Observing Presenters' Use of Visual Aids to Inform the Design of Classroom Presentation Software

Joel Lanir, Kellogg S. Booth, Leah Findlater
Department of Computer Science
University of British Columbia, Vancouver, Canada
{yoel, ksbooth, lkf}@cs.ubc.ca

ABSTRACT

Large classrooms have traditionally provided multiple blackboards on which an entire lecture could be visible. In recent decades, classrooms were augmented with a data projector and screen, allowing computer-generated slides to replace hand-written blackboard presentations and overhead transparencies as the medium of choice. Many lecture halls and conference rooms will soon be equipped with multiple projectors that provide large, high-resolution displays of comparable size to an old fashioned array of blackboards. The predominant presentation software, however, is still designed for a single medium-resolution projector. With the ultimate goal of designing rich presentation tools that take full advantage of increased screen resolution and real estate, we conducted an observational study to examine current practice with both traditional whiteboards and blackboards, and computer-generated slides. We identify several categories of observed usage, and highlight differences between traditional media and computer slides. We then present design guidelines for presentation software that capture the advantages of the old and the new and describe a working prototype based on those guidelines that more fully utilizes the capabilities of multiple displays.

Author Keywords

High resolution displays, Multi-screen displays, visual aids.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

It is almost inconceivable today for a salesperson or a presenter at a conference to appear without a computer-generated slide deck. In business settings, conferences, and many classrooms, presenters use computer slides as the main visual aid to support their talks. To create these slide decks, presentation tools such as Microsoft's PowerPoint or Apple's Keynote are used. While these tools enable the presenter to easily build sophisticated presentations that use animation and other multimedia capabilities, many critics claim that they are speaker-oriented and not content- or audience-oriented [27]. With electronic slides, presenters are forced to use a rapid, thin, sequential information style that is primarily targeted for business presentations and is not well suited to contexts where non-linear explanations and complex reasoning are needed [12,21,27]. These presentation tools may not adequately support classroom lectures: lecturers often resort, sometimes exclusively, to traditional blackboards or newer whiteboards.

Figure 1: Presentation hall and conference room with multiple screens

Current presentation software is tied to a paradigm of a single, static slide projected onto one display screen, changing sequentially over time. Yet, with increasing large display resolution and computer power to support multiple displays, and decreasing projector prices, presentation software need not be constrained to this paradigm. Many lecture halls are equipped with two or more projectors (Figure 1), and future lecture halls will likely have high-resolution, wall-size displays. Current presentation software provides minimal support for the use of multiple projectors, beyond the common practice of displaying the same slide on many projectors at once. Our work is aimed at designing next-generation presentation software that will capitalize on larger and higher-resolution displays to support existing practices, while capturing more of the advantages of traditional blackboard presentations so lecturers have a full range of options. We believe many techniques easily used with blackboards have been lost with the move to computer-generated presentations. Our goal is to combine the best of both traditional and electronic media techniques. In contrast to electronic slides, instructors have been using blackboards and whiteboards in classrooms for over two centuries [3] to present and explain complex ideas. We believe there is much to learn by looking at how older technology worked.

As a first step, we conducted an observational field study to examine current practice with both electronic slides and more traditional visual aids, comparing presentations in both conference and classroom settings to identify problems with existing presentation software and to understand how best to utilize multiple high-resolution screens to support both presenter and viewers. A blackboard (this refers equally to whiteboards unless otherwise noted) allows instructors to visually present ideas using a large surface that they dynamically control. Lecturers decide what information to erase and what to leave for future reference. Multiple or sliding blackboards allow a large amount of information to be simultaneously visible to viewers, while newer computer slide systems seldom do. Our field study formalizes these intuitions by providing a catalog of usage patterns, including a taxonomy of event types, distinctions between content types and their respective roles, and analysis of temporal phasing of material.

Based on our findings, we developed design guidelines for electronic presentation tools and have implemented a prototype system that enables lecturers to present computer-based visual aids using multiple displays. The system blends the advantages of traditional blackboards with modern computer-based tools to support learning, and serves to validate the design guidelines and illustrate the principles gained from the observational field study.

PREVIOUS WORK

Electronic Slides

The most prominent presentation tool is Microsoft PowerPoint, which is estimated to be used for about 95% of presentations world-wide [21]. As the market leader PowerPoint has garnered much criticism, but similar critiques can be applied to almost all other presentation tools, such as Apple's Keynote or OpenOffice's Impress. Perhaps the best known critic is Tufte, who claims PowerPoint degrades communication by forcing users to separate content and analysis, reduces concepts to meaningless bullets, and enforces strict, unneeded hierarchies [27]. Of particular relevance to our work, Tufte also claims that PowerPoint slides have low data resolution, and that visual reasoning is impaired because information is stacked over time instead of adjacently over space. Others criticize PowerPoint for fragmenting thoughts and editing ideas by dictating how information should look and be organized [12,21], while defenders argue that PowerPoint is only a tool sometimes used poorly [20].

