INSTRUCTOR INKING IN PHYSICS CLASSES WITH UBIQUITOUS PRESENTER

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1. ABSTRACT

We analyze the use of digital ink by three instructors of introductory university physics classes, discussing how they organize their slides, the ways in which they ink, and how they support their dynamic classroom activity with instructor notes – a part of the Presenter (UP [1] and CP [2]) framework. We find modes of usage including using ink to explicitly link multiple representations; making prepared figures dynamic by animating them with ink; and preparing slides with sparse text or figures, then adding extensive annotations during class. We discuss each of these uses from a pedagogical standpoint. While the inking modes of other disciplines are not directly explored in this paper, we suggest that our analysis has relevance beyond physics.

2. PROBLEM STATEMENT AND CONTEXT

As instructors from increasingly diverse disciplines utilize pen-based computing in their classrooms, new and interesting ink usage patterns emerge. The electronic nature of inking supports easy capture of formerly infrequently captured material – dynamic lecture delivery of written content. We explore the specific context-sensitive inking practices of higher education physics instruction through the analysis of three instructors' lecture materials as captured via UP. We provide a pedagogical analysis and discussion as to the purposing and valuation of inking within physics education. We invite discussion among the community on these inking practices, how they relate to ink usage in other disciplines, and how to promote "best inking" practices in our communities.

3. SOLUTION EMPLOYED

We jointly reviewed lecture materials from three university-level physics classes taught by three instructors (including author Price) at two institutions. Course A (57 students, taught by author Price) was a semester long course for physical science and mathematics students at a public regional university; course B (180 students) was a quarter long course for life science students at a public research university; and course C (200 students) was a quarter long course for engineering students at a public research university. All instructors lectured with UP and allowed their students to view ink online; all were using UP for the first or second term; all had basic training in the usage of the system and described themselves as comfortable with it. One of the instructors utilized UP for active learning – though that is not a central focus of this work. An analysis of the frequency of instructor inking, and student perception and review of instructor ink are described elsewhere [3].

For this study, ink was reviewed both in “final” form on each slide, and, when interesting, “replayed” stroke by stroke to observe instructor inking pattern. Finally, informal, post-hoc discussions occurred among the instructors in which they reflected on their use of ink in the classroom. Discussion is based on both these discussions and the teaching and educational research experience of author Price.

4. EVALUATION

We characterize patterns of use observed across instructors and relate the usage to the known affordances of electronic inking, including spontaneous augmentation of prepared lecture materials, electronic archiving, and natural pacing. Three primary patterns emerge: using ink to explicitly link multiple representations; making prepared figures dynamic by animating them with ink; and preparing slides with sparse text or figures, then adding extensive annotations during class. Each of these activities is notably supported by Presenter’s instructor objects. Instructor objects are simply text, figures, ink, etc., that are visible only on the instructor's screen, but are not visible to students on the in-class projected view or on the web. Instructor objects can provide prompts or reminders, or serve as scaffolding for instructors' in-class inking (such as working examples or drawing graphs). Below we provide examples of each usage pattern, describe how instructor objects were observed to support the activity, and discuss the pedagogical rationale for the usage.

Linking Multiple Representations. Most introductory physics classes focus on developing conceptual and quantitative understandings of natural phenomena, including energy, motion, forces, electricity, and magnetism. Physicists describe and analyze phenomena with a variety of representations, including graphs, diagrams, and algebraic expressions. Each of these representations has particular strengths, and helping students develop fluency with these different representations and the ability to translate between them is a widespread goal – and challenge – of introductory physics instruction. Physics education researchers have documented many student difficulties in using and translating between representations [4]. Nevertheless, the use of representations can play a role in student learning: Podolefsky and Finkelstein found that representations appear to cue students to focus on particular characteristics of physical phenomena [6].

