

INK-12: A Pen-based Wireless Classroom Interaction System for K-12

Kimberle Koile *MIT Center for Educational Computing Initiatives, kkoile@mit.edu*

David Reider *Education Design, Inc., david@educationdesign.biz*

Andee Rubin *TERC, andee_rubin@terc.edu*

1. ABSTRACT

This paper describes research conducted in the two-year NSF-funded *INK-12: Interactive Ink Inscriptions in K-12* research project. In this project, we have been investigating the role that pen-based wireless technology could play in upper elementary and middle school science and math. We have conducted tablet computing trials in eight schools in the Boston, MA, area—six fourth, one sixth and three eighth grade teachers’ classrooms, working with a total of 400 students. During each of these trials, the project team helped teachers adapt their lessons to make best use of the tablets and to think strategically about pacing the lesson, accommodating different types of learners, and dealing with unexpected technological challenges. The tablets were particularly successful in (1) facilitating students’ creation of drawings and other mathematical and scientific representations, and (2) providing teachers with tools to promote classroom discussions. The research identified areas that need further work, including providing a more flexible metaphor than “slides” for lessons and student submissions, and designing professional development to support teachers in choosing appropriate student work for class discussion.

2. PROBLEM STATEMENT AND CONTEXT

In the two-year exploratory *INK-12: Interactive Ink Inscriptions in K-12* research project, we have been investigating how the combination of two technological innovations—pen-based input and wireless communication—can support and transform classroom practices and student learning in K-12 STEM disciplines. In particular, we have been investigating how the technology can enhance the teaching and learning of mathematics and science by (1) giving students enhanced capabilities to *create and manipulate* representations of mathematical and scientific objects, and (2) providing facilities for *communicating* representations that can support conversation among teachers and students about science and mathematics content. *Pen-based* interaction enables the creation of *inscriptions*—handwritten sketches, graphs, maps, notes, etc., which are critical in STEM fields, where content is often most easily expressed as a mixture of text and drawings. Teachers and students can easily draw and write on a tablet computer’s screen (create “ink” inscriptions), thereby extending the representations possible with only the typical keyboard and mouse or pencil and paper. *Wireless* networking enables facile communication of inscriptions, and other representations, among teachers and students. The communication provides a teacher the opportunity to look at all her students’ work at the same time on her tablet and makes possible discussions based on selections of student work that can be made visible to all students and the teacher simultaneously. In this way, the technology can support a “conversation-based” classroom in which students discuss their reasoning and listen critically to others’ reasoning. Such conversations provide valuable opportunities for feedback to both students and teachers, feedback that can be used to improve both learning and teaching.

3. SOLUTION EMPLOYED

The technology used in the trials consists of a set of tablet computers running a software system called Classroom Learning Partner (CLP), developed by the first author's research group [3, 4, 5]. CLP is built on top of the wireless presentation system Classroom Presenter [1, 2]. Classroom Presenter provides the underlying wireless communication, as well as much of the user interface's functionality and style, both of which are very intuitive. Like Classroom Presenter, CLP embodies a "presentation slide" metaphor for classroom interaction: A teacher creates a lesson as a series of Powerpoint slides. In the classroom, the teacher and students all have tablets on which the lesson is running; the lesson also is projected on a large public screen. The teacher can annotate a displayed slide by using the tablet's stylus to create digital ink, which, by way of a wireless network, is then visible on the students' and public screens. Students, in turn, can write on their tablet screens and send the digital ink to their teacher, e.g., as answers to in-class exercises. The teacher then can select some, or all, of those answers to display on the public screen and engage students in class discussion. Examples of student work from our research are shown below in Figure 1.