Presentation Systems Research

Some research systems provide alternatives for linear presentation style using "mindmaps" [10] or zoomable user interfaces [9]. Others add support for delivering the presentation [18,19]. In classroom settings, systems incorporating flexible pen-based interaction with slides include Classroom Presenter [2], which integrates pen-based writings with prepared computer slides on a tablet PC, and E-Chalk [7], which uses electronic whiteboards that allow recording classroom whiteboard activities. Focusing on the audience, Livenotes [11] supports students' cooperative note-taking overlaid on top of the instructors' slides. Other projects [4,23] support multiple projectors to enable information to persist longer, but require sophisticated infrastructure and are limited to showing previous slides on separate projectors, each slide filling an entire screen. Other classroom systems concentrated on capturing the lecture for later viewing. Classroom 2000 [1] incorporated technology in the classroom to facilitate capturing, archiving, retrieving and presenting of classroom activities. Classtalk [5] and ActiveClass [22] focused on facilitating active learning in classrooms by using technology to encourage student participation.

These systems address some limitations of existing presentation tools or introduce technology to the classroom to promote learning, yet none fully investigate the design space of slide presentations or make comparisons with older, non-computer presentation technology. Our approach is to first observe existing practice, identifying limitations and possibilities to inform new solutions.

Computer Slide Use in Education

Theories of cognitive and educational psychology acknowledge the advantage of using visual aids to assist learning. Meyer [15,16] theorized that we process information through two separate channels, visual and auditory, and that learning can be enhanced using both channels together so that working memory can organize and unify the two channels for long-term memory. Channels are limited in their processing abilities. We risk cognitive overload if we overwhelm them.

Although computer slides are prevalent in classrooms, the pedagogical implications of using them remain unclear. Most studies focusing on whether or not electronic slides are preferable have found that students responded positively to the use of computer slides in the classroom in comparison to blackboards and overhead transparencies [6,14,26]. Students indicate that slides help them improve organization of course material, help them learn material more effectively, and make classes more interesting and entertaining [14]. In many schools instructors are expected to use presentation software. Those who do not are considered by students to be unprofessional. In sharp contrast, most studies examining the effect computer slides have on learning outcomes have found no significant improvement in student performance with slides compared to other visual aids [14,26]. Two surveys of the literature on the effect of interactive whiteboards in classrooms [8,24] include mostly small-scale studies on the impact of interactive whiteboards on pedagogy and classroom atmosphere. They report positive feedback from both

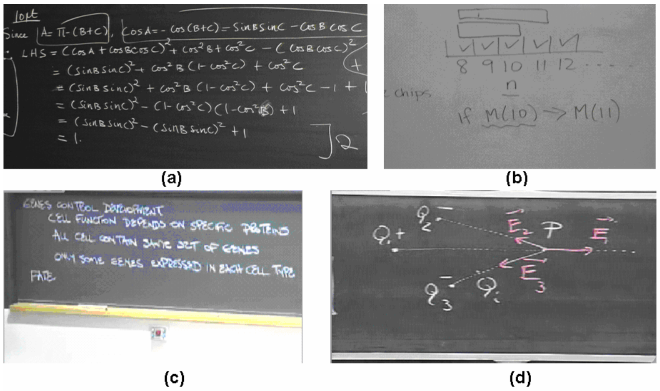

Figure 2. Examples of different types of board usage: (a) Logical progression, (b) immediate aid, (c) text, (d) diagram.

students and teachers: teachers report having more flexibility and versatility in their presentations, while students report being more motivated.

While the education community is still unsure of the pedagogical implications of introducing computer slides into classrooms, and they debate if and how slides should be used, everyone agrees that computer slides are already in widespread use [14]. Seldom, however, does the literature address questions of how presentation systems should be designed to aid students' learning. In our field study, we address these questions by observing usage of traditional and computer-based visual aids and examining how they are used to promote learning.

METHODOLOGY

We first observed use of general visual aids in classrooms at our university. From these initial observations we developed a coding scheme for presentations, which we then applied in a larger, structured observational field study of both classroom and conference presentations.

Initial Observations

We attended 60 hours of undergraduate classroom lectures to develop a general understanding of how instructors use visual aids in the classroom, and to identify categories of usage that could be used to build a coding scheme for subsequent structured observations. We observed many different lecturers on a variety of subjects including chemistry, mathematics, political science and psychology. We purposely attended lectures in classrooms of various sizes and with different visual aids: whiteboards, blackboards, overhead transparencies, computer-generated projected slides and combinations of these. We did not record detailed interactions or content, but instead gathered general observations concerning visual aid usage. Further details can be found in [13]. Usage categories identified for whiteboards and blackboards in classrooms: were logical progression, immediate aid, text, diagram, table and graph. The first four are shown in Figure 2.

Logical Progression (LP) is common in science, engineering and mathematics classes. The instructor solves a problem writing one line beneath another, each line derived from previous lines until a conclusion is reached. An example is an instructor writing a proof for a mathematical theorem (Figure 2a).

Immediate Aid (IA) acts as a "just-in-time" visual aid. It only exists in the context of explaining something specific, and loses meaning without the context of the instructor's speech. It may be a collection of disconnected sketches, equations, numbers or words as anchors, tangible objects concurrent with the instructor's words (Figure 2b). Looking at it afterward usually will not have much meaning.

