Student-Owned Devices for Classroom-wide Communication and Collaboration

J. Ben Schafer and Stephen Hughes
Department of Computer Science
University of Northern Iowa
Cedar Falls, IA 50614-0507
schafer@cs.uni.edu

Abstract

It has become commonplace in college classrooms for students to regularly bring some form of computing device. For example, current reports indicate that upwards of 60% of college students own and carry smartphones. The future of technology enabled college classrooms is no longer an existential question, but rather one of degree. While it is evident to many that such devices can extend students' reach to the global network, it is often overlooked that these devices can also foster collaboration and communication within the classroom itself. This paper discusses the development of an open software infrastructure developed to facilitate classroom-wide communication between student-owned mobile devices. Our goal with this project was to attempt to close the gap between the potential of the smartphone and the level of interactivity currently provided by standard classroom response systems. We have built a system that takes a student response system – where each student in the room controls a device which allows them to participate in "large room" assessment – and extends this concept to move collaborative activity to shared discovery and inquiry. Our main goal with this project is to shift the technology focus in the classroom from a scenario where the individuals in a class are interacting with the technology, to one where the class is interacting with each other through the technology.

1 Motivation and Background

1.1 Computer Supported Collaborative Learning

A natural emphasis on technology in the classroom over the past decades has been the development of computer-based instruction. Under this model, students are encouraged to work at their own pace with computer software facilitating learning with challenges and remediation as necessary. This popular approach has led to the call for technology enhanced classrooms and so called 1:1 initiatives which aim to provide each student with their own laptop. However, a potentially harmful side-effect of this model is for students to be channeled by individual activities and become cut-off from their peers (McGrail, 2007). An alternative approach, Computer Supported Collaborative Learning (CSCL) attempts to actively promote social interaction in the classroom through the use of technology. This effort is grounded in the educational theory of "Communities of Practice" (Wenger, 1998), which characterizes support for group-based and collaborative learning. The implementation of collaboration systems have traditionally been limited by the dependence on expensive, task-specific hardware (Myers B. A., 2002), although that has begun to change with the arrival of low-cost, generalizable mobile computing. Two particular methodologies seem relevant to the work we are discussing – Classroom Response Systems and Single Display Groupware.

1.1.1 Classroom Response Systems

Classroom response systems, colloquially referred to as "clickers", allow students to quickly and anonymously submit feedback to questions that are submitted during class. Responses are collected and typically displayed to the class, allowing a teacher to quickly assess the understanding of the class as a whole and for the students to also be aware of other perspectives. Any disparities can be discussed and resolved in real time before moving on the next topic or problem. Although the technology for recording audience participation has been in existence since the mid-1960s, recent advances in wireless technology have lead to a renaissance in commercial viability and interest in integrating this technology into the classroom. Proponents of this technology argue that clickers can enhance the classroom experience by actively engaging students, immediately gauging their level of understanding and providing prompt feedback (Martyn, 2007). Other benefits include an increase in participation, attention and overall engagement during classroom activities (Lantz, 2010). There are numerous clicker hardware solutions available, including: iClicker (iclicker, 2011), Promethean (Promethean, 2011), eInstruction (eInstruction, 2011) and SmartResponse (Smart, 2011), with each of these systems requiring the purchase of dedicated hardware at a cost of approximately $25 - $45 per unit. While the unit is compatible with any classroom using that system, the device itself serves no additional purpose.

1.1.2 Single Display Groupware

Single Display Groupware (SDG) is another critical contribution to CSCL. This model comprises multiple input devices that maintain an independent connection to a single shared display (Stewart, Bederson, & Druin, 1999). This allows users who are colocated, such as students in a classroom, to visually inspect and manipulate a shared a common model. SDG has been widely adopted in CSCL systems, but even at its inception, the authors warned of several trade-offs with this technology. These tradeoffs centered on the potential for "conflicts and frustrations" that stemmed from inconsistent actions and intentions. Modern implementations still need to account for these possibilities and focus on supporting interaction strategies for their users that can mitigate these latent faults.