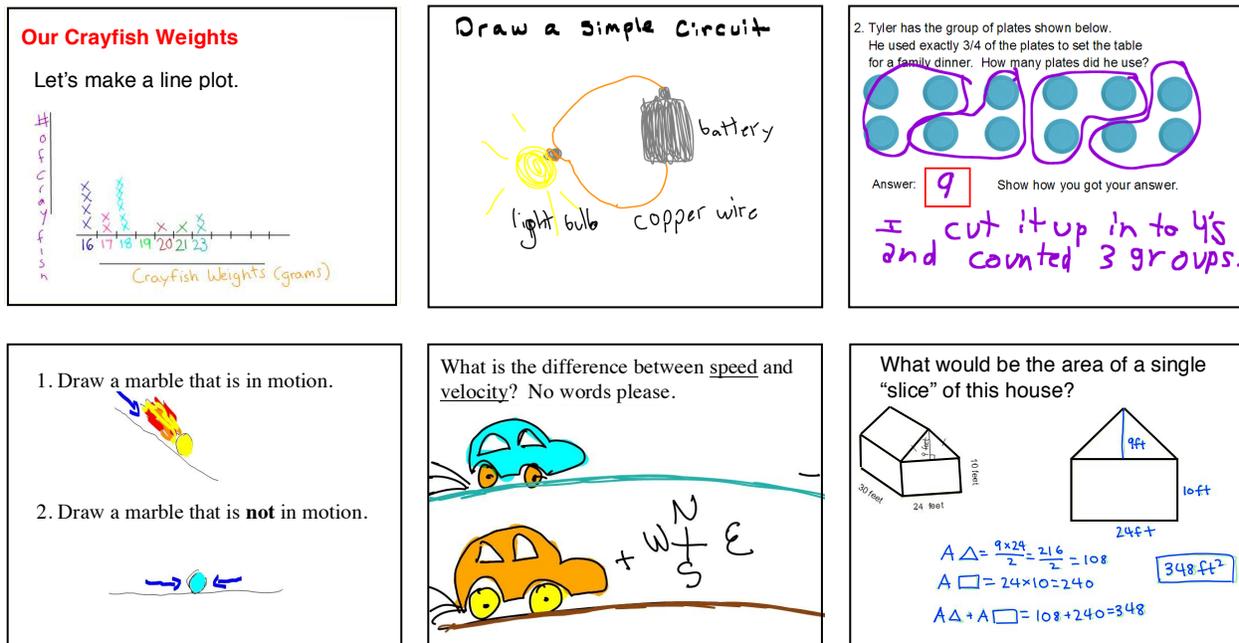


Figure 1. Fourth grade (top) and eighth grade (bottom) student work

The current version of CLP extends Classroom Presenter in the following ways.

Classroom setup: We run CLP using a classroom server and local peer-to-peer network, which is automatically established as soon as the tablets are started up. With this setup we avoid using school networks, which are often unreliable and without on-site technical support. We automated much of the software startup procedure so that teachers and students (1) only use the tablet pen, not the keyboard, and (2) spend very little time initiating a lesson. Teachers and students start the software by tapping on an icon on the tablet desktop; the software connects to the peer-to-peer network, retrieves the lesson from the server, and connects to the current classroom session. When the students start CLP, a login window pops up, allowing them to choose their names from a class list, which is populated from data retrieved from the server. The login information is used for storing student submissions on the server, and for labeling

submissions so that teachers can match submissions with students—a feature that we found K-12 teachers needed, especially in order to respond to requests from students to “show mine.”

Teacher’s features: We implemented a number of features that facilitate the teacher’s use of student work as a basis for classroom conversation. Student submissions are organized by slide on the teacher’s machine, with one submission deck per slide. The teacher has easy access to submissions via a tab associated with her version of each slide. Figure 2a shows a teacher’s screen, with her lesson slides in the vertical filmstrip on the left; CLP’s gray tab on the right of a slide indicates the presence of submissions, and the number on the left indicates the number of students who have sent submissions. Tapping on the tab displays the student submissions for that slide in the filmstrip; tapping on a particular submission slide in the filmstrip displays it on the both the teacher and public machines. Tapping on the “multidisplay” icon at the top of the filmstrip enables the teacher to select submissions to display simultaneously on the public machine—another feature that teachers found enhanced their ability to hold class conversations about multiple representations and problem-solving approaches. An example of creating a multidisplay is below in Figure 2.b-d: Student work is “stacked” and displayed in a filmstrip on the left, one stack per student; the teacher expands stacks as desired, by clicking on a student’s name on a stack, and drags submissions onto a “stage”, then selects column or grid view.