Among the three instructors considered here, all were observed to make frequent use of ink to make explicit, dynamic links between multiple representations. In Figure 1A, Instructor A is comparing the momentum of a ball before and after it bounces off a wall. Lines have been used to link pictorial representations of the ball approaching and rebounding to algebraic variables and to a graph of force as a function of time. Variables are thereby explicitly and graphically connected to the physical situations they represent and simultaneously correlated with the forces. This pattern of usage rests on the affordance of spontaneous inking: instructors can easily add or erase a line in a different color. While an instructor writing on the board has the ability to make “drawn” connections – she may be limited in the accuracy or ease of representation of real word objects or actions. Furthermore, since lines on a board cannot be erased as a single entity or object, instructors may feel that linking representations in this way will unacceptably clutter the board. In Figure 1B (Instructor B), we see an example where a written problem statement is linked to a mathematical equation and variables are further linked directly to the expressions substituted for them. In this example, however, the linkage is temporal, not graphical. On this slide, Instructor B successively circles variables in the problem statement, then draws on the corresponding part of the diagram; later, he circles one variable in a formula, draws a

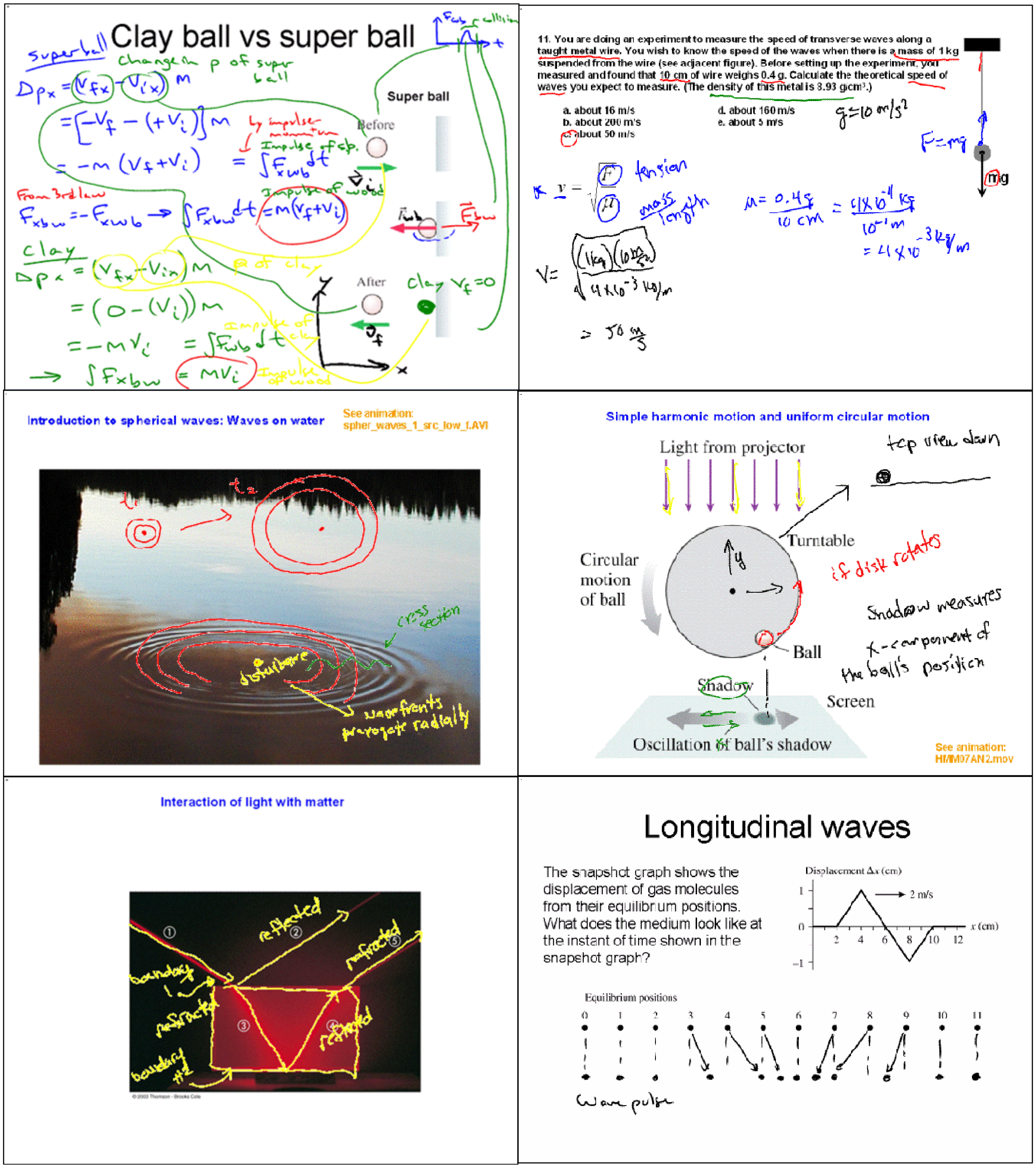

Figure 1A-F (clockwise from upper left). Examples of instructor slides and ink used to link multiple representations (A-C), animate figures (D-F).

corresponding vector on the diagram, and writes an algebraic expression for the variable in terms of other quantities. Because students can 'play back' instructor ink on the web, this temporal sequencing is archived for students' later use. Figure 1C (Instructor C) exhibits the type of linking of representations that would be hard on a blackboard. The crests of ripples in a pond are traced, and a corresponding graph of displacement versus position is drawn over them directly on the picture. Instructors using non-Tablet digital projection frequently exhibit such connections with gestures (possibly using a laser pointer) – fleeting, non-permanent, connections that may appear to have diminished or less than explicit meaning to students. Instructors writing on a Tablet PC running UP readily used ink for this purpose, thereby creating a graphical, permanent, possibly annotated, reviewable link.

Animating prepared figures with ink. Many phenomena studied in introductory physics have a dynamic aspect – they change in time. Visualizing these dynamic aspects can be difficult for students, and explaining them can be difficult for instructors. While many textbooks now offer web-based animation resources that can be used as live lecture demonstrations, students may not know how to attend to relevant cues or details provided by animation [6]. Furthermore, difficulties often occur in connecting these dynamic occurrences to static pictures which can be analyzed in depth and annotated. Our instructors were extremely