Text occurs when the instructor writes text to emphasize an important point, to provide a heading, to write down a bullet-point list, or just to spell out a word (Figure 2c).

Diagram is when the instructor draws a sketch, usually to convey an abstract concept: in a lecture on physics the concept of electric fields might be illustrated by drawing particles and arrows to represent the field (Figure 2d).

Table occurs when the instructor draws a tabular arrangement and ***Graph*** occurs when the instructor draws a chart. Both are special cases of Diagram, or hybrids of Diagram and Text.

For instructors using computer slides, we categorized slide content similarly. Slides can contain LP, text, diagrams, graphs or tables. Slides may also include images, but not IA because that requires the presenter to dynamically change visual content.

Structured Observations

Based on our initial observations and categories of usage, we developed a two-level coding scheme for the main field study. We coded use of visual aids during presentations from three different corpora: (1) conference presentations that used computer slides, (2) university lectures in which the majority of the lecture was given using computer slides, and (3) online lectures in which the majority of the lecture was given using a blackboard or a whiteboard. We chose these corpora to compare usage of computer slides in two different settings (conference and classroom), and to compare slides with multiple blackboards, which are more dynamic and utilize more real estate.

Conference Slide Presentations

We attended 21 presentations at the ED-Media conference in June 2007. These were research presentations in the field of educational multimedia held in small rooms (up to 50 seats) using a standard data projector and a free-standing screen with an approximate size of 1.5m x 1.5m. The screen was situated at the front of the room with the top of the screen at a height of approximately 2.5 meters so the presenter could gesture at a slide. Average presentation time was 17.8 min (SD = 4.4).

Figure 3. Classrooms with 3x3 and 5x2 arrays of sliding blackboards (images used under license from [17])

Classroom Slide Lectures

To see if presentation style and use of slides differ between formal conference presentations and classroom lectures, we attended 18 undergraduate lectures by 12 different instructors presented at our university in which the main visual aid was computer slides. Classes included anatomy, biology, chemistry, economics, nutrition and political science. All were held in large lecture halls (more than 150 seats) equipped with projectors. The size and location of the screens varied, but most were positioned high above the presenter. To gesture some instructors used a laser pointer or a laptop's mouse, while others did not use a gesturing device. Average lecture time was 48.0 min (*SD* = 8.7).

Classroom Blackboard Lectures

We coded 15 lectures by 15 different instructors offered on MIT Open Courseware [17]. All used blackboard or whiteboard as the main visual aid. The videos were professionally recorded in MIT undergraduate classes. Most (13) were in large lecture halls using a 3x3, 3x2 or 5x2 grid of sliding boards (see Figure 3). The remaining three were in small classrooms using only two blackboards. Subjects included biology, chemistry, computer science, electrical engineering, material science, mathematics and physics. Average lecture time was 44.8 min (SD = 6.0).

Coding Schemes

We developed two coding schemes, one for the blackboard lectures and one for the slide corpora. The overall goal was to explore how content is spatially and temporally organized and presented. Gestures were recorded because they show a degree of interaction with the material being presented, thus providing an indication of how and when content was used.

Slide coding scheme. For both the conference and the slide lecture corpora we used the same coding scheme, recording the time for each event. The major events were:

- *New slide.* A new slide appears. Slides were further categorized based on their most prominent type of content: text, LP, diagram, graph, image, or table.
- *Layer*. New information is added to a slide.
- *Slide back*. The instructor returns to a previous slide.
- *Gesture.* Both hand gestures and gestures using an aid, such as a laser pointer or the computer's mouse, were counted as gesture events.

Blackboard coding scheme. Each event occurs on a single *board unit*. A board unit is a part of the board that the instructor uses as one logical area. Often a board unit is one physical board, but the instructor may draw a line to divide a physical board into two or more units when she wishes to have separate logical units. We recorded the location and time of the following major events:

- *Writing.* A single writing event was determined according to the content: text, LP, IA, graph, diagram, and table. The act of drawing a diagram or writing a sentence was coded as a single event.
- *Layer*. New information is added to content written earlier.
- *Erase*. The entire board or item of content is erased.
- *Gesture*. Gestures at the board were recorded.

Coding Reliability

All lectures were coded by the first author. To assess the reliability of the coding scheme, a second coder attended two of the classroom slide lectures and two randomly chosen blackboard lectures. For slide lectures, there was a 94% agreement on events between the two coders (Kappa coefficient = 0.89), with only a few gesture events missed, and 93.2% agreement on content (Kappa = 0.85). In the blackboard corpus there was 86.7% agreement on events (Kappa = 0.79), but we encountered difficulties assessing content. For the first blackboard lecture, the second coder forgot about the IA category and coded those events as text. This was identified and corrected for the second lecture, but only 4 out of the 7 IA events were coded by both coders. This suggests there may be a lack of precision in the IA category. Coding the three missed IA events as text yielded a 91.5% agreement on content (Kappa = 0.87); coding them as errors yielded an 84.1% agreement (Kappa = 0.80).

