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Weak Guidance with "Look" Functionality in Handheld-Based Classroom Activities

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Abstract. Wireless handheld technologies can be used to move technology into the classroom framework rather than to move classrooms into the technology framework. To make such technologies effective, we support activities and teaching practices crucial to children's creativity and competence. However, because of the small screen size and distributed nature of some of the activities, it can be hard for teachers to engage in *formative assessment*, that is, finding out what students know and can do. The current work reports an idea about how to solve this problem and the first assays of this idea in the classroom. We try to enable what we call *weak guidance* during collaborative activities, by implementing a system feature called "Look."

Keywords: Mobile Computing, Constructivist Pedagogy

INTRODUCTION

Ms. Smith was using a handheld-based math activity called "Match-my-Graph" with one of her eighth-grade classes. Students were grouped into pairs. Alice drew a line on an animatable velocity graph on her handheld. Brian's goal was to produce the equivalent function on a position graph on his handheld. To do this, he beamed each of his guesses to Alice, who gave him progressively more refined hints, until the graphs described the same trajectory. The challenge was for Alice to devise useful hints describing position change based on the relationship between two velocity graphs, and for Brian to interpret velocity-based hints in terms of required changes to the position graph. In this case, Alice had the hypothesis that velocity graphs below the x-axis meant that the object had a negative position, leading to systematically incorrect hints. Both students were becoming frustrated when the teacher came by. She watched them argue about whose mistake it was. She glanced at one screen, when the student was not drawing or beaming. Then she said, "Is everything all right?" Both students responded yes. She moved on. Ten minutes later, they were still working on the same problem when time ran out, each quite distressed at the failure of the other.

This scenario is taken from a month-long intervention using NetCalc with 8th grade students, which showed considerable gain scores and, even achievement on qualitative AP-calculus problems (Tatar, Roschelle, Vahey & Penuel, 2003; Vahey, Tatar & Roschelle, 2004). The class wide consequences of the study were overwhelmingly positive; therefore, arguably, the time the students spent struggling on the problem was well spent. However, at the same time, compared to when observing the use of manipulatives, worksheets or desktop, the teacher's ability to gauge the nature and seriousness of the problem was curtailed. Wirelessly-connected handheld PDAs hold great potential for the classroom because they are portable, easy-to-maintain and relatively inexpensive (Tatar, et al, 2003; Soloway, Grant, Tinker, Roschelle, Mills, Resnick, Berg & Eisenberg, 1999). It may be affordable to provide a handheld for every student, when it is too expensive to provide a desktop computer or too bothersome to go to the computer lab.

Handhelds can be used many ways in the classroom. For example, employing both handhelds and large screen displays, Wilensky and Stroup (2000) use a distributed programming language, StarLogo, to allow students to explore complex distributed systems. Kaput and his colleagues (Kaput and Hegedus, 2003; Kaput, Roschelle, Vahey, Tatar & Hegedus, 2003) also emphasize aggregation activities, highlighting the individual's contribution to the whole class. In these situations, there is a relatively close relationship between the acts of individuals and their publication to the whole classroom, including the teacher. This publication provides opportunity for formative assessment. However, another class of activities involves a slightly longer tether. For example, students may develop complex and sophisticated idea-networks using Picomap, a concept-mapping tool, before uploading them to a desktop or large screen formats (Luchini, Quintana, Krajcik, Farah, Nandihalli, Reese, Wieczorek & Soloway, 2002). Likewise, the Sketchy tool (www.goknow.com) and elaboration in

ImageMakers (www.projectwhirl.org) allows students to produces animations of science processes. Indeed, ImageMakers has formative assessment as a goal; nonetheless, it primarily supports uploading at the end of the activity, using HotSyncing. In the NetCalc project, activities moved between whole class, small group, and individual work. The students had a clear idea when they had finished the tasks, but there were barriers to fine-grained formative assessment (Davis, 2002).

In this paper, we describe the beginning of an investigation of how formative assessment can be integrated into the classroom using Infrared-based (IR) communication (e.g. beaming). We focus on IR in this work for the same reasons we used it in the NetCalc project: IR machines are less expensive, and require no server. On the other hand, any success we have with implementing formative assessment tools with IR should only be amplified with radio-frequency (RF) communication. Since, unlike IR, RF is not directed at a particular other person, overhearing can be accomplished less intrusively.