1.2 Bring-Your-Own-Device

It has become commonplace in college classrooms for students to voluntarily bring some form of mobile computing device with them. These devices span a wide range of power, capabilities and platforms, from smartphones to laptops. By virtue of reports that upwards of 60% of college students own and carry smartphones (Truong, 2010), the future of technology enabled college classrooms is realistically no longer an existential question, but rather one of degree. Educators who wish to tap into these resources have branded their efforts and emerging practices as Bring-Your-Own-Device (BYOD). BYOD is a potentially transformative movement that could dramatically hasten the integration of technology into the classroom. This approach could help schools to realize the benefits of 1:1 initiatives while relaxing some of their budgetary obligations. However, as with any change, there is resistance. Cell phones are often seen as disruptive and banned from many classrooms. Much of the discussion surrounding BYOD programs focuses establishing boundaries and acceptable use policies to allow this technology to be accepted (Meech, 2011).

The pedagogical arguments for BYOD are still in their infancy and consist largely of anecdotal, abstract or qualitative reports (Ash, 2010). Proponents suggest that BYOD allow students use their personally owned devices to access online information; leverage the device capabilities such as cameras or microphones; and run educational software (Schachter, 2009). As with many 1:1 programs, these benefits emphasize personalization of the student's educational experience. However, McGrail observes that with personalization, there is an increased risk that students become engaged in cut-off from the teacher and their peers (McGrail, 2007).

The CSCL community envisions a classroom environment where students are encouraged to interact through the technology rather than strictly with the technology. While students are able to use their own devices to individually connect to the outside world from the classroom, a major thrust of BYOD classrooms should be to effectively using the technology to collaborate with their peers. Surely the devices support a range of connectivity capabilities such as telephony, SMS (text messaging), Wi-Fi and Bluetooth. The challenge is how to harness this technology in a coordinated effort to promote learning.

1.3 Smartphones as Input Devices

As the collaborative potential of these devices receives more scrutiny, it becomes more critical for interaction strategies to be understood. Numerous studies, including (Zurita &

Nussbaum, 2004), (Lie & Kao, 2007) and (Yang & Lin, 2010) motivate the need and explore the benefits for connecting handheld devices to a shared display. These approaches allow class members to better understand the workspace or visual focus of their peers, leading to a better "shared conception of the problem", which is the heart of collaborative learning activities (Rochelle & Teasley, 1995). However, shared viewing is only half of the collaboration equation.

Smartphones and their progenitor, the personal data assistant (PDA), have long been recognized for a duality in their purpose. Not only do they have the ability to extend an individual computing environment to the user's current location, but they also provide a mobile user interface, allowing the user to interact with situated computing resources (Myers, Stiel, & Gargiulo, 1999) (Myers B. A., 2002) (Ballagas, Borchers, Rohs, & Sheridan, 2006). Using the device's touch screen to record the location and movement of the user's touch, mouse input can be provided in the same style as a touchpad, standard on most laptops (Durand, 2011). In fact, it can be observed that the 3 inch touch screen of a common smartphone is roughly the same dimensions as a touchpad, leading to the expectation that this kind of interaction would already be familiar to many users. Full keyboard capabilities are also available on smartphones and tablets. Although the keyboards on these devices are significantly smaller than standard keyboards, performance studies suggest that typists are still able to quickly gain proficiency of over 60 words per minute (Clarkson, Clawson, Lyons, & Starner, 2005).

2 Project Description

With existing classroom infrastructure (display technology and wireless communication) and the emergence of the BYOD paradigm for input devices, the modern classroom environment is ripe for a transformational shift toward collaboration technology. The immediate challenges to realizing this transformation are the lack of:

- A collaboration infrastructure that is openly accessible to potential BYOD practitioners
- Tangible case-studies and examples that model interaction styles
- Guidelines for best-practices that can maximize pedagogical value

This project proposes to develop, refine and distribute an open, extensible framework to support the integration of student-owned mobile devices with an existing classroom technology to support classroom collaboration. This section describes the architecture of the prototype infrastructure and identifies some broad interaction strategies that will guide refinement of future versions of this infrastructure.

2.1 Classroom Collaboration Infrastructure

To begin exploring the implications of mobile input on a shared display system, a prototype infrastructure has been designed and implemented. This system was originally designed from the perspective of implementing a Classroom Response System that could be extended to a) solicit and collect a wide spectrum of student input and b) allow the input put to be processed and interpreted generically. The architecture for this system (illustrated in Figure 1) consists of the following components:

Question Management Package – The software in this component allows an instructor to pose questions or invite students to interact with additional software. This component allows teachers to prepare questions in a variety of types and formats both during and prior to class. Such a system should "ask" questions of the class, or a subset of participants in the class, and manage the potential interaction, sequencing and branching of multiple questions.