excited by the ability to use dynamic in-class inking to “hand animate” static textbook figures (which they commonly display with digital projectors) during the course of discussion. In Figure 1D, Instructor B has traced over the light rays, drawn a line showing the motion of the ball, and indicated the path of the moving shadow. In Figure 1E, Instructor B has traced the path of light rays as they reflect and refract through a clear block. In Figure 1F, the prepared slides shows points on a spring in equilibrium; then, using ink, Instructor A has redrawn the points showing their displacement during a wave pulse.

In these examples, ink very naturally enabled natural animation of a static figure – because inking occurs dynamically, it can convey what figures often struggle to. Instructors also noted that this worked well in combination with discussion – that ink not only allowed them to animate, but functioned as “attentional ink” – helping students organize a timeline behind events happening in succession and establishing cause and effect relationships. Again, UP’s support for the replay of ink, one stroke at a time, can allow students to reproduce after class the motions and animations as developed and annotated in class. Rieber suggests that animation can be beneficial when, in addition to a need for visualization, there also is “a need to conceptualize changes to an object over time (motion) and/or in a certain direction (trajectory),” but cautions that “students are probably not accustomed or trained in interpreting animated information” and therefore “must be sufficiently cued and guided in order to take advantage of the potential learning effects of animation” [6]. By adding dynamic features to static figures, instructors are able to use UP to conceptualize changes over time (in a limited fashion), while also guiding students through the interpretation of the diagram.

Preparing and augmenting sparse slides. Instructors often extensively inked sparse slides – slides with little prepared material. The sparse prepared material included outlines (filled out in class); rhetorical, motivational, or transitional statements (leading to related analysis or derivations); problem statements (worked as examples in class); and graph or figure templates (drawn on in class, *e.g.* to show data collected in class). This is illustrated in Figure 2A. Instructor A’s prepared slide only includes a problem statement, diagram, and steps in a general problem solving strategy; the example is then worked in ink during class. The time-consuming step of writing out the problem – which students can quickly read and comprehend – is thereby avoided, while the problem solving process takes place at a more natural pace. Figure 2B, also from Instructor A, shows a slide that was prepared with space listing examples of vectors and scalars. During class, the instructor populated the lists with student suggestions. In general, in sparse slides the instructors used prepared material as an anchor, a prompt, or a workspace. Since the ink is added dynamically the presentation is "created" in front of students. Instructors are frequently frustrated with the "canned" feel of non-Tablet digital presentation lectures and the

