

Integration of Multimedia into Tablet-based Science and Math Notebooks for Elementary Education Using Classroom Learning Partner

Claire M. DeRosa

Advisor: Dr. Kimberle Koile

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1. Introduction

The Road to 21st Century Learning: A Policymaker's Guide to 21st Century Skills states, "To thrive in the world today, students need higher-end skills, such as the ability to communicate effectively beyond their peer groups, analyze complex information from multiple sources, write or present well-reasoned arguments about nuanced issues and develop solutions to interdisciplinary problems that have no one right answer. In this light, technology is a powerful springboard to higher-level learning."¹

It is inevitable that technology will make its way into our children's classrooms in the same way it has infiltrated nearly every other aspect of our lives. The ultimate goal is to usher technology into the educational setting in a way that enhances the traditional curriculum by facilitating teacher and student communication and inciting curiosity in children to learn and explore. Classroom Learning Partner is a project at the forefront of that mission. The use of tablets in contrast with traditional pen and paper as an educational medium represents a potentially significant endeavor to both enhance learning through technology, as well as to familiarize students with the use of technology as an integral component of the skill set

¹ *The Road to 21st Century Learning: A Policymaker's Guide to 21st Century Skills* (2003) is available online at http://www.21stcenturyskills.org/images/stories/otherdocs/p21up_Policy_Paper.pdf

necessary to excel in our 21st century society and higher educational system. Multimedia is one of the ways that the tablet's abilities can be leveraged to enhance the learning experience and engage students on a level that may not be as accessible through traditional means.

In this paper, I will give discuss the Classroom Learning Partner (CLP) project and explain its role in the classroom. I will then introduce my contribution to the project and present a description of the multimedia integrated into CLP for this project along with a scenario to demonstrate how this would be used in the classroom. Finally there will be a discussion of contributions and future work.

2. Background

Classroom Learning Partner (CLP) is a software system for use in classrooms run on tablet-PCs developed by Dr. Kimberle Koile's research group. CLP enables fast and seamless communication between teacher and students by transmitting information from student to teacher laptop and back over a wireless network. CLP has been developed for use in 4th and 8th grade classrooms. The current version of CLP features a notebook metaphor, which will aid students in understanding the role of this technology in their learning.

2.1 Classroom Learning Partner

Classroom Learning Partner(CLП) is a software system run on tablet-PCs in classrooms to facilitate the educational process by allowing students to track and share their own work, as well as enabling teachers to quickly and effectively review the submissions from students and use the class's own submissions as learning tools. The current target age is elementary school classes, specifically focused on fourth grade students for the Spring 2011 semester.

The application is presented to the students as their own personal notebook. The work is done on individual pages that can be sequentially searched. We hope that this notebook metaphor will ease the transition from paper and pencil to tablet and stylus for the teachers and students. The students interact with the laptop only in tablet position with the keyboard not visible. They can use either the stylus or their finger to interact with the application to complete exercises. Which mode of interaction is better suited for specific tasks is still being explored and also drives some user interface decisions.

An important component of CLP is the ability of the teacher to analyze and sort student submissions based on certain features that she defines. This allows the teacher to quickly review the students' submissions and recognize if some students have unique methods for solving a problem. The teacher can choose to project certain submissions or exercises onto the board for the class to discuss. These exercises often turn into useful peer learning exercises where many children contribute to solving a problem. For the sorting of submissions to be possible, the submissions must have relevant information that can be extracted and sorted on. This is an issue to consider when integrating new media into the notebook.

The development platform used for CLP is C# and Windows Presentation Foundation (WPF). Although not technical, the curriculum is an integral part of the project and the design of the notebook should consider the content and grade levels for which CLP will be used. Thus the project is collaboration between MIT and curriculum and education experts from TERC, The Education Resource Center, who are helping us design the software to allow smooth integration of age-appropriate curriculum.