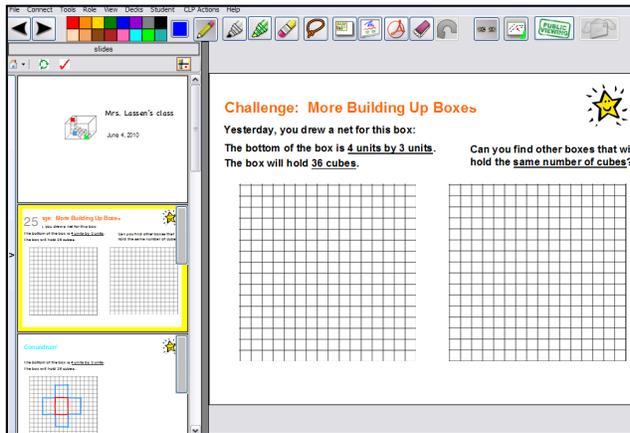
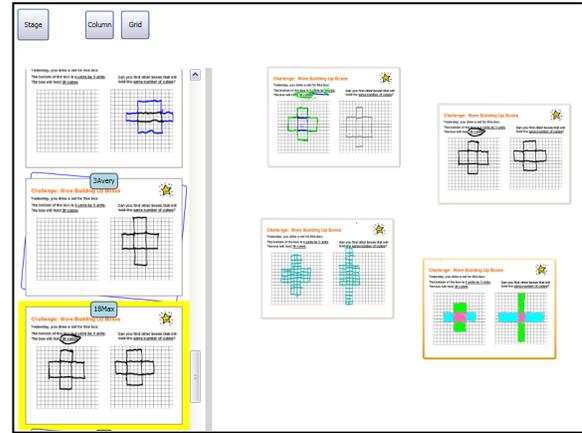


Figure 2. a. Selects slide, then taps multidisplay icon



b. Drags submissions; yellow shows one chosen

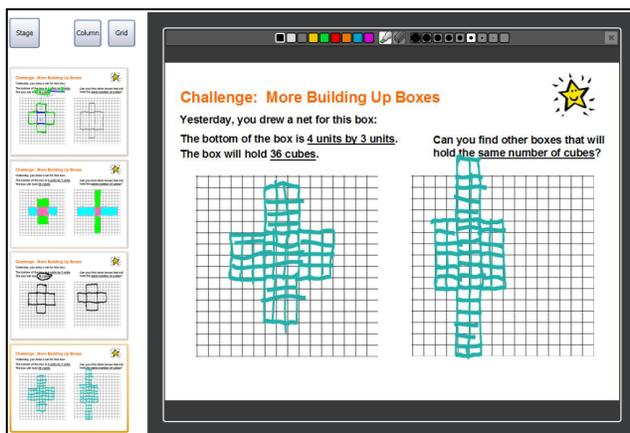
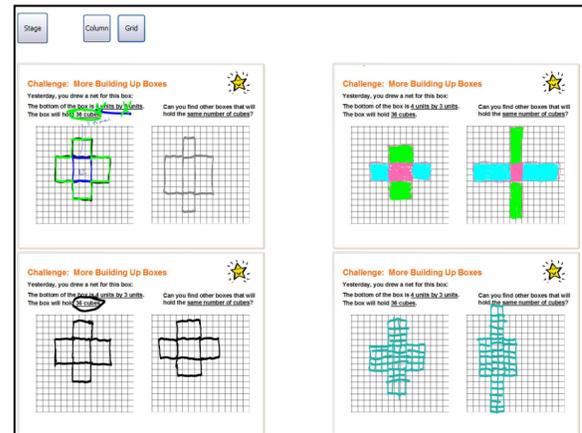