Student Input Clients – These clients are software packages that run on the student devices. Upon receiving a question, the software in these components generates an appropriate graphical interface to collect input from the student. It is important to note that the composition of the interface is dependent on the type of question asked. In its most basic form, the client can display a set of multiple-choice buttons, emulating a traditional classroom response system. However, a wide array of additional control widgets are also supported, including, sliders, dials, and dropdowns. As described earlier, these devices can also provide keyboard (either virtual or physical) and mouse or touch-screen functionality.

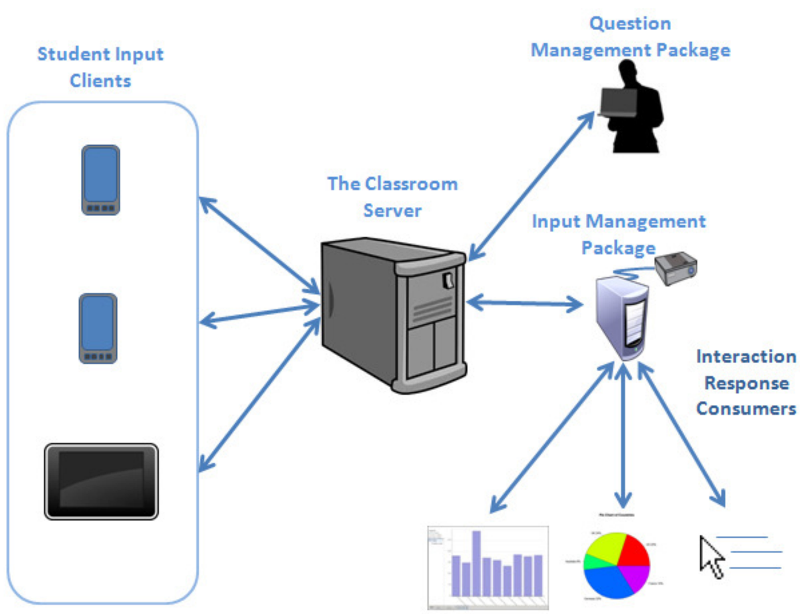

Figure 1 : System Architecture

Input Management Package – The software in this component gathers and pre-processes the responses from the Student Input Clients. It performs basic data aggregation services such as filtering, tallying and categorizing responses or providing simple statistical calculations such as mean, mode, minimum and maximum operations. The data is packaged into a standard API for use by additional components.

The Classroom Server – The components above need to be able to communicate with each other. The server provides a mechanism to allow each of the components listed to focus on its specific job and limit communication to be between the component and the server. The server coordinates message passing and data sharing between the separate components.

Interaction Response Consumers – These components allow for the processed responses to be displayed to the class. These consist of both stock visualization tools – such as distribution graphs/tables and word clouds – as well as custom visualization programs. Consumers can also allow student input to be interpreted as commands, acting as a bridge to specialized OS or API based events to trigger interaction in existing software.

The overall architecture of this system follows the general design pattern of a CSCL system, but there are two important distinctions.

1. Flexibility is built into both ends of the interaction pipeline. As described above, the client is responsible for building the student interface based on the question that it receives. The question types will be formalized in an API to ensure that a client is fully compliant. As new question types are identified and explored they can be added to API. On the display end, there is a critical refactoring that abstracts the processing of the input. This means that the input collected from the class can be interpreted differently according to the current needs of the teacher. For example, all the input could be directed to a bar graph showing the class response, the fastest response could be displayed, or input could be collectively interpreted as a single input command.

2. Unlike many collaborative systems where all participants are viewed as equal participants, this system explicitly recognizes that the teacher serves as a moderating presence. Additional support must be provided for delegating authority to users, granting and restricting access to shared resources and generally managing the flow of the shared experiences.