2.2 System Overview

The system was run on 30 Lenovo ThinkPad X Series tablets with both touch and pen input enabled. There are three modes of running CLP: Student, Instructor, and Projector. The teacher runs the Instructor mode, while each student runs their own instance of Student mode. There is one tablet running in Projector mode to project selected examples of exercise and student submissions onto a board for public display and discussion.

The goal of CLP is to provide each student with his or her own personal tablet that acts as their science and math notebook for the year. Design decisions were made to the user interface to reinforce the notion that this tablet should be treated as a lab notebook that students can refer back to and record data in throughout the year. Math and science exercises can be created by the teacher for each lesson. The tablets also provide a way to organize student work which is much more manageable than the traditional use of worksheets to do math and science exercises.

Students, teachers, and parents can use the CLP tablet to access all of a student's work from the entire year and easily observe progress.



A fourth grade student working on a math exercise in her CLP math notebook

3. Multimedia in CLP

Two types of multimedia were explored for integration into CLP for this project: Games and the use of cameras to take digital photographs were used with CLP in classrooms.

3.1 Games

The two main considerations that dictate which games are selected for use with CLP are the curriculum value and the integration feasibility. The game must have some educational merit in that there needs to be some way to incorporate gameplay into the context of the lesson and relate the game to topics or concepts taught in the classroom. There are many ways that a game can be incorporated into a curriculum and extensive research on the subject is ongoing at the Education Arcade at MIT (Klopfer & Osterweil, 2009). Since the tablet is a science notebook for students and because teachers, as well as our algorithms, need some way to evaluate the progress of the students, it is very important for work to be recorded and saved. The form of the saved data varies based on the level of control we have over the game's source code.

A game for which the source code is open and available to us as developers is more valuable to the CLP project than a game that is proprietary and thus the source is not available. A game that the developers have access to can provide more meaningful and detailed information about the student's actions and progress during the game. This is important because the system classifies student work based on certain features and presents the data to the teacher in a useful representation. Important features can be more easily extracted from open source than from a black-box application.

An example of this difference in access is between a classic Sudoku game and Crayon Physics (<http://www.crayonphysics.com/>). The Sudoku game is an open source C# application

from which we can extract exactly which number the student placed in which boxes and whether that was correct or incorrect by simply adding event listeners for the events of interest. In contrast, to track the progress of Crayon Physics, which is a black-box application, we have little information that is easily accessible and interpretable other than the images on the screen during gameplay. For these games the best solution at the moment for recording progress is to take screenshots of the game at interesting points during gameplay. This requires the student to take pictures while they are concentrating on the game, which is not ideal.