Interviews

To supplement the observational results, we conducted semi-structured interviews with six experienced university instructors from commerce, computer science and mathematics. During a one hour session, instructors were asked about their usage of visual aids, including but not limited to blackboards and slides. The goal was to understand what types of aids were used, and for what purpose different types were used.

FINDINGS

We report quantitative and qualitative findings. Comparing classroom to conference slide presentations allows us to understand if and how people adapt their use of presentation software between the two settings. When comparing slide-use and board-use our goal was not to quantitatively compare slides and boards since interactions with each were quite different. Our purpose was instead to isolate and identify the differences and understand how blackboards are used in ways that slides are not.

Similarities of Slide-use in the Two Settings

Computer slides were used as the main visual aid in both conference and classroom corpora. The average time spent on a slide was significantly less in the conference (54.5s)

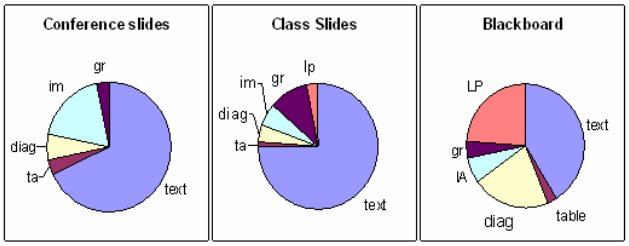

Figure 4. Proportion of each content type for conference (390 slides), classroom slide (413 slides), and classroom blackboard (474 writings) corpora. gr=graph, im=image, diag = diagram, lp = logical progression, IA = immediate aid, ta = table

than in classrooms (112s) ($t(806) = 35.2$, $p < 0.001$). This matched our expectations because conference presentations are shorter and usually provide higher density of information. Differences in the average time spent on different content types within each corpus were not significant.

The distributions of content types in the three corpora are shown in Figure 4. In both slide corpora, text was the main visual component (68% of conference slides and 75% of lecture slides). In the blackboard corpus, different types are more evenly distributed with less text content and more diagram and LP content. While this can be partly attributed to the types of classes using the blackboard (more scientific), it may also be caused by the fact that writing of text takes too much time for the blackboard.

Figure 5 shows the percentage of slides gestured at for both slide corpora. The corpora were surprisingly similar. Although both were very different in the setting, type and content, and show significant differences in time per slide, both the distribution of types of slides and the amount of gesturing for each type of slide (Figures 4 and 5) were relatively similar in comparison to the blackboard corpus.

Rich and Support Content

As can be seen in Figure 5, in both slide corpora, there was a dramatic difference between the percentage of gestures on text slides and on other types of slides. Text slides were least gestured at (17% of conference corpus and 11% of classroom corpus). Diagrams, graphs and tables on the other hand, were highly gestured at (combined, 73% of the conference corpus and 88% in the classroom corpus). Image slides were gestured at (36% and 25% of the conference and classroom corpora, respectively) more than text and less than tables, diagrams and graphs.

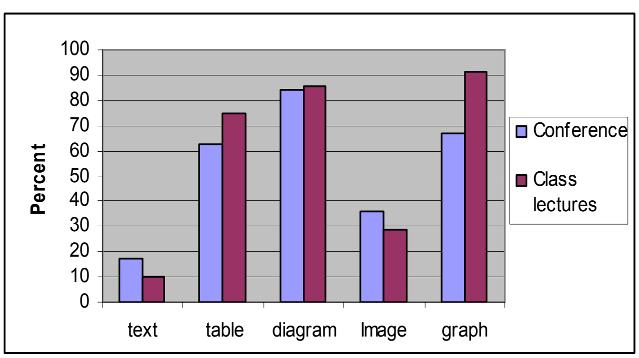

Figure 5. Percentage of slides gestured at for each content type for conference and class slide corpora.

Figure 6 presents the percentage of events gestured at for each type of content of the blackboard corpus. The pattern is similar to that of the slides, with a high percentage of gestures on tables, diagrams, graphs and LPs (combined 75.2%), and a lower percentage on text (27.6%) and IA (40.6%).

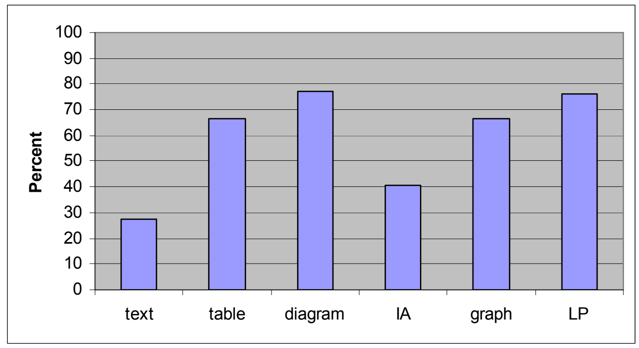

Figure 6. Percentage of writing events (*N*=474) gestured at for each content category in the blackboard corpus.