The current implementation of this prototype is built on the Android platform (Google, 2011). This option was chosen to allow for inexpensive development of this framework as a proof-of-concept. An extension to support iOS devices (Apple, Inc., 2011) is expected as part of the ongoing project work. The design attempts to avoid dependence on advanced or proprietary features in an attempt to maximize its potential audience. Specifically, the core feature set is intended to support devices with the following characteristics:

- Small screen (3.1 inches)
- Touch screen input
- Wireless connectivity
- Minimal storage

With the initial architecture for this system in place, attention must be turned to tuning and enhancing the system to support a diverse set of educational activities. The groundwork has been laid for an electronic question-response system. However the dynamic between teacher and student is much more complex than this simple back-and-forth. To be truly useful and gain teacher acceptance, the system needs to be capable of soliciting proper input, allowing students to respond effectively, and interpreting their input in meaningful ways.

2.2 Interaction Strategies

A critical innovation of the architecture described above is the ability to abstract the way student input is managed and interpreted. This development not only holds the potential for practicing teachers to customize the system according to their needs, but it also invites comparative research on the effectiveness of multiple interaction strategies. From a research perspective, some of these strategies are well understood and they can be revaluated for effectiveness in a BYOD classroom setting. Additional strategies have the potential to emerge from studying the dynamic created by a BYOD classroom. This section identifies several strategies that we have identified and hope to explore in more detail within the context of a classroom setting.

2.2.1 Shared Work Product

The most elementary form of interaction with this system is to identify an individual student and allow them to share their work product with the audience. In this scenario, a teacher would issue a request for a certain set of data, such as an image, file or URL, which would be submitted by a student input client. The input management package, directed by the teacher, would receive this data and display it to the class.

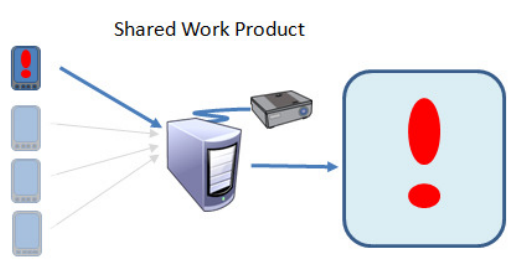

Figure 2 : Shared Work Product

The classroom value of this kind of interaction aligns with the common practice of having students sharing their solutions. It has the appeal of expediency; students do not need to copy their work to a whiteboard, or load their work onto a classroom computer, but rather can provide visual access to their work from their seats. While this interaction is very simple, it holds a lot of potential as more of our data is stored and accessed through the cloud. It is not unreasonable for students to have access to complex documents, spreadsheets or source code through a variety of popular products such as GoogleDocs (Google, 2011) or Dropbox (Dropbox, 2011).

2.2.2 Classroom Response Systems

Classroom response systems allow data to be collected and aggregated from an entire class. As previously noted, these systems have traditionally required the purchase of proprietary hardware, which generally limits student input to multiple choice selections. While this style of questioning can allow an instructor to quickly identify gaps in the class's understanding, the questions must be engineered deliberately to gain this insight.

Several applications have begun to emerge that allow students to use their mobile devices to emulate clicker hardware (PollEverywhere, 2011), (Socrative, 2011), (Turning Technologies, 2011). A common approach behind these apps is to rely on SMS responses (text messages) or to provide web-based forms that are accessible through a smartphone browser. However, these approaches have inherited the multiple choice mindset and fall short of the full potential afforded by smartphone interfaces.

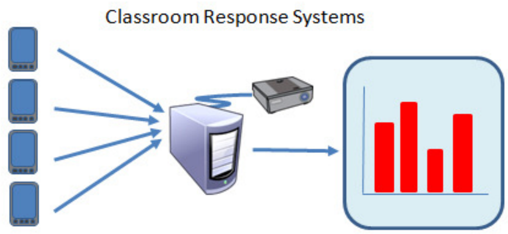

Figure 3 : Classroom Response Systems

In revisiting the opportunities for smartphone-based classroom response systems, the proposed infrastructure offers maximum flexibility. The smartphone offers a software-based interface that allows for numerous widgets, controls and input types to be combined and tested. It is even possible that sensor-based input, such as detecting the pose of the device can be used to collect feedback from the class. As part of this exploration, the output will be examined as well. Many classroom response systems default to sharing results through a bar graph because it is a natural mapping to multiple-choice responses. Given that alternative inputs will be considered, there is an opportunity to explore a variety of feedback displays.

