimes provide a framework to be modified to encourage students to enact their understanding, not just provide an answer. Figure 1C shows a problem in which students were asked to apply DeMorgan's law, showing their work on a number line. In this case it was more natural for ink users to utilize the number line. One text user did make a slide with points like: "left of this point inclusive", which managed to convey the same information as the inked slides. The nature of this answer was easily identified by the instructor due to the text placement. Most text students avoided annotating the diagram, with a few improvising other ways of showing their understanding.

4.3 Creating a diagrammatic solution

Some learning scenarios benefit from the creation of a diagrammatic solution. Asking students to describe or draw the result of inserting a set of values into a Binary Search Tree (BST) and asking students to design a particular type of user interface are examples. In our study, we asked a BST question. Ink submissions invariably showed a diagram of a tree. Text submissions varied, with some attempting ASCII art, some placing the items to be inserted in approximately the "right place" in a tree (but not "drawing" the connecting lines), one tongue-in-cheek writing code ("BST.insert(X)"), and one (an instructor) giving a LISP-like description using nested braces to specify the tree.

Having anticipated issues with text submissions on this problem, we next gave the same question providing a skeletal tree structure (lines between nodes were pre-drawn). As instructors, we felt this problem design made for a different learning experience, and we were more right than anticipated. Virtually all student creativity seen in the unstructured version was absent in these answers (and, the nested braces solution was precluded). In this sense, our accommodation of students using text backfired: restricting the method of solution also eliminated viable solution methods.

4.4 Code writing

Enabling students to make connections between new concepts and their successful implementation in a programming language is an

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[2] Classroom Presenter does include a slide preview option, which shows the instructor a slightly larger view (3.3 inches by 2.5 inches), but it is limited to a single slide at a time.

important task in computing education. We asked participants (at the junior level and above) to write a loop to print out all the odd numbers from 3 to 33 inclusive. All responses were expressed in (mostly) legal code. One ink response included a meta-comment ("Why won't this compile in ANSI C?"). During the first mock lecture, we discovered that our text widget did not support formatting like indentation (this bug also would have foiled the use of "ASCII art" in the tree drawing problem). A text submission from the second session (where this problem was fixed) was carefully formatted and used long, self-documenting identifier names. Reviewing the video revealed that the students had first constructed a quick, technically correct answer, and then had renamed the identifiers using the text widget's basic editing features. We found that the ink submissions were somewhat easier for an instructor to review, based on text size.

5. ANALYSIS: CROSSCUTTING ISSUES

In this section we report our preliminary findings on issues of collaboration and student choice of modality. The issues revealed are key considerations in the development of systems to support multi-modal communication in the classroom.

5.1 Collaboration

We note differences in the type of team collaboration occurring when student pairs use a Tablet PC compared to a laptop (with an external mouse).

We used an HP tc1100 Tablet (10 inch screen) presented to students opened but with the screen flat back on the table, so that both the keyboard and the screen were available for use. The observed team quickly raised the screen for visibility and inked on the screen while upright, even though they never used the keyboard unless instructed. The Tablet team sat close to their screen, with one student using the pen as a pointer when discussing problems. At times the other student would point in a similar manner, with a finger. On many activities, both students would contribute to the solution: one student would ink, then quickly pass the pen to the other student. This occurred when the watching student would interrupt with a suggestion, or when each would provide a distinct answer (usually with a color change to distinguish the authorship). It was clear that both students worked closely with the Tablet screen, huddling over it, and that the low time cost and naturalness of handing the "pen" back and forth contributed to tight collaboration. Pedagogically, this interaction was interesting in that finer-grained interleaving allows students to develop their answer jointly and is more indicative of true active learning.

In contrast, though the laptop team used a smallish laptop (12 inch screen), they generally took turns having one person answer each activity (when turning a laptop towards a teammate we hear "it's your turn"). The physical location and size of the external mouse proved an impediment to collaboration. We provided an external mouse to eliminate issues of unfamiliarity with a touchpad and to provide as much fine-grained control to the laptop team as possible (even though external mouse use in a classroom setting is likely limited).

The laptop team sat "back" from their machine. One person at a time would have a hand on the mouse (which stayed to the right of the machine, requiring much leaning). Rarely did both students contribute to a single problem. Once they both contributed to a question asking them to describe themselves. Once they each made an individual submission to the same problem. But, in general, group discussion of the answer was quite limited. Interestingly, we noted that the mouse played a key role in identifying current "ownership" of the laptop and enabled only one person to use it at a time – even though the laptop team knew each other and seemed very friendly.

5.2 Student Modality Choice

Do students prefer to express solutions to active learning-style exercises with ink or text? And does that preference depend on whether they use a Tablet PC or a mouse-equipped laptop? What affects these choices?

5.2.1 Observations

In the second mock lecture both Tablet and laptop users could choose between making ink or text solutions. The Tablet student team always chose ink (7/7). The laptop student team produced all ink solutions except for the coding question (6/7). The instructor subject in this session produced many more text submissions than ink submissions, though occasionally tried out both types of submissions on a given activity.

