AC 2010-490: MUSEINK: SEEING AND HEARING A FRESHMAN ENGINEERING STUDENT INK AND THINK

David Bowman, Clemson University

David R. Bowman is a Lecturer in the General Engineering Program within the Department of Engineering and Science Education at Clemson University. He is also a Computer Science Ph.D student in the School of Computing at Clemson University. His educational background includes a B.S. and M.S. in Computer Engineering from Clemson University.

Lisa Benson, Clemson University

Lisa Benson is an Assistant Professor in the Department of Engineering and Science Education at Clemson University, with a joint appointment in the Department of Bioengineering. Dr. Benson teaches first year engineering, research methods, and graduate engineering education courses. Her research interests include student-centered active learning in undergraduate engineering, assessment of motivation, and how motivation affects student learning. She is also involved in projects that utilize Tablet PCs to enhance student learning. Her education includes a B.S. in Bioengineering from the University of Vermont, and M.S. and Ph.D. degrees in Bioengineering from Clemson University.

MuseInk: Seeing and Hearing a Freshman Engineering Student *Ink* and Think

Abstract

In many fundamental engineering courses, students are required to work problems on paper in order to demonstrate their understanding of course material. In first year engineering courses, there is a huge range of entering skill levels due to differing student backgrounds in math and science. Some students submit highly structured and adequately labeled work that is logical and correct, whereas some other students write down too little or too much information which makes it difficult to assess the procedure the student took to solve a problem.

At Clemson University, we have developed a Tablet PC application called MuseInk that allows students to work problems using a pen and a Tablet PC, which instructors can then evaluate. They can view not only the final submission of the work, but can *play back* student work (including all *Ink* strokes and erasures) using controls similar to a DVD player. As a pedagogical tool, MuseInk allows the instructor to play back student work live in class so that the students are exposed to common misconceptions, where they occur, and engage in conversation about how to correct the procedure from a specific point in time within a student submission. In addition, instructors can insert "tags" to mark up student work, much like a traditional assignment, but the student can see what they did wrong, when they did it wrong, and learn how to correct their misconception. This gives instructors richer feedback capabilities than the traditional paper-based method because they're able to temporally evaluate processes rather than attempting to interpret a static image.

We present here the features we're developing in MuseInk to facilitate research on problem solving strategies of freshman engineering students. Using MuseInk, we're able to tag interesting events during playback from a "universe" of tags we're developing to assess procedural and conceptual problem solving knowledge, and visualize the tags using built-in visualization tools. Additionally, MuseInk contains an audio recording capability that allows researchers to implement a think aloud protocol by associating the student's spoken word to a specific stroke or erasure in their problem solving strategy. This paper discusses the preliminary development of a universe of tags for assessing problems worked in a first year engineering course, initial results from think aloud interviews, and the early visualization tools that will guide our continued work on this study.

Statement of Need

Popular Tablet PC applications like DyKnow[1] and Classroom Presenter[2] allow instructors to incorporate rapid pen-based feedback on select student work live in class, but are only intended to serve a pedagogical purpose. For our research project, we needed a tool that allowed us to collect digital ink from students so that we can conduct a thorough analysis of the conceptual and procedural strategies each student demonstrated in typical freshman level engineering problems. The tool we needed had to be able to play back each ink stroke and erasure in the order the student committed them to (digital) paper. Being able to watch a student work out an engineering problem gives the researcher a sense of the algorithmic or procedural knowledge