2.2.3 Selected Individual Control

The previous two interaction strategies relied on groups and individuals providing input that is interpreted by the system as data. Interpreting student input as commands is another valuable organizing principle for interaction strategies. As with "Shared Work Product", it is easy to see that the proposed infrastructure can support the core functionality of an SDG system: multiple independent input channels connected via a shared output channel (Stewart, Bederson, & Druin, 1999). Many approaches have been identified for how the smartphone can be used as an input mechanism; a good review of these techniques can be found in (Ballagas, Borchers, Rohs, & Sheridan, 2006).

The management of the selected controller is a critical component of the overall interaction. It is probably desirable for the teacher to have the ability to designate a single user. This style of interaction parallels the "Shared Work Product" approach. Often when a student wants to share their work, there is a certain degree of manipulation (scrolling and zooming) and gesturing (pointing with the mouse cursor) that naturally accompanies this activity. However in a classroom setting, it may not be desirable to transfer full remote desktop authority to the student. Studying this interaction style in the context of a BYOD classroom should help to identify the balance points and conditions that determine the amount of control authority that teachers are willing to share with their students.

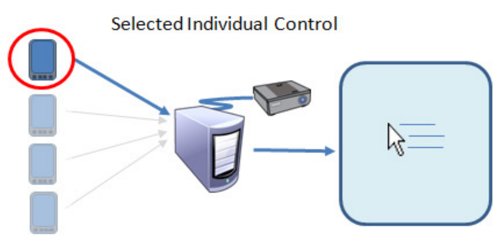

Figure 4 : Selected Individual Control

Alternatively, the selected controller can be designated by a automated manager that enforcing a turn-taking style of interaction. In this scenario, each user has the ability to direct interaction with the group display on their turn. Giving the teacher the ability to adjust the duration of turn, or the conditions for changing turns opens the potential several different classroom dynamics. By setting the duration of a turn to a relatively long duration, students have the ability perform a complex text or demonstrate a sequence of steps to their peers. With an intermediate duration, the teacher can add some urgency to student response: act quickly before your time is up. Finally, by setting the duration to very small units, interaction effectively adopts a time-sharing sharing model where students appear to simultaneously interact with the display. Teachers may also value the ability to transition turns based on task. A student is able to complete a unit of work, i.e. a selection task, or entering a block of input text before their turn is up.

2.2.4 Simultaneous Control

Extending the idea of "taking turns" even further, we can consider the value of scenarios where students are granted simultaneous control of the shared display through multiple mouse pointers. This approach is foundational to SDG, but has typically been explored with relatively small groups ($n < 5$). What are the implications of extending this kind of control to a classroom environment ($n>15$)?

Recently, Microsoft released "Mouse Mischief", a plug-in for PowerPoint that allows students to interact with a common display using their own wireless mouse (Microsoft Corporation, 2011). Each student controls a visually distinct mouse pointer on a shared screen to select answers or collaboratively draw on, circle or cross out regions on the screen. Many of the usage scenarios for this approach center on the concept of a visual swarm; students benefit from seeing a critical mass of their peers moving toward a selection region of the shared display (Moraveji, Inkpen, Cutrell, & Balakrishnan, 2009).

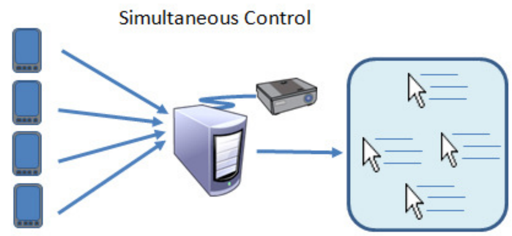

Figure 5 : Simultaneous Control

While this alters the mechanism for student response, the example effectively maps into a multiple-choice question scenario. At the other end of the interaction spectrum, students can be invited to use this technique to draw on a shared canvas. This scenario raises numerous interesting challenges to effective interaction, such as protocols for seizing and abdicating solitary/unique/unsharable resources and tracking the state or mode of an individual's input or even just tracking and identifying one's input location on the shared display. While students may engage in cooperative behavior, there is nothing inherent to the operation of the system that promotes or discourages this. It is possible for a dominant personality to shoulder the responsibility for completing a task. Likewise it is possible for partially complete, conflicting actions to be manifest on the same workspace. A skilled educator would need to be able manage both of these situations.