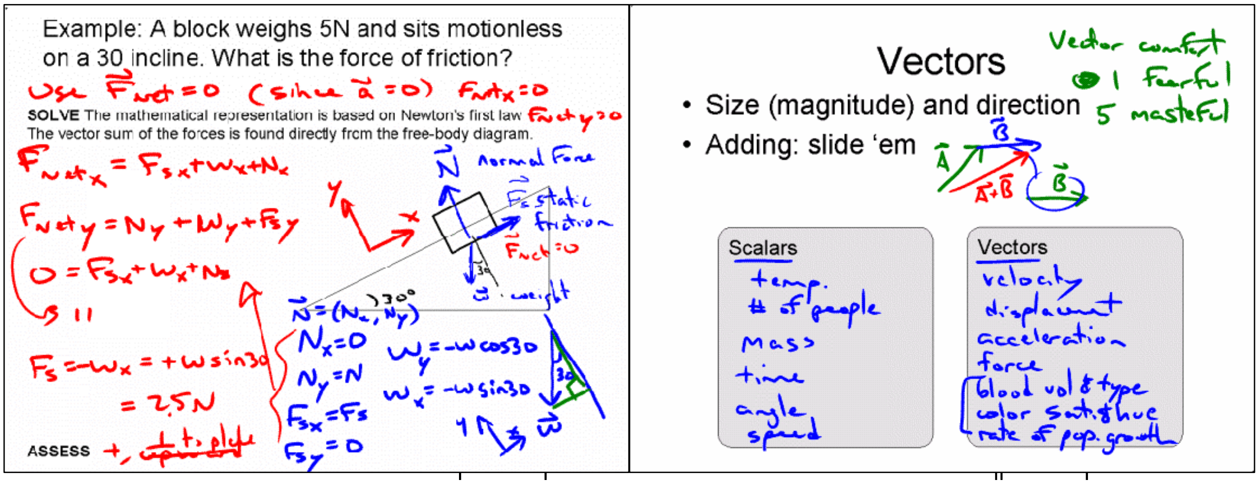

Figure 2 A (left) and B (right). Examples of instructor slides and ink used to fill in sparse slides or templates.

limitations of and effort required for animation that must be prepared in advance. Because UP affords spontaneous inking, instructors can capture the "live" feel of a chalkboard lecture. Indeed, we find that slides are often inked extensively, to an extent that would be overwhelming if presented all at once instead of built up incrementally.

Use of Instructor Objects. In general, we saw very significant use of instructor objects among all professors, but less use of instructor objects by the instructor with more than a decade of teaching experience. The most extensive use of instructor objects occurred on sparse slides – where instructors would pre-plan not only the solution, but an ordering of how to break down the solution most effectively for students. Instructor objects were also used to indicate animations to be made in class, either on top of diagrams or freehand. Significant time savings were noted in using instructor objects for this purpose, as they only have to signify the intent of what to do in class, rather than being "perfectly drawn". Fewer instructor objects were seen in linking of multiple representations – as this activity flows naturally from spoken discussion about a problem.

5. FUTURE WORK

We were somewhat surprised at the extent of the commonality in usage across the three instructors studied – but these were similar, introductory courses. While we feel that these behaviors will likely extend to more advanced physics courses, we look forward to the opportunity to see if any new modes of use will be evidenced. Though the commonality in usage among these instructors suggests a disciplinary character to the usage ('physics inking'), we are cautious to avoid over generalizing from our sample of only three instructors; study of additional instructors is warranted. Additionally, it seems likely that instructors in similar disciplines would follow similar inking modes, but, again, this is a question that should be answered with data. We look forward to interdisciplinary comparisons, specifically in subjects where linking of representations is critical.

6. ADDITIONAL RESOURCES

To get started using Ubiquitous Presenter (free for non-commercial use) visit http://up.ucsd.edu. Additional examples of physics instructor and student slides can be found at http://physics.csusm.edu/physics/faculty/eprice/innovations.html

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