demonstrated by students. Similar "play back" capability exists in some Tablet PC applications like LectureScribe[3], which is typically used by an instructor to record audio and ink to create a Flash video file to embed in a web-page or email. This functionality is perfectly acceptable for instruction, but does not have the flexibility needed to allow the student to play back their own work and associate audio commentary to a particular event in the problem solving procedure. In addition, we needed a tool to allow the researcher to mark where specific events, concepts, or procedures occur while playing back student work. We refer to these marks as "tags" and the collection of all events, concepts, procedures, or other items of interest as the "tag universe." Our solution, MuseInk (Figure 1), addresses these deficiencies while providing visualization tools to help researchers investigate student work and listen to provided audio commentary.
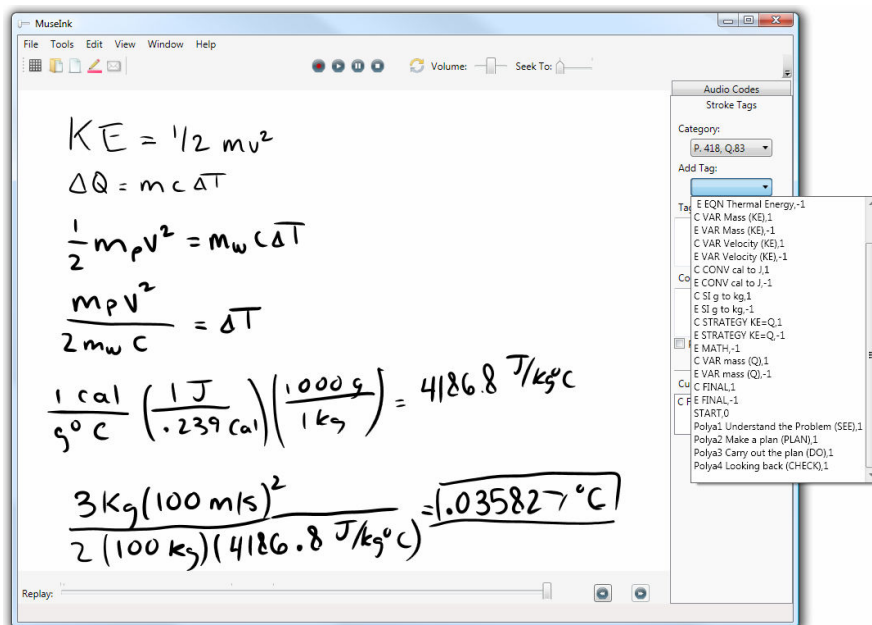

Figure 1: A screenshot of MuseInk playing back student work and adding procedural and conceptual tags from the tag universe. Once inserted, locations of tags will appear as marks in the replay scrollbar at the bottom of the screen.

Demonstration of Need

In this section, we detail work submitted by a single freshman engineering student (herein referred to as Jacob) using MuseInk for collecting Ink and adding post-hoc audio commentary in a think-aloud session. In class, students worked an energy/power problem to determine the efficiency of a component in a power delivery system. Jacob began his work (Figure 2, top left) by heading down the wrong path initially by dividing the total input power to the system by the overall output power of the system. A minute later, he erases all of his work and says "well, that wasn't right, so I started over." Jacob began working again (Figure 2, top right) using a different strategy, justifying what he wrote down in his audio commentary, but immediately erases his work yet again. After erasing his work, Jacob explains "that was not wrong, I just thought it was wrong at the time," indicating that he second-guessed his approach early in the problem. Finally, Jacob began working on the problem again using a slightly different approach than he used in his previous two attempts. In his audio commentary, he correctly describes his approach and