2.2.5 Collective Interaction

Another intriguing variation for managing collaborative activities is to ask the Input Management Package to enforce coordination policies. Krogh & Petersen (2010) coin the term "Collective Interaction" to describe the natural phenomenon of individuals deliberately coordinating their input to achieve more complicated tasks. For example, when moving a heavy piece of furniture; there is an active dialogue about where to lift, how quickly to move or if a break is needed. In this paradigm, the operators must focus their attention on the input that is needed to produce a result rather than strictly on the end result.

This constant negotiation of user input may prove quite valuable in an educational setting. As the class attempts to collectively come to agreement on a course of action, students would need to justify their strategies in attempts to persuade their classmates to alter their behavior. For this model, there are several ways that Input Management Package needs to be able to reconcile both direct and indirect input as commands. Direct manipulation consists of actions such as mouse commands that are restricted for certain elements of the display. For example interface elements may be perceived as 'too heavy' for one student to manipulate by themselves; they would need to coordinate with a peer to collectively manipulate the object. Bricker proposed that an object's attributes can be parameterized and control of those parameters could be distributed among multiple users (Bricker, 1997). Likewise, Bederson's concept of "Local Tools" (Bederson, 1996) can be employed to divide the responsibility across class members, each of whom possess a tool that is integral to solving the problem. Indirect manipulation may come in the form of alphanumeric responses that can be mapped to the generation a visual model. For example, the class may collectively manipulate the appearance of a line by entering a value for its slope.

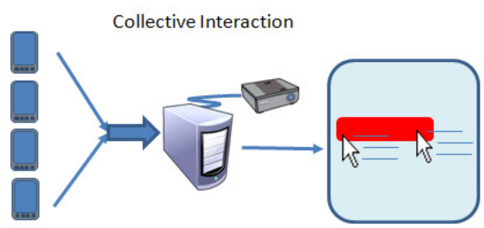

Figure 6 : Collective Interaction

A big part of the technological innovation of this project is the design, creation, usage and refinement of a significant number of Interaction Response Consumers. The nature of this project allows our team to explore stock solutions to ideas during year one and then to iteratively design and test more involved and customized solutions during years two and three. The goal is that by studying a reasonably large number of these consumers across multiple disciplines over the three years of the project that we can develop an understanding of a core set of interaction types and potential pitfalls so that we can develop a more generalized framework of interaction consumers.

3 Future Work - Support for a Diverse Community of Educators

Technical considerations, like those addressed by the infrastructure above, play a large role in the decision to implement a BYOD strategy. It is also important for educators to have a clear vision for how the technology will support their teaching style and objectives. The interaction strategies outlined above are fascinating to a Human-Computer Interaction researcher, but how does that fit into lesson planning for a teacher?

Consider the following scenario where a class is attempting to understand the equation of a line: y=mx+b. What are the set of interactions, collaborations and visualizations that the teacher could use to best increase student learning?

Clearly the exploration of this concept could be done by individual students in isolation. It would take little effort to produce a web based drill that would present the graph of a line to a student and ask him to indicate the slope and intercept of the line displayed. The student's response could be graphed along with the original line and the student could be allowed to adjust his settings until he gets the lines to match. A student whose line is incorrect would be able to adjust his responses, somewhat by trial and error, until he arrives at the correct response. Arriving at the correct response does not suggest understanding of why that is the correct response or that the student understands the general rules for determining slope and intercept.

Similarly, we could use a traditional classroom response system to allow students to vote for the correct response for slope or intercept. In this manner, students might select from one of several pre-determined responses. A bar graph might show the class distribution among these responses. The instructor could engage the students in a discussion about why different students feel that one response is the correct response over the others and re-voting could occur until the class comes to an overall consensus. In this scenario the students who are actively involved with the discussion are required to articulate why they feel they are correct. They are forced to think not only about how to calculate the answer but also how to demonstrate that other answers are incorrect. They are encouraged to consider the generalization and develop an overall mechanism for translating a line to a pair of values that produce that line. Opting to display the class results as a bar graph means that some level of instructor interaction is required to let students know that they do or do not have the correct response. Students do not have a convenient mechanism to explore or understand how their answer is incorrect without additional instructor involvement. In educational terms, the "authority" for this problem still rests with the instructor (Stein, Engle, Smith, & Hughes, 2008). Using a Collective Interaction approach, authority could be transferred back to the students by using student input to directly affect the plot of a line on a shared display. As suggested above, students would be able to immediately see disparities between the collective line and the target line.