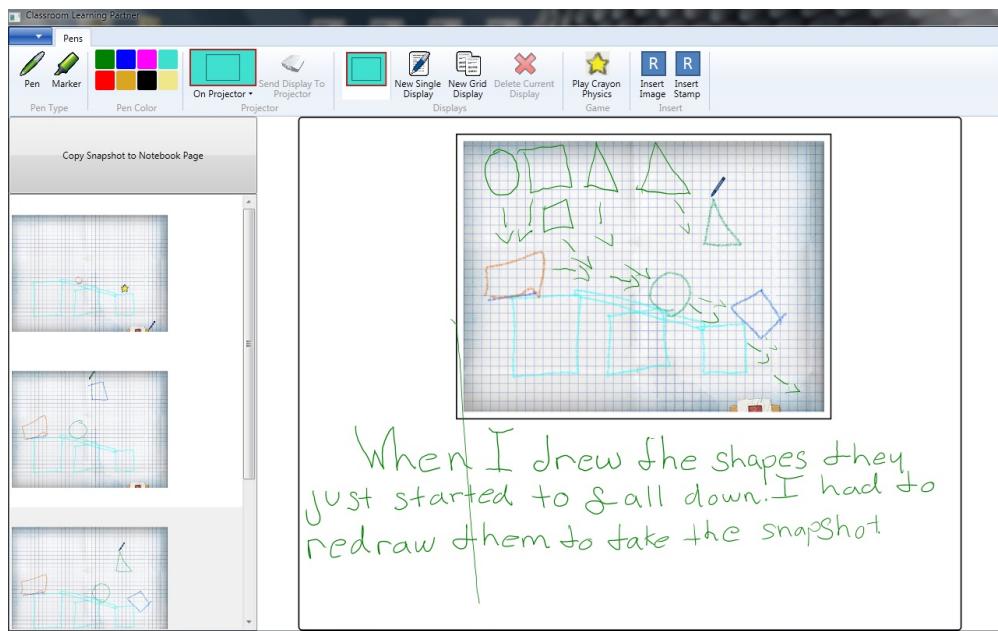


Figure 1. The view of the student notebook after playing Crayon Physics and writing an explanation of an exercise in the game

The student notebook shows all of the snapshots taken while playing the game in the left window. A selected picture can be moved to the page by clicking the large gray button on the left. The snapshot can then be annotated and drawn on by the student. As for the student whose example is presented in Figure 1, the task of taking a snapshot during continuous gameplay can be frustrating, which he/she expresses in the explanation that, "I had to redraw them[the shapes]

to take the snapshot.” The bottom square, circle, and triangle are the original shapes drawn by the student in the game. The green shapes and arrows are the annotations made by the student when the picture was inserted into the notebook to explain what happened.

3.2 Photographs

Webcams were integrated into the notebook application to enable students to easily take pictures of real world phenomena and seamlessly embed these photographs in their notebooks. This allows students to document things from the real world in their digital notebook. Like the screenshots, these pictures can be annotated to provide visual as well as textual ways for students to explore the concepts and phenomenon.

The use of real life photographs to help students express themselves while explaining a new physical concept is especially useful for elementary school students. At the ages of 10 to 11 years, most children are reaching mastery of spatial relation, perceptual skills and motor planning. (Lane, 2005: 110-114) Drawing an accurate depiction of a phenomenon or situation may be frustrating for students who cannot convey their thoughts due to a bad drawing. It would benefit these children to provide real photographs for them to use in explanations to remove the barrier of drawing. Photographs are not intended to replace student drawings but rather to supplement drawings where it would be beneficial.

4. Scenario

To demonstrate how games and photographs can be incorporated into a lesson we will walk through a lesson about the concepts of gravity and friction. These concepts will be introduced through a lab experiment in which students measure the response of rolling an

object down a ramp as the height is varied. This lesson has three stages; the investigation, pre-lab, and experiment stages.

4.1 Investigation

First, the students are asked an investigation question prompting them to predict how the height of a ramp affects the distance a car travels after it leaves the bottom of the ramp.

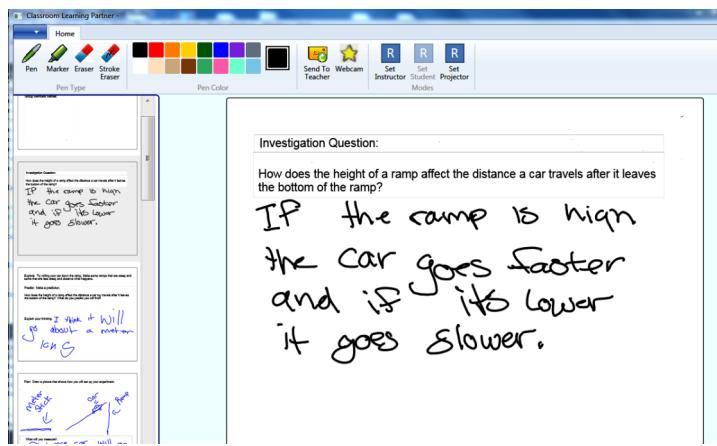
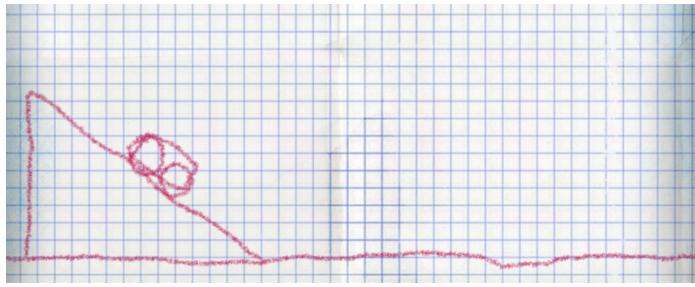