Figure 2. c. Can select Column and “zoom” in on work

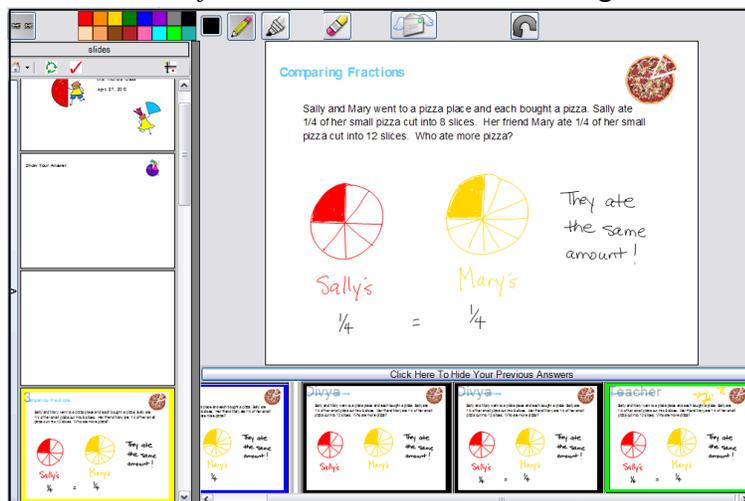


d. Can select Grid view to display all chosen

We also added a feature that enables the teacher to send ink only to the projector, not both public and student machines—students wanted to see the teacher’s annotations on the public screen, but

most became incensed when the teacher’s ink showed up on their slides! We added features that enable the teacher privately view and annotate student submissions, and send the annotated slides back to students without other students seeing her comments.

Student’s features: We made three changes to the elementary student’s view of the screen:



added a color palette, which we also incorporated into the teacher’s view; removed distracting commands (lasso, highlighter, erase all); and added a history panel, which students can hide or reveal, that enables them to view and restore their submissions and to view messages from their teacher. (See Figure 3.) For middle school students, the interface is similar: We only removed the highlighter, which, even though useful, proves distracting even for adults!

Figure 3. Student view; history shows current slide (far left), submissions, teacher message (far right)

4. EVALUATION

The INK-12 project team has conducted tablet computing trials in eight schools—six 4th, one 6th, and three 8th grade teachers’ classrooms, working with a total of 400 students.

School System/School	Grade	Length of time	Class size	Topics
Lexington/Fiske	4	1 day	22	Graphing scientific data
Lexington/Bridge	4	1 day	23	Graphing scientific data
Cambridge/Baldwin	4	4 days	18	Math, test prep for math & language arts state tests
Cambridge/Baldwin	4	4 days	18	Math, test prep for math & language arts state tests
Lexington/Clarke	8	5 days/5 classes each day	20	Physics
Lexington/Clarke	8	5 days/5 classes each day	20	Algebra
Cambridge/Amigos	8	3 days/2 classes each day	22	Algebra
Waltham/Northeast	4	two 3-day trials	20	Math (fractions), science
Waltham/Kennedy	6	3 days/4 classes each day	21	Science
Newton/Cabot	4	3 days	23	Math

Figure 4. Schedule of our classroom trials Fall 2008 to Spring 2010 in 4th, 6th, and 8th grade classrooms

4.1 Study Design

During each of these trials, the project team helped teachers adapt their lessons to make best use of the tablets; in most cases, the teachers did not deviate from their planned lessons, but rather extended and deepened them using the tablet capabilities. Project staff helped teachers think strategically about pacing the lesson, accommodating different types of learners, and dealing with unexpected technological challenges. Teachers needed the most help planning how

to choose and use student work; they needed support in both technological aspects (how to navigate the student submission system) and pedagogical considerations (how to choose appropriate work examples).

Data collection included formal observation of classes using an observation protocol, post-residency interview with participating teachers, student focus group discussions, inventory analysis of student work samples, and student evaluations collected at end of residencies.

4.2 Classroom Observations

The following classroom behaviors were encoded and included in the analyses: lecture, demonstration, lecture with discussion, class discussion, small group discussion, teacher interacting with student, tablet technology use, hands-on activity (non-computer), revising work, sending/receiving wireless data, interruption, passive learning, active learning.

Our findings suggest that overall students were highly engaged (85% of the time). They also suggest that INK-12 tablet sessions provide ample classroom opportunities for interactive instructional methods (lecture with discussion), increased communication and feedback (send/receiving wireless data), and engaging students in active learning. Students adapted quickly to the tablet interface; very little class time was spent in technology training or support.