This basic algebra scenario gives a reasonable picture of how the system might be deployed. This simplified example not only gives a tangible example but explores the concept through the lens of multiple interaction strategies. This leaves the teacher the flexibility to align the strategy to his own teaching philosophy.

To encourage adoption from a wide audience of educators will require a substantial collection of case-studies that adhere to two criteria. First it is essential that there is a critical mass of these scenarios that span a diverse set of topics. Second, these scenarios need to be grounded in real-world applications and class discussions. The algebra scenario seems plausible, but it is entirely hypothetical. If the educator cannot insert themselves into the details of the case-study, it is not going to be of value to them. Likewise, the decision to implement a BYOD classroom requires a level of commitment that cannot be sustained by a minimal set of activities; educators will not be persuaded to make this commitment based on a limited set of examples.

This project will organize a preliminary advisory group of four practicing educators to identify usage scenarios and begin development on this case-study library. This group will be recruited from a diverse group of disciplines including STEM, Social Sciences, Humanities and Education fields. Members will commit to actively using the BYOD collaboration system in their classrooms, providing feedback to the development team and contribute documentation to a centralized repository. A major outcome of this advisory group is to "prime-the-pump" with enough case studies to attract and establish a community of users that will ultimately take on responsibility for sharing their own discoveries of best-practices for this style of classroom management.

4 References

Apple, Inc. (2011). *Apple - iOS 5*. Retrieved Dec 15, 2011, from http://www.apple.com/ios/

Ash, K. (2010). Teachers Testing Mobile-Learning Methods. Retrieved Dec 15, 2011 from *Education Week:* http://www.edweek.org/ew/articles/2010/03/18/26mobiletools.h29.html

Ballagas, R., Borchers, J., Rohs, M., & Sheridan, J. (2006). The Smart Phone: A Ubiquitous Input Device. *Pervasive Computing, IEEE* , 70-77.

Bederson, B. B. (1996). Local Tools: An Alternative to Tool Palettes. *Proceedings of the 9th annual ACM Symposium on User Interface Software and Technology* (pp. 169-170). New York: ACM.

Bricker, L. J. (1997). Support for Cooperatively Controlled Objects in Multimedia Applications. *In Proceedings of Extended Abstracts of Human Factors in Computing Systems* (pp. 313-314). Atlanta: ACM Press.

Clarkson, E., Clawson, J., Lyons, K., & Starner, T. (2005). An Empirical Study of Typing Rates on mini-QWERTY Keyboards. *Proceedings of CHI 2005, Human Factors in Computing Systems* . (pp. 1288 - 1291). Portland: ACM Press.

Dropbox. (2011). *Dropbox*. Retrieved 12 10, 2011, from www.dropbox.com

Durand, P. (2011). *PRemoteDroid.* Retrieved Dec 15, 2011, from PRemoteDroid: http://code.google.com/p/premotedroid/

eInstruction. (2011). *einstruction.com*. Retrieved Dec 15, 2011, from Student Response Systems: http://www.einstruction.com/products/student-response-systems

Geeknet, Inc. (2011). *Sourceforge*. Retrieved Dec 15, 2011, from sourceforge.net

Google. (2011). *Android*. Retrieved Dec 15, 2011, from http://www.android.com

iclicker. (2011). *iClicker*. Retrieved Dec 15, 2011, from icliker home page: http://www.iclicker.com/dnn/

Krogh, P. G., & Petersen, M. G. (2010). Designing for Collective Interaction: Toward Desirable Spaces in Homes and Libraries. In D. Randall, & P. Salembier (Eds.), *From*

CSCW to Web 2.0: European Developments in Collaborative Design (pp. 97-114). London: Springer.

Lantz, M. E. (2010). The use of 'Clickers' in the Classroom: Teaching innovation or mearly and amusing novelty? *Computers in Human Behavior* , 556-561.

Lie, C.-C., & Kao, L.-C. (2007). Do Handheld Devices Facilitate Face-to-Face Collaboration? Handheld Devices with Large Shared Display Groupware to Facilitate Group Interactions. *Journal of Computer Assisted Learning* , 285-299.