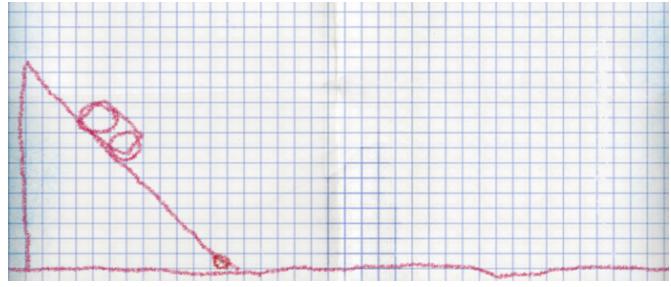
Figure 2. The initial prediction stage of the lab and a student response

4.2 Pre-Lab

Next, as a pre-lab exercise, the students use Crayon Physics to simulate the ramp experiment. Crayon Physics is a 2D physics puzzle game produced by KlooniGames created by Petri Purho. The game allows the player to draw shapes that are “magically transformed into real physical objects.” The students are instructed to use Crayon Physics to test their hypothesis and make decisions about how they will setup the real experiment.



(a)



(b)

Figure 3. Pre-lab testing done by the students in the Crayon Physics environment as a simulation tool

Figure 3a shows a shorter ramp, and Figure 3b shows a taller and steeper ramp.

The students are encouraged to try changing different parameters (angle, height, car size, etc.) in Crayon Physics and to note the response of the car. This exercise should lead to a better understanding of the system components that they are working with. A solid base knowledge of the ramp and car system enables the students to create and plan a more effective experiment, as shown in Figure 4. The students have designed an experimental setup based on the results observed during the simulation.

Explore: Try rolling your car down the ramp. Make some ramps that are steep and some that are less steep and observe what happens.

Plan: Draw a picture that shows how you will set up your experiment.

Predict: Make a prediction.

How does the height of a ramp affect the distance a car toy travels after it leaves the bottom of the ramp? What do you predict you will find?

The car will get more speed.

Explain your thinking.

The car will get more speed because it would be easier for the car to go down.



What will you measure?

I will measure the distance the car rolls when it comes off the ramp.

Figure 4. The prediction and experimental setup completed by students after simulating the experiment with Crayon Physics

4.3 Experiment

In the third stage, students carry out the experiment. They are placed in groups of three to four students assigned by the teacher and each is given a role. Each group has a student to perform the responsibilities of recorder, measurer and car holder, and consistency patrol if there are four students. They are given cardboard to use as ramps as well as a Lego car and a yardstick. Each group also has one tablet and a webcam. The students set up the ramp, piling books under the end then measure the height of the top of the ramp. They then drop the car from the top of the ramp and measure how far from the end of the cardboard the car rolls and the recorder writes down the measurements in the tablet. They repeat at the same height for two more trials then either add or remove books to change the height of the ramp and repeat the process. During the experiment, the students are prompted not only to record numerical results in the results table but also to document their methods using the webcam.

Collect data _____

Kind of car: LEGO or wood? _____

Ramp Height (centimeters)	Distance (meters)			
	Trial 1	Trial 2	Trial 3	Median
41 cm	2.5 cm	18.4 cm	18.0 cm	18.4 cm
38 cm	16.6 cm	16.6 cm	17.9 cm	16.6 cm

Figure 5. Examples of student data recorded during the ramp experiment

Set up: What does your setup look like?

Take a photo of your setup, and put the photo on this page.

See if you can get the car in the photo!

Write on the photo to label the parts you'll use in your experiment.



(a)

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See if you can get the car in the photo!

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(b)

Figure 6. Pictures taken by students of their experimental setup using the webcam.