4.3 Teacher Reflections

Teachers felt that the tablets were easy to use from the beginning; most had less than 30 minutes of training and quickly adapted their teaching style to instruct with the tablets. They unanimously reported that students were motivated to use the tablets, to try activities normally completed with paper and pencil. The teachers felt that tablet use changed the way the teaching and learning occurred in their classrooms, but were reluctant to postulate that student outcomes, retention, or performance improved as a result of using the tablets. All teachers, however, felt that they wanted to continue using the technology and to develop more sophisticated and longer curriculum units in order to investigate how student learning is affected. All teachers felt that increased student engagement, focus, questioning, and work completion as a result of tablet use directly led to increased active student participation in the learning process, which they felt, if continued, would result in improved outcomes. Several teachers identified ways they saw the tablets providing options for teaching a lesson, providing a variety of entry points for different kinds of learners, e.g., those who: like technology, like communicating, didn't like writing but liked drawing, were shy, were slower, or who typically didn't complete assignments.

4.4 Student Comments

Students were asked to respond to questions related to their experiences with the tablets. The greatest number of student comments mentioned the assets of receiving fast feedback from the teacher, ease of erasing on the tablet, varied visual representations possible with the colors and pen shapes, how they thought the technology helped cover more material than they normally did, and the importance of seeing other students' answers publicly. In addition, when we asked if they preferred to have their name on their publicly displayed work, 78% of those who responded said either yes or that it didn't matter; 22% responded that they preferred anonymity.

4.5 Summary

Overall, students seemed very engaged, not just during the first "novelty" moments, and excitement resulted in increased participation. The drawing component provided an alternative input to handwriting or typing, and proved popular and successful with all kinds of students, especially those in the lower academic sector. Student sharing of work provided a classroom

context that invited discussion and student-led explanations. Teachers were unanimously enthusiastic about using and developing lessons specifically for the tablets. They suggested features, improvements, and thought of many potential uses beyond those specified by the project. All felt to some extent that wider and longer-term use was possible within their classrooms, and would be eager to continue trialing the technology should the opportunity arise.

What we have learned from teachers and students is that the INK-12 tablet computing environment has much to offer classrooms, at both the elementary and middle school grade levels. Classroom learning characteristics represent many of those associated with project-based learning, interactive instruction, active learning, and inquiry-based learning. Students respond well, in particular to those elements social in nature, e.g., publicly sharing work and communicating with the teacher via wireless networking.

We also learned that several issues need further work. The slide metaphor was too restrictive at times: Students sometimes needed more answer space than provided by one slide; an electronic notebook metaphor may prove more appropriate. At times teachers wanted students to be able to construct representations that were more accurate than could be drawn by hand, e.g., an equilateral triangle. In addition, teachers found it challenging to select student work for public display; some chose randomly, others chose by student, some felt more comfortable looking at student work after class and displaying student work the following day.

5. FUTURE WORK

The project team has just been awarded a 4-year NSF grant to continue studying the use of INK-12 technology in K-12 classrooms. The upcoming work will target upper elementary math and science and will focus on (1) developing the technology, monitoring teacher and student responses in order to inform the development process; and (2) collecting data as empirical evidence about such technology's effect on teaching and learning in K-12 STEM education

6. ACKNOWLEDGMENTS

This research was funded by NSF DRK-12 collaborative awards DRL-0822278 (Koile), DRL-0822055 (Rubin); many thanks to program officer Michael Haney for his support. The PIs gratefully acknowledge the contributions from members of the MIT CLP research group: Steve Diles, Neil Chao, Martyna Jozwiak, Brandon Pung, Brian Wheeler, William Gaviria. At TERC, we thank Swapna Reddy and Tracey Wright for classroom and logistical support.

7. REFERENCES

- [1] Anderson, R., et. al. Experiences with a Tablet PC Based Lecture Presentation System in Computer Science Courses, in *Proceedings of SIGCSE 2004*. <<http://classroompresenter.cs.washington.edu/>>
- [2] Anderson, R. et. al. Classroom Presenter: Enhancing Interactive Education with Digital Ink. *Computer*. Los Alamitos, CA: IEEE Computer Society. 40 (9), 56-61.
- [3] Koile K., et. al. Supporting Feedback and Assessment of Digital Ink Answers to In-Class Exercises. In *Proceedings of IAAI 2007*.
- [4] Koile, K., et al. Supporting Pen-Based Classroom Interaction: New Findings and Functionality for Classroom Learning Partner. *Proceedings of the First International Workshop on Pen-Based Learning Technologies 2007*.
- [5] Koile, K. and Singer, D. Assessing the Impact of a Tablet-PC-based Classroom Interaction System. In *Proceedings of WIPTE 2008*.