Martyn, M. (2007). *Clickers in the Classroom: An Active Learning Approach*. Retrieved Dec 15 2011, from Educause Quarterly: http://www.educause.edu/EDUCAUSE+Quarterly/EDUCAUSEQuarterlyMagazineVolum/ClickersintheClassroomAnActive/157458

McGrail, E. (2007). Laptop Technology and Pedagogy in the Engligh Language Arts Classroom. *Journal of Technology and Teacher Education , 15* (1), 59-85.

Meech, S. (2011). The Future of Ed Tech is "Bring Your Own Device"... BYOD. Retrieved Dec 15, 2011 from *EdReach*: http://edreach.us/2011/05/22/the-future-of-ed-tech-is-%E2%80%9Cbring-your-own-device%E2%80%9D-byod/

Microsoft Corporation. (2011). *Microsoft Mouse Mischief*. Retrieved 1 4, 2011, from http://www.microsoft.com/multipoint/mouse-mischief/en-us/default.aspx

Moraveji, N., Inkpen, K., Cutrell, E., & Balakrishnan, R. (2009). A Mischief of Mice: Examining Children's Performance in Single Display Groupware Systems with 1 to 32 Mice. *Proceedings of CHI 2009, Human Factors in Computing Systems*, (pp. 2157-2166). Boston.

Myers, B. A. (2002). Mobile Devices for Control. In *Lecture Notes in Computer Science* (Vol. 2411, pp. 569-579). Springer.

Myers, B. A., Stiel, H., & Gargiulo, R. (1999). *Collaboration using multiple PDAs connected to a PC.* Pittsburgh, PA: Institute for Software Research .

PollEverywhere. (2011). *Classroom Response System - Clicker Free.* Retrieved Dec 15, 2011, from Polleverywhere.com: http://www.polleverywhere.com/sms-classroom-response-system

Promethean. (2011). *Promethean*. Retrieved Dec 15, 2011, from Learner and Student Response Systems from Promethean: http://www.prometheanworld.com/server.php?show=nav.16

Rochelle, J., & Teasley, S. D. (1995). The Construction of Shared Knowledge in Collaborative Problem Solving. (C. OMalley, Ed.) *Computer Supported Collaborative Learning* , 69-97.

Schachter, R. (2009). Mobile Devices in the Classroom. *District Administration* , 31-34.

Smart. (2011). *smarttech.com*. Retrieved Dec 15, 2011, from Smart Response Interactive Student Response System for the Classroom: http://smarttech.com/us/Solutions/Education+Solutions/Products+for+education/Complementary+hardware+products/SMART+Response

Socrative. (2011). *Socrative Student Response System.* Retrieved Dec 15, 2011, from socrative.com: http://www.socrative.com/features.php

Stein, M. K., Engle, R. A., Smith, M. S., & Hughes, E. K. (2008). Orchestrating Productive Mathematical Discussions: Five Practices for Helping Teachers Move Beyond Show and Tell. *Mathematical Thinking and Learning* , 313-340.

Stewart, J., Bederson, B. B., & Druin, A. (1999). Single Display Groupware: A Model for Co-presnt Collaboration. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, (pp. 286-293). Pittsburgh, Pennsylvania.

Truong, K. (2010). *Student Smartphone Use Doubles; Instant Messaging Loses Favor.* Retrieved Dec 15, 2011, from Chronicle of Higher Education: http://chronicle.com/blogs/wiredcampus/student-smartphone-use-doubles-instant-messaging-loses-favor/24876

Turning Technologies. (2011). *Mobile & Distance Learning.* Retrieved Dec 15, 2011, from turningtechnologies.com: http://www.turningtechnologies.com/studentresponsesystems/mobiledistancelearning/

Wenger, E. (1998). *Communities of Practice: Learning, Meaning, and Identity.* Cambridge University Press.

Yang, J. C., & Lin, L. L. (2010). Development and Evaluation of an Interactive Mobile Learning Environment with Shared Display Groupware. *Education Technology & Society* , 195-207.

Zurita, G., & Nussbaum, M. (2004). Computer Supported Collaborative Learning using Wirelessly Interconnected Handheld Computers. *Computers & Education , 42*, 289-314.