The photographs are automatically embedded into the notebook and are used as another representation for students to explain the concepts they are learning. Figure 6a is a photograph that the students decided to take from a side view. This allows the photograph to show the books piled under the ramp as well as the starting point of the car at the top of the ramp. Figure 6b shows another approach where the photograph is taken from a different angle than Figure 6a, however this group used the functionality of the tablet to annotate their photograph to label components of their setup. The ability to annotate a photograph to enable the expression of the

students' ideas can be especially useful for elementary students for whom accurately drawing the experiment might be a challenge.

5. User Interface Design

When integrating new technologies into the CLP notebooks, it is important to maintain the notebook metaphor. The user interface of the entire CLP project has been designed to look and feel like a notebook rather than a computer in that it has pages and is used with pen input as opposed to mouse or keyboard input. The technologies that are incorporated to allow multimedia representations to be integrated in these notebooks must maintain the notion of the tablet as a notebook and our design choices reflect this.

The webcam is started from a button embedded in the notebook. When the webcam button is tapped on with the pen or finger, a new window appears that has the webcam view in the top left portion of the window and a “Take Snapshot” button below. The students have a small webcam connected via USB that they can aim at the target of the photograph. The large viewer allows them to see the image before taking a photograph. The photograph is taken by using either the pen or a finger to tap the large “Take Snapshot” button(Figure 7). An analogy can be drawn between the webcam in the notebook and a normal handheld camera that is reinforced by allowing the snapshot to be taken by a simple tap of the finger, much like the button is pressed to take a picture on a normal camera. The right hand side of the webcam window shows all of the snapshots that have been taken in the current instance of the webcam window. Students can easily scroll through the images and remember which aspects of the experiment they have or have not captured images of yet.

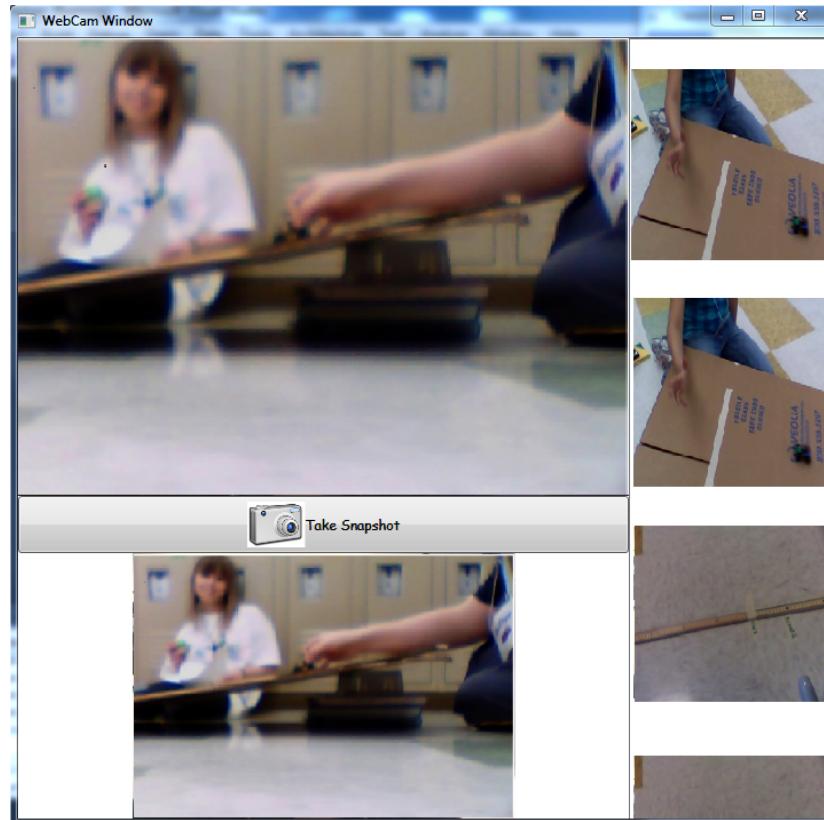


Figure 7. The webcam window during the ramp experiment

After the students have completed collecting photographs, the webcam window is closed. The pictures are shown in a scrollable sidebar in the side of their notebook page, as shown below in Figure 8. A picture can be easily selected by tapping on the picture and inserted into the notebook by tapping the “Put Selected Photo on Page” button at the top of the sidebar. The photo is then inserted into the page in the top right corner, a location specified by the teacher while creating the exercise.