correctly identifies the variables he should be using to solve the problem, but did not realize that he accidentally wrote down the wrong value for a variable that he correctly identified in his commentary. Without Jacob's audio commentary, an instructor might be led to believe that Jacob had a severe conceptual misunderstanding of power and efficiency. However, using MuseInk to evaluate his work by playing back his writing and listening to his audio commentary reveals that Jacob simply made a mistake copying down the value of variable, but had a correct understanding of the problem and the meaning of the variable in the equation he was writing.
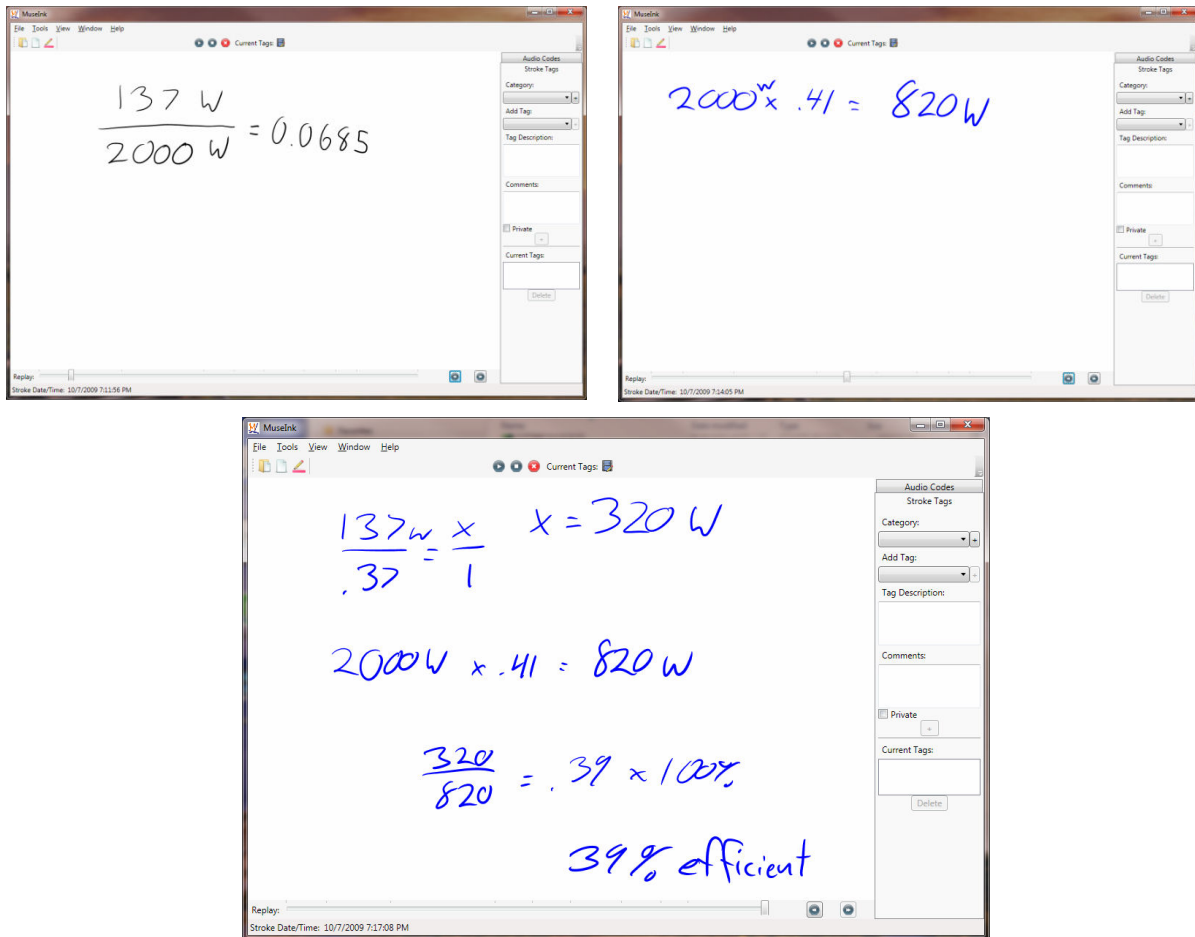

Figure 2: An example problem worked in MuseInk by a freshman engineering student, starting with an incorrect approach (top left), starting over with a correct approach (top right), and concluding to solve the problem with a minor mistake (bottom).

Tag Universe

One key feature of MuseInk is the ability to mark student work with "tags" from a "tag universe," a database of errors, procedural events, concepts, and other items of interest in student work. We are currently investigating the nature of items that might be included in a tag universe for problems in a freshman engineering course; these include items such as drawing a picture or diagram, using a guess and check method, or identifying known and unknown values in a

specific problem. When we began our initial draft of tags, we collaboratively developed a list of items we might want to look for in student work using a Microsoft Excel worksheet. For ease of use, MuseInk creates the tag universe for student work using a list imported from Microsoft Excel. In Figure 3, we show conceptual (left) and procedural (right) tags in a tag universe authored in an Excel worksheet. For the remaining figures shown in this paper and the tag universe displayed in Figure 3, we created procedural tags based on Polya's[4] four step problem solving procedure. In this study, a single person tagged multiple students work using the procedural tag universe on the right in Figure 2, but in future studies, multiple people with high inter-rater reliability will tag submissions using a newer tag universe currently in development.
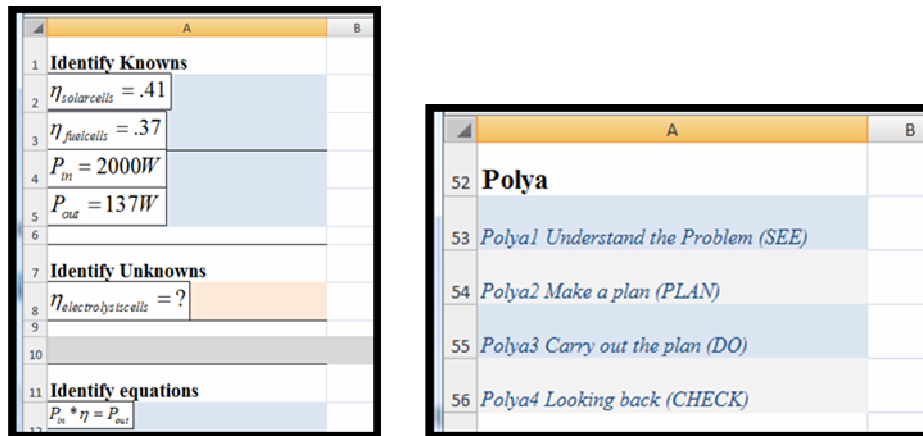