The Tablet PC team never discussed the question of whether to use ink or text. The laptop team asked each other which type of submission to make two times: the first time they had an option, and during the coding question. That first time, one student asked "Want text?" and his partner replied, "I want ink, it'll be more fun". In the coding case, the first student asked "Ink or text?", and the partner replied "It's gotta compile, it has to compile."

Although first session students did not have choice, we still note modality issues. First, text students were heard complaining that they had to use the text interface. Second, many students multitasked, reading e-mail after submitting their solution. Students using Tablets with keyboards were observed with their pens under their chins, typing away, which was notably awkward. Students with keyboardless slate Tablets multi-tasked far less, and were more likely to embellish their submissions until time was called.

5.2.2 Analysis

It is clear from observed use and discussions that choice of modality itself is a key factor affecting creativity of results. While students often appeared to prefer ink, examples such as that shown in Figure 1B's text solution indicate that some participants (possibly strong typists) are not restricted by a text interface. The results obtained from the first mock lecture (no modality choice) make it clear that students can find a way to answer in either modality (e.g., Figure 1C's text solution). The design or nature of an activity may make their task more difficult, however, perhaps interfering with the learning event, And, in such cases, it seems less likely that they will go beyond merely answering the question – likely not providing elaborating information such as in Figure 1B.

When some students in the classroom have access to ink and others don't (or have it at lower quality due to use of a mouse instead of a Tablet pen), there is an envy effect. While this is certainly due, in part, to a novelty effect, the freedom of response was noted as desirable. The students seemed to viscerally understand that a given modality could make them more effective and disliked others having an advantage.

We were unable to identify any anxiety in use of the pen and drawing for submissions. This is perhaps because true drawing ability was not a prerequisite to successfully solving the problems, again highlighting the gestural nature of many short active learning problems. However, students did express frustration over bugs and poor

interface design, such as lack of formatting in the text widget and difficulty of erasing part of an ink submission.

When student submissions aren't the only activity — notetaking or reading e-mail for example — linking effects across activities are likely to be observed, either leading to the abandonment of secondary activities (that might be active learning exercises) or a fairly permanent change of modality.

Coding problems were the one problem type we saw a definite split in the preference between text and ink. One student said that the informality of ink served as an important signal that the answer was meant to get across the idea, not be compilable. Others, as cited above, saw compilability and coding style to be important dimensions of elaboration. There is no resolving this divide as long as we encourage students to think beyond the basic problem. Multimodality is its own affordance.

6. CONCLUSIONS AND FUTURE WORK

Advances in computing technology offer the opportunity to conduct more substantive active learning exercises in large classes. This exploratory study reveals that the modality of student communication in the classroom does affect the style of expression and sometimes the approach to the problem. Across a range of activity types, students showed both creativeness and resourcefulness in answering with either ink or text modalities, although the need for resourcefulness often comes at the expense of elaboration in one's answers. Stated positively, multimodality increases the elaboration in student problem solving, aiding one of the common objectives of active learning.

This work also indicates that providing new modes of communication in the classroom can help students side-step concerns that currently lead them not to participate. For example, ink answers encourage expression of less polished, more speculative work. Student reactions indicate that providing choice of modality is a way of showing respect – broadening acceptance of learning styles, expression styles, and individuality, as well as, we hope, the range and amount of communication in the classroom.

More generally, students have preferences for a given modality for a given problem, and can justify them. The justifications and the corroborating facts of observation range widely across several categories, including physical (e.g., switching between pen and keyboard is cumbersome), software features (ease of erasing, the expected placement of text), social (envy, pens promote intimate collaboration), and personal (a desire for informality versus elaboration in coding problems).

What do our results mean for instructors? We advise:

1. Design problems with the available modalities in mind, but be aware of partially prepared solutions — they may preclude unanticipated, creative solution strategies.

2. Account for the physical configuration of the space. Small desk tops reduce students' options for configuring space to use a tool (a mouse) or facilitate collaboration (placement of the device in a "neutral zone" for rapid switching between students).

3. Watch for unexpected effects when introducing a new technology, such as envy or lack of elaboration in answers.

For tool designers, we provide the following recommendations:

1. A modality isn't just "text" or "ink". Take care in using the platform's integration features, such as supporting cut-and-paste and providing consistent look-and-feel (e.g., text widgets perform as expected).

2. To support instructors, text should be magnifiable or zoomable across multiple slides to increase ease and speed of viewing.

3. Provide affordances for gesture (pointing, grouping, etc.). For instance, perhaps an option for a check symbol ($\sqrt{}$) to lead-off a text entry would make answering selection problems more natural.

4. Look beyond purely functional considerations in the design, identifying social and personal issues of use, as well as how the tool is used in multi-tasking situations.

Our next step is to conduct studies in the classroom setting, to gain insights on scale, the impact of subject matter and teaching style, and linkages to notetaking and studying. Technical issues to address include joint ink-and-text interaction and augmenting the instructor interface to support review of text responses.

7. ACKNOWLEDGMENTS

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