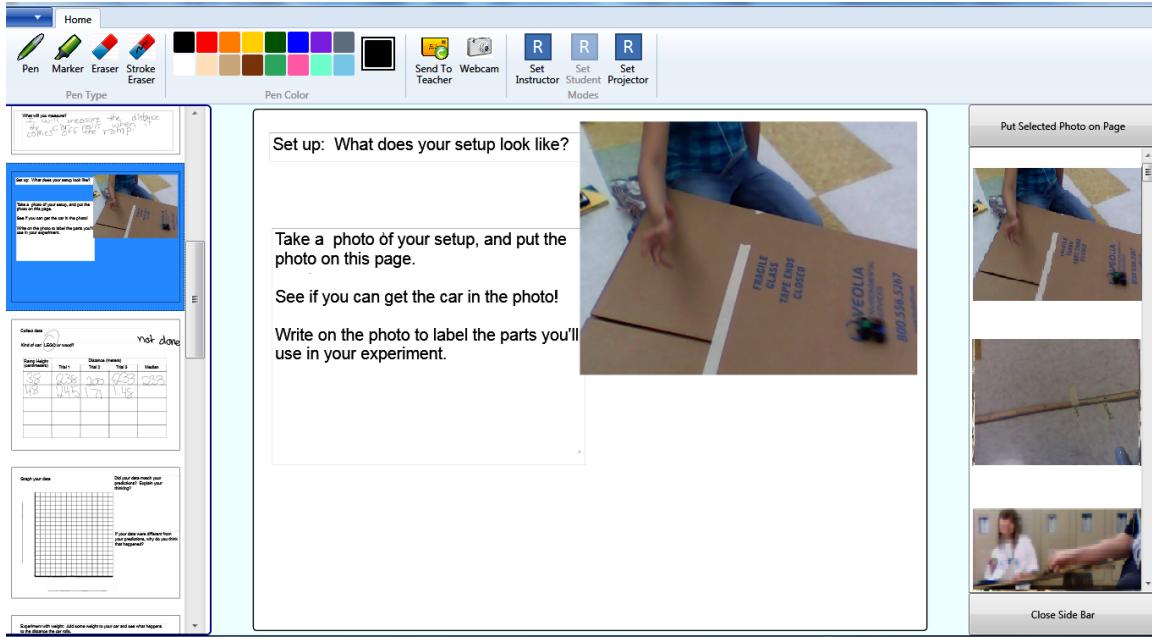


Figure 8. The view of the notebook after the webcam is used to take pictures

6. Contributions

The work described in this report contributes to Classroom Learning Partner in that it demonstrates a way in which a “black box” application and external hardware can be incorporated into CLP and used to enhance the learning process.

6.1 “Black box” Application

When searching for the best multimedia materials to use effectively alongside curriculum, it is very likely that there are some great resources made by third party vendors or developers that we want to use in CLP. Sometimes these applications are open-source, in which case we as developers have some control over where and how the program is run. This usually also gives us access to information about the user interaction with the program and we can extract some meaningful data about the user’s actions to be presented to the teacher as a record of student work. However, if the source code is not available, i.e. this is a “black box”

application; we have little control over the environment the application can be run in and the information that can be accessed about user interaction. This was the case with Crayon Physics. The game could not be forced into a window that could also include a WPF sidebar to show the screenshots that had been taken (as in the right pane of the webcam view in Figure 7). Instead, a new window is placed next to the Crayon Physics window. This did not prove to be much of a problem for students using the software, but it demonstrates some of the limitations of working with a third party application. The only data we could extract from Crayon Physics was in screenshot form. This was due to both the lack of access we had to the code and the complex nature of Crayon Physics activity. An action by the user requires many details about the context and other actions both before and after the given action. This work shows that screenshots can be an effective way for students to document their work in a simulation such as Crayon Physics and can help them explain their actions and reasoning afterwards.