Figure 3: Creating a "tag universe" of conceptual tags (left) and procedural tags (right) for use with MuseInk is as simple as creating a list of items of interest in a Microsoft Excel worksheet

Visualization Tools

We are currently developing new visualization tools for investigating student problem solving strategies in MuseInk. Currently, we have two tools that allow us to graphically represent procedural events in student work. In order to get a sense for what our students were doing, we built two tools to generate diagrams similar to those created by Kohl and Finkelstein[5] to examine patterns of multiple representations. Kohl and Finkelstein create a timeline similar to a Gantt chart to describe when certain events occur in the work completed by their students. The visualization technique used was originally used by A. H. Schoenfeld[6] to represent time spent in different problem solving stages by novice and expert problem solvers. After work has been "tagged" in MuseInk, a "Schoenfeld-style" plot is automatically generated to illustrate and examine how much time a student spends working in different stages of their problem solving strategy. In Figure 4, the two plots generated by MuseInk show the strategic difference between a student who fluctuates between different methods for solving a problem and eventually ends the problem with an incorrect answer (top) compared to a student who spends an adequate amount of time demonstrating an understanding of the problem, planning, and finally quickly solves for the correct answer (bottom.) The "duration" in Figure 4 is computed based on the number of strokes and erasures in each step of the problem solving strategy. A future "Schoenfeld-style" plot will be developed that uses actual timestamps from the *Ink* data to show how long (in minutes and seconds) the student actually spent in each step in their problem solving strategy. Using time rather than the number of strokes and erasures as a duration

measure will allow us to examine the actual amount of time different students actually spend writing while solving a problem and begin to investigate what students are doing while they're not writing.
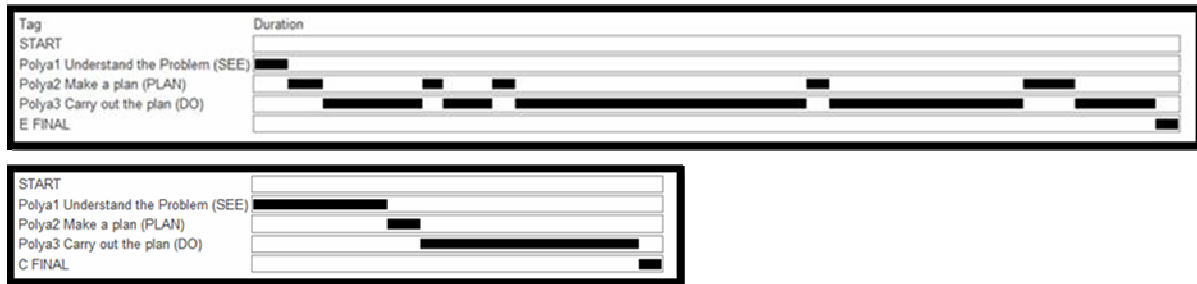

Figure 4: "Schoenfeld-style" plots of visualized tags generated by MuseInk. The plot on the top reveals a student moving between "planning" and "doing" stages and concluding with an incorrect final answer. The plot on the bottom shows a student who writes down nearly an equivalent amount of work "understanding" and "planning" as he does "doing" and correctly solves the problem.