Figure 7 shows the average amount of time instructors spent writing each type of data in the classroom corpus. This was measured from the beginning to end of writing, and may include pauses for explanation. We conducted a one-way ANOVA to evaluate the effect of content type on time. A main effect of content type was significant ($F(1,5) = 16.4$, $p < .001$). The pairwise comparisons, using a Bonferroni adjustment, showed that text ($M = 18.9$s) was significantly shorter to write than diagrams ($M = 53$s), graphs ($M = 54$s) and LP ($M = 36.1$s), ($p < .001$ for all comparisons). IA ($M = 9.8$s) content was also significantly shorter to write than diagrams, graphs, and LP ($p < .001$).

Summarizing these findings clearly distinguishes two different groups of content. *Rich content* includes diagram, table, graph and LP types, while *support content* includes text, IA and image types of content. Rich content is focused on much more by the instructor: it is gestured at more often (Figures 5 and 6), takes more time to be written (Figure 7),

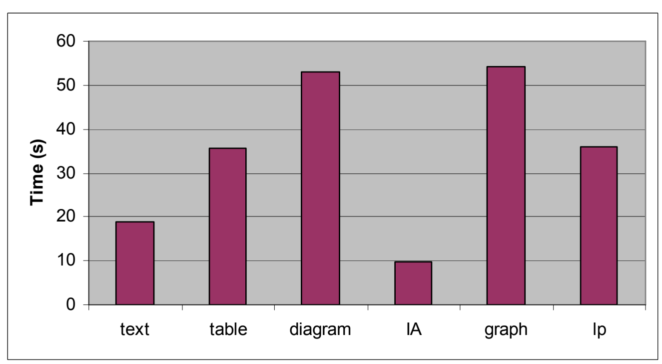

Figure 7. Average duration of writing events for each content type for the blackboard corpus.

and results in more gesture iterations (Table 1) than support content. In contrast, support content takes less time to write, and is gestured at and iterated upon less.

In the rich content group the presenter uses the visual as the focus of the idea, and therefore will spend much time and will gesture often. Support content, on the other hand, is used as a secondary visual aid to the spoken explanations. Text, for example, is used mainly for headings or redundancy. It is self explanatory and in the same modality (verbal) so it does not need to be gestured at.

The Importance of Gestures

During a writing event, many times the instructor would lift the pen or chalk, explain the content with gesturing, then continue writing the same content. We recorded this as one writing event, but we also recorded the number of writing *iterations*, distinguishing between two iterations as having a gesture between them. The average number of iterations and frequency of iterations can be seen in Table 1. We can see that for the rich content types, especially graphs and diagrams, a high percentage of events is iterated upon.

	D	G	LP	Table	IA	Text
Average iterations	3.4	4.6	3.3	3.6	2	3
% of events iterated upon	41.1	42.8	32.4	25	3.1	0.5

Table 1. Average number of iterations and percentage of events iterated on for each type of content for the blackboard corpus. (D = Diagram, G = Graph)

In a blackboard setting, the instructor is usually close to the board, making it easier and more natural to gesture at the desired content as there is an embodiment of the instructor with the visual aid. We had therefore expected there would be more gestures in the blackboard corpus than in the slide corpora. To compare the number of gestures using the blackboard and computer slides, we compared between the two classroom corpora. There was a significant difference showing more gestures in blackboard classes (M = 38.2) than in slide classes (M = 6.5) ($t(28) = 16.4$, $p < 0.001$), even though the lecture lengths were similar between the two corpora.

Gestures are important for the presenter to connect the audio and visual parts of the presentation, focus the attention of the audience on the visual aid, and specifically show some detail on the visual. As we have shown, this is most important on rich content types. Using slides, there may be a feeling of a disembodied voice when the audience is viewing slides and only hearing the notes. An instructor writing on the blackboard and gesturing at what is written will retain the audience attention on him or her, thereby communicating nonlinguistic behaviour that is important for the interaction with the audience. We observed that when an instructor looks at the slides projected on the wall, or stands behind the podium looking at his or her laptop, the audience will focus on the slides and not on the instructor. This may create a learning environment in which there is no

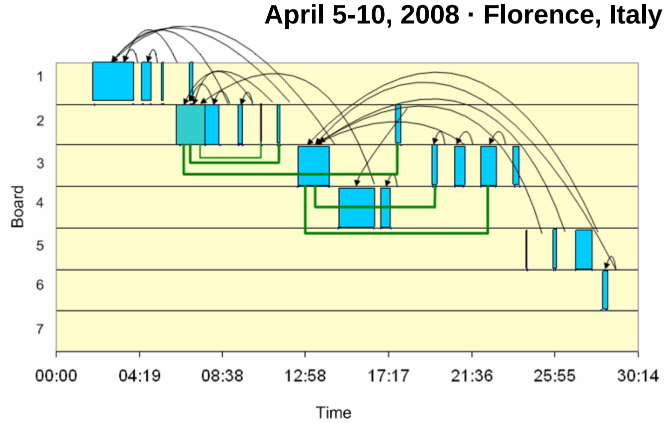

Figure 8: Diagrammatic example of a blackboard lecture. Blocks represent writing events, curved arrows represent gestures, rectangular lines represent layer events.

interpersonal engagement between the presenter and the audience, thus reducing learning outcomes [14].