6.2 External Hardware

This work contributed proof that external hardware can be integrated into the CLP framework to bridge the gap between real world and the tablets. By using a webcam to take pictures of their own experiments the students can document their own experiment as opposed to being limited to drawing a diagram or using a stock image to annotate. Integration of the external hardware requires compatible drivers as well as a few additional DLLs to enable the full functionality of the webcam from the CLP application. This work creates opportunities to easily integrate video functionality alongside the photograph capabilities as well as leads the way for integration of other types of hardware

7. Future work

There are many exciting opportunities and options when considering the future of bringing multimedia into classrooms through CLP. There are improvements that can be made on the current features that have already been integrated, as well as new types of features such as videos and simulations that can be incorporated into the project.

To improve the current implementation, I would make modifications to integrate the technology more smoothly into the application. The webcam currently pops up as a new window to take pictures, however it would appear to be a part of the notebook if window was embedded into the notebook page itself instead of in a new window. This is also an issue in Crayon Physics, where the game is intended for play in a full screen mode. Currently, both the webcam and Crayon Physics are launched from a button within the notebook but take the student “outside” the notebook for use, then immediately the student is returned to the notebook after the task is completed.

Another design choice that needs further exploration is the use of finger and stylus to interact with the notebook components. Through user testing, it was apparent that some elements of the interface needed to be changed, such as scroll bars that were too narrow to slide with a finger, but not intuitive to manipulate with a pen. The size of some buttons will dictate whether students are inclined to use their finger or pen to tap it. In general, tasks that are meant to leave ink on the page should be performed with the pen whereas actions such as selecting a button or turning a page are better suited for the finger.

We are interested in exploring any other types of multimedia that could be used to enhance the learning experience of students, especially those that will take advantage of the pen-

based input feature of the tablets. In the next year, I hope to help integrate video and interactive simulations for classroom use with CLP.

The framework to technically integrate video into CLP would be similar to the way webcam photographs are integrated. The same webcams used for taking snapshots have the functionality to capture video. Video can be used to record a phenomena or experiment; one could imagine the students taking video of the car rolling down the ramp in the scenario described in Section 4.3, for example. Frames of the video could be annotated by students much like the photographs. The speed of a digital video could also be varied as a tool to show slow motion or various stages of an event or process. Video could become a different and interesting means to communicate information, for example students could record a video of themselves describing a concept or explaining a story. This video recording could be played later on the projector for the whole class to see and can also be saved for the whole year so students can watch a video of themselves to be reminded of topics covered earlier in the year.

Simulations have been known as a way to bring aspects of the real world to classrooms, and as such there are many benefits to incorporating simulations into CLP. More specifically, we hope to bring interactive simulations to the notebook. Crayon Physics is one example of an interactive physical simulation in that the students draw shapes in the Crayon Physics environment and the forces of physics are applied to those objects as soon as the pen is lifted, allowing students to see the response of the system under varying inputs. Simulations are most pedagogically useful when they represent something that the students will not be able to recreate or try in the classroom either because it is dangerous, too small to observe, expensive, or takes a long time to see results. For example, the ramp experiment could easily be performed in the classroom so a simulation may add little educational value compared to the real experiment, but

to observe the movement of tectonic plates or the reason for the tides a simulation is the most practical way to become familiarized with these kinds of phenomena.

There are many exciting potential multimedia features we could add to CLP. There are two important factors in choosing which features to implement. The effectiveness of these new components in enhancing the curriculum will be an important factor as well as the access we have as developers to the source code of this software to be able to integrate it and extract meaningful data from it about the student's interactions with the feature.

8. References

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