In addition, Kohl and Finkelstein use a "sequence diagram" to show how students move in and out of using different representations during problem solving. The researchers use the information in this diagram along with the "Schoenfeld-style" diagram to categorize students as novice or experts. This same type of visualization can be used to examine how different procedural tags marked in student work occur (or re-occur, in some instances) to allow investigation into the amount of time students spend on certain steps within a problem, and how many times they repeat or iterate through those steps. This will provide insight into the cognitive processes behind student strategies and steps. In Figure 5, we show the same tagged student work, represented as "Schoenfeld-style" plots in Figure 4, displayed using the sequence diagram visualizing module in MuseInk. These plots show how the "novice" student (left) frequently jumped between the "planning" and "doing" steps in his work to end up with an incorrect answer in contrast to the "expert" student (right) who took his time understanding and planning to solve for the correct answer, which created a very clean and linear sequence diagram.
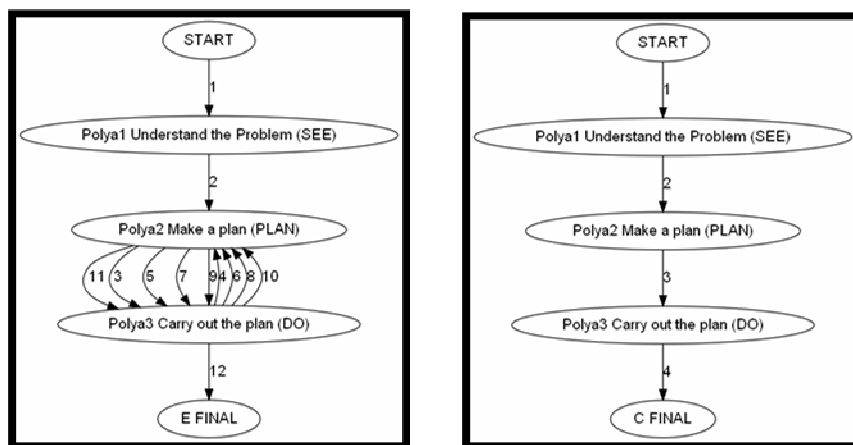
Figure 5: Sequence diagram of tagged work generated by MuseInk. On the left is work by a "novice" student who toggled between several steps; on the right is work by an "expert" student who efficiently sequences through the steps of the problem.

Conclusions and Future Work

We have begun development on a pedagogical and research tool, MuseInk, which allows users to distinguish between conceptual and procedural events in student work through the use of tags and visualizations. With inspiration from prior work on visualization of problem-solving strategies, we were able to add two procedural tag visualizations to MuseInk. Future development into the visualization capabilities of MuseInk will involve modules for graphically representing conceptual tags, not just procedural tags. A popular tool for visualizing tags (similar to metadata encountered on the World Wide Web[7]) is a tag cloud structure to graphically show a frequency of occurrence of tags. Tag clouds can be implemented in MuseInk to quickly and accurately reveal frequent misconceptions in student work. In addition, we will be developing a graphical tool to represent a variety of information about misconceptions that occur within student work, including when they occur within playback and where they occur procedurally. This graphical technique will branch the conceptual and procedural tags in a problem to provide information on what, when, and where difficulties occur in student problem solving procedures, with the goal of improving our understanding of student strategies when working engineering problems. Continued development of new visualization techniques, in addition to refining our tag universe, will position MuseInk to be a critical tool for informing our understanding of the underlying cognitive processes involved in solving first year engineering problems.

Acknowledgements

References

1. DyKnow. http://www.dyknow.com
2. Classroom Presenter. http://classroompresenter.cs.washington.edu/
3. LectureScribe. http://www.cs.clemson.edu/~bcdean/lscribe/
4. G. Polya, "How to Solve It", 2nd ed., Princeton University Press, 1957.
5. P. Kohl and N.D. Finkelstein, "Patterns of Multiple Representation Use by Experts and Novices during Physics Problem Solvings" in *Phys. Rev. ST Physics Ed. Research 4*, 010111, 2008.
6. A. H. Schoenfeld, "What's All The Fuss About Metacognition?" in *Cognitive Science and Mathematics* p. 187. Erlnaum, Hillsdale, NJ, 1987.
7. Lohmann, S., Ziegler, J., and Tetzlaff, L. "Comparison of Tag Cloud Layouts: Task-Related Performance and Visual Exploration." In *Proceedings of the 12th IFIP TC 13 international Conference on Human-Computer interaction: Part I* (Uppsala, Sweden, August 24 - 28, 2009)