Data Persistency

Long-Term Persistency

Using the blackboard, data persists for longer than when using slides, allowing the audience to see previous content. To examine if data not only persists longer, but is also used more at later points by the presenter or audience, we examined gesture and layer events on older board units.

To illustrate the degree to which instructors refer back to previous content in blackboard lectures, Figure 8 shows one blackboard lecture using sliding boards throughout time. The X axis represents time, while the Y axis represents board units. Each box represents a writing event in time (X) and space (board in Y). Arrows represent gestures at the corresponding content, and the bottom square lines represent the addition of layers on top of existing content (e.g., adding new content to a previously sketched graph). This diagram, can help to understand the flow of blackboard use during the lecture.

The *active board* is the board where the most recent writing event occurred. A *referral back* is defined as a gesture to a previously written content item on a board unit other than the active board. Often, when instructors verbally refer back to a concept, they gesture at the visual aid used when explaining that concept. This helps the students easily recall the previous item and reduce their cognitive load when they learn new items, since they connect the concept with the place and image of the visual aid. An example of this can be seen in Figure 8A. There was a total of 117 referral backs for an average of 7.8 per lecture (SD = 4.4). The average elapsed time between a writing event and a referral back to that content was 8:55 min (SD = 6:43m). If we try to compare referral backs with computer slides, the only similar behavior is the presenter navigating back through the slide presentation to a previous slide. This behavior occurred only six times in the entire classroom slide corpus and only three times in the conference corpus. Although we did not explicitly record duplicate slides, which could be used as a form of referral back, our informal observation is that their use occurred rarely.

A *write back* is a writing event on a previously used board which is not the active board. This usually occurs when the instructor adds a layer to existing content (like a diagram) or when the instructor writes new content in proximity to previously written content usually because it is semantically related. An example of this can be seen in Figure 8B. Instructors averaged 2.0 write backs a lecture ($SD = 2.9$).

We observed that in many lectures, there were content items that were the center of attention for a long time. The writing event highlighted in Figure 8C, for example, took a minute and a half to write, but then from around minutes 20 to 30 it was referred back to and written on several times and was clearly still active. To examine how many of these content events occurred per lecture, we defined a *highly referenced content* item as one which was gestured at or layered back on at least five times from different points in the lecture. Given this definition, there was an average of 1.9 highly referred to content events per lecture ($SD = 1.2$). All but one of these events was of rich content. This suggests that only a few items need to be kept persistent for a long length of time.

Short-term Persistency

Most of the gestures instructors made were to recent information. Referral backs, which are mostly at items written less recently, comprised 23.5% of all the gestures, while 62.3% of the gestures were at content items that were no more than four writing events in the past. This emphasizes that instructors most often use information that was only recently presented. From informal discussion with students, we believe that students can benefit largely from having the most recent data persistent. First, having previous content visible may help to understand how current explanations have been reached. Second, students copying notes often need the recent data to be kept for longer. Third, by having more data persistent, the control of what to look at and how to assimilate data is transferred from the instructor to the student. Using slides, the instructor tells the student what he or she needs to look at. Using sliding boards with the whole lecture data persistent, the student is empowered to use what is best for him or her, thus encouraging active learning.

Some instructors post their slides to allow students to bring printed handouts of slides to class. While handouts allow content persistence for students, we did not see an effect on instructors' teaching styles. Instructors cannot refer back to handouts in the same way they interact with information displayed for the entire class. In interviews, some instructors said they were reluctant to post slides because students might not attend or would not pay attention in class, having the content available ahead of time.

Pacing and In-depth Exploration of Rich Content

From our initial observations, we hypothesized that a slide lecture shows more information than a blackboard lecture, and that the pace of a blackboard lecture is slower. Five of the six instructors interviewed agreed to this, as one instructor commented:

"You can move more quickly with slides. [...] I use the whiteboard whenever I want to slow down the pace."

To get a very rough estimate of the amount of information in slides and boards, we conservatively estimate the number of slides that would be required to display the visual information in the blackboard lectures according to the following transformation: any one diagram graph or table event, two LP events, or three text or IA events equals one slide. Using this estimation, we calculate that blackboard lectures present less visual information on average; when the length of lecture is divided by the number of estimated slides, the average is 162s per slide. In contrast, the average slide length in the slide classroom corpus was 112s. This supports the idea that slide lectures show more information in a shorter period of time than blackboard lectures. This difference in pacing could be because the computer slides are premade and do not require content creation during the lecture. Another possibility is that the slower pacing of the blackboard is a result of its support more in-depth, dynamic development of rich-content ideas. Using slides, presenters usually follow a steady pace, going from one idea to the next in a linear manner. Blackboards, on the other hand, support a slower, less deliberate pace, showing less information for longer periods of time. For example, in our interviews, one math instructor who mainly uses the blackboard commented:

"The first thing I can say about blackboard teaching is that the pace is slower, and that already has much value [...]. The Pace of writing stuff on the board is much more adequate in terms of the ability of people to digest [mathematical] derivation."

Boards support more in-depth exploration of a single idea. The temporal build up of a problem plays an important role, allowing the audience to gradually understand each building block of the problem. This is shown mainly in rich content types like diagrams or LP that usually represent more abstract, complex information. Indeed, diagram (21%) and LP (24%) type were much more common in the blackboard corpus than in the class slide corpus (4% and 2% respectively). Looking back at Table 1, we see that rich content has a higher number of gesture iterations suggesting temporal build up of the information. This can also be seen in the layer events. In the blackboard corpus there were a total of 47 layer events in which additional information was added onto existing information. Although possible to do in existing slideware,, this type of behavior was not observed in the slide corpora.

Comparing Between Two Content Items

We noticed that in some cases, instructors explicitly compared two items on a single board or on two different boards. This could be identified by iterating gestures between two content items. We asked instructors if they compared items when they use the board. All instructors said that they do compare items, and some said they wish they could compare two slides. One instructor commented:

"I often feel a slide is too small, and a lot of times it's because there is something I'd put on one slide that I wish I could put on the other slide and see them at the same time"

Dynamic vs. Static Nature of Content

Slides are commonly presented in a static manner, and rarely does one see a presenter navigating through his or her slides in an order other that which was predefined; in our observations, presenters have returned to previously shown slides only 3 and 6 times in the conference and classroom corpora, respectively. Although it is possible to annotate slides using electronic ink in PowerPoint, which would allow for more flexibility, we did not observe this in either slide corpus. Blackboards, on the other hand, afford much more spontaneity. As one instructor has said:

"I tend to switch back to the whiteboard when I'm doing something particularly ad-hoc or spontaneous".

Using the blackboard, the presenter can drift from one idea to another without having to plan the entire lecture in advance. IA content, for example, reflects use of the visual aid as support for spontaneously given explanations.

DISCUSSION

Table 2 summarizes the advantages of slides and of blackboards, as found in our observations and interviews. Incorporating characteristics from both will be important for designing effective classroom presentation systems.

According to Tufte [27], using PowerPoint as the main visual aid dictates a certain cognitive style of presenting information that most presenters use regardless of the situation and content of presentation; this should also apply to competing commercial presentation tools. Our findings support Tufte's claim by showing similar trends for the usage of slides in two very different corpora using slides, and showing different trends of usage than a different medium such as a blackboard. This also suggests that instructors are not adapting their slide use for teaching.

Slide presentations are inherently sequential over time showing one slide after another: we observed that presenters using slides rarely go back to previously shown slides. This may have implications for cognitive load theory [25], which states that best learning is achieved when cognitive load on working memory is minimized. It suggests that instead of loading the working memory by mentally integrating pieces of information one should try to physically integrate these sources of information. When instructors refer back to information using the blackboard, they physically integrate the different pieces of information. Using slides, on the other hand, increases cognitive load of

Computer Slides	Boards
Multimedia capability	Dynamic and spontaneous
Easily shows premade content	More space (multiple boards)
Data persists before and after presentation	Natural gesturing – embodiment of presenter with visual aid
High resolution images displayed	Enables temporal buildup of rich data
Legible and organized	Non-linear
	Simulates problem solving

Table 2. Comparison of the advantages of slides and boards

the audience because of the need to remember previous ideas.

We suggest a two-fold approach for data persistency in presentations. First, we suggest broadening the window of persistence of current content. As we have shown, most gestures are aimed at recent writing events. By showing the most recent content as long as possible this will accommodate the audiences' need for immediate context. Second, we suggest allowing the presenter to keep certain data available for longer times. We have shown that some data needs to be referred to from later parts of the lecture. This need not take much space. We have shown that only two items on average were referred to multiple times throughout the lecture. By allowing the instructor to keep these items persistent, we can help reduce the audience's cognitive load, and assist learning.

We have distinguished between two types of visual data: rich content and support content. We found that rich content, which include diagrams graphs tables, and LP, took longer to write, had more gestures, and in the blackboard corpus also had more iterations of gestures. When supporting rich content in presentation software, we should allow more space, focus attention on it, provide long-term persistency possibilities, and, if possible, support gesturing. Support content, in particular text, does not necessarily need to be in the focus of the attention. IA content is a special case. While all other types refer to the data's content, IA refers to how the data is being used. Without electronic ink or some other input interaction, it would be difficult to emulate this kind of behavior because of its dynamic nature.

The pace of the presentation is different when the presenter uses slides or board. Slides show more information, and generally have a faster pace, and therefore may be more suitable for business or conference settings in which the presenter wishes to convey more preset information in a short amount of time. Boards, on the other hand, are more suitable for learning of complex ideas. They are more dynamic, and support more in-depth exploration of rich-content ideas using temporal build-up of the information. They support non-linearity since the presenter can more easily show how several ideas, written previously on the board, support the current idea.

Limitations

Most courses in the blackboard corpus were science and engineering lectures. Math-related courses usually use blackboards for visual support because of their advantages in problem solving and slower pacing. This poses a possible limitation on how our results generalize to other domains. We believe that while our insights stem from the observations of mostly science lectures, they are valid for any area that conveys complex reasoning and learning.

Design guidelines

Summarizing the important points from our analysis, the following guidelines are given for designers of presentation systems that support learning:

1. *Provide short-term persistency of data*. Data usually builds on top of other data. Showing the latest data for longer is beneficial to the audience.
2. *Provide long-term persistency of data*. Some data is important throughout longer periods of the presentation. It is important to provide the instructor with a means of showing specific data for longer.
3. *Support gradual build-up of information*. Gradual, temporal build-up of the problem is important for learning complex ideas.
4. *Rich content is different than support content.* Designers of systems that handle content should emphasize support for presenting rich content information, allowing for long-term persistency and easy gesturing. Support content can be more peripheral.
5. *Gestures are important.* Gesturing is important to connect the visual aid with the presenters' auditory explanations. A presentation tool should ideally support specific gesturing at areas of the visual presentation. This will be especially important in high-resolution, wall-size displays.
6. *Support dynamic content.* Presenters should be allowed to dynamically add, control, change, and remove content.

MULTIPRESENTER

Based on the guidelines outlined above, we have built MultiPresenter, an early prototype slide presentation system for multiple displays (Figure 9). MultiPresenter allows the presenter to author presentations for two screens, and control the presentation flow using her laptop. Following our guidelines of *short-term persistency*, *long-term persistency*, and *dynamic content*, it allows the presenter to show previous content (either automatically or user-controlled), to compare between two slides, to have an important slide persist for a long time, or to interactively manipulate content from one screen to the other.

Unlike other systems that use multiple projectors with dedicated servers or a complicated infrastructure, we believe that for the system to be usable it should be lightweight and able to run on any laptop connecting to existing projectors in any room. The only requirement is that the computer used for presentation must have two video cards to control the two screens. We use the Village Tronic VTBook© card that connects to a PCMCIA slot.

System Description

MultiPresenter does not currently allow authoring of slide content. Slides can be authored in PowerPoint and saved in image format, then loaded to the system. They are presented to the instructor in a split-screen view in which a stream of slides is shown on the left. When presenting, the instructor's display changes to a presentation view showing the current two slides on display, enabling the presenter to navigate to different areas in the presentation.

The system has three basic modes. The first two modes assume that the instructor does not want to interact with the system during the lecture. In the first, the instructor simply progresses from one slide to the next., as she would in PowerPoint. Following the short-term persistency guideline, the current slide is on one screen and one, two or four previous slides are on the second screen to give the audience more context,and to allow the audience to look at content that may have been missed.

The second mode is a custom-made presentation using two screens. In authoring mode, there are two columns of slots in which slides can fit, representing the two screens. The slide deck loads on a single column, and the user authors a dual-screen presentation by copying, moving or stretching a slide to one or more locations in the second column. This presentation mode is useful when comparing two slides, showing an overview slide and a detail slide, or when an important slide is kept for a longer time alongside regular slides. This follows the long-term persistency guideline.

The third mode requires interaction by the presenter, but allows the presentation to be more dynamic and interactive. The system shows the main stream of slides on one screen. The instructor can at anytime select a part of the slide (e.g., an important diagram) and drag and drop it to the other screen. She can then move, resize or erase any snippet on the other screen. All interactions are shown on the presenter's laptop as well as to the audience so the audience knows where the data have come from. The presenter can thus create and manipulate a "clipboard" of highly referred to content that she deems important, following the long-term persistency and dynamic content guidelines.

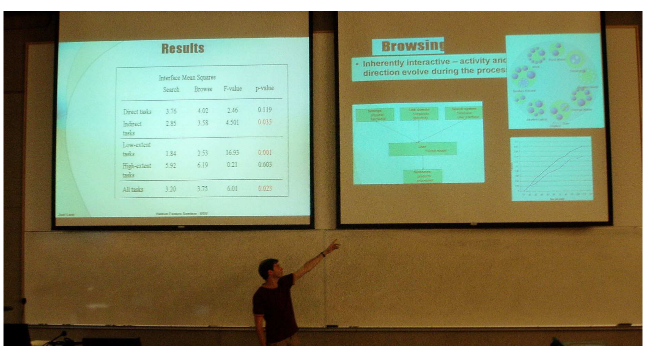

Figure 9 - Image of our MultiPresenter in use in a classroom

Future work

MultiPresenter is at a very early stage of development. An important next step will be to evaluate the system in use. Although further design iterations are required in the short-term, our long-term evaluation goal is to have instructors at our university use MultiPresenter as an integral part of their classes. We plan to evaluate how they use the system, their response to it, the audience's response, and the audience's learning outcomes. Electronic ink adds another level of dynamicity and allows the student to follow the presenters' way of thought [2]. We intend to add the ability to annotate slides for tablet PC users: one screen could show the slides, and the other used as a blank writing area, similar in interaction to using slides and boards together. We also plan to investigate methods to support IA content and gradual build up of information.

CONCLUSIONS

Our observational study identified important themes and usage trends in different settings, the importance of persistency of data, and differences in rich and support data. We devised design guidelines for presentation systems on high-resolution and multiple displays using these guidelines, and an initial prototype for multiple displays.

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