To abstract the issue of overhearing, we created a game that is an electronic variant of the Tangram game so widely used to explore the creation and maintenance of common ground in the CSCW and psycholinguistic literature (Clark, 1996a; Clark, 1996b). Indeed, the NetCalc Match-My-Graph activity was based on the structure of the Tangram game. Like Tangrams, our game involved two participants, a matcher and a director. For each round, the director had a sequence of images in a new random order. The matcher also started with the same sequence of images in a random order. By discussing each one in turn, the matcher was able to put the images on his screen into the same order (see Figure 1) as the director. The game is complete when the matcher and director agree that they have the images in the correct order. In our game, KCM, the images were Korean characters. The KCM game system runs on a Palm OS handheld computer and uses a stylus for drag and drop characters from one place to another and to initiate task actions, such as "shuffling" the image order.

Figure 1. Korean characters matching (KCM) game

WEAK GUIDANCE WITH LOOKING IN CLASSROOM ACTIVITIES

KCM is a coherent activity in which participants are trying to understand what the other one is talking about, in other words, in which they are learning. However, the purpose of our study was to investigate another feature, *Look*. In activity-based classroom environments, the ideal teacher has often been characterized a "guide on the side" rather than a "sage on the stage" (National Research Council, 2000). This pedagogical goal is based on the idea of constructivism, that active engagement in knowledge creation is vital to deep understanding. From a psycholinguistic point of view, teachers engaged in coaching would ideally be characterized as "side participants" to the interaction they are observing. Their job is to assess and provide weak guidance, not to distract the students from their focused work. Typically, side participants enter in to a conversation about an object by watching the interaction until they can make an informed contribution. Of course, it is the teacher's prerogative to ask students for an explanation of what they are doing, but typically, she picks her moment. Additionally, KCM provides a chance for the teacher to introduce secondary information, including the names of the Korean character

Look supports formative assessment by allowing the teacher to capture objects from other screens by beaming to them (Figure 2). Instead of having the owner of the information beam stop on-going activity to beam to the newcomer, the newcomer could request data from the students' handhelds without disruption.

In our project, *Look* was implemented using *Exchange Manager* in the Palm OS API. The Exchange Manager provides a high-level interface to use the *exchange* socket structure. We embedded and tested this *Look* functionally as a component for the KCM game.

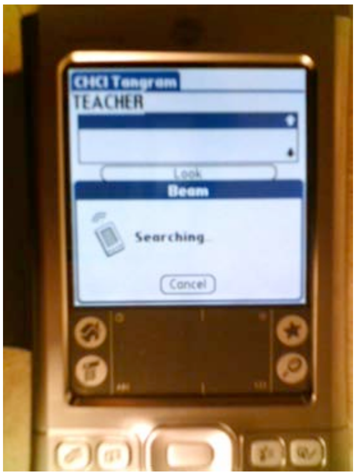

Figure 2a. Initiating a *Look* to capture data from student's handheld.

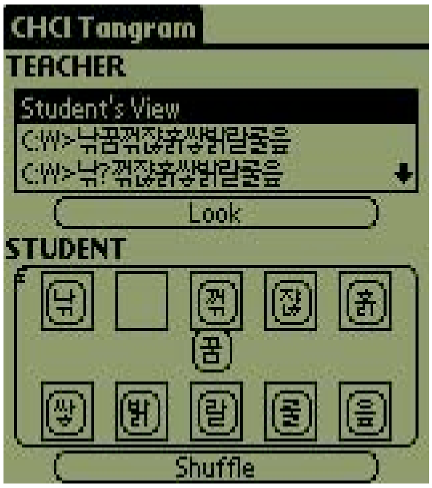

Figure 2b. What the teacher sees after a *Look*.

PROOFS-OF-CONCEPT

In April 2004, during the annual *Women in Computing Day* at Virginia Tech, eight local middle school girls (ages 12-14) experimented with our application and *Look* functionality. They were divided into three groups of two "learners" plus two student "teachers." One "teacher" monitored two matcher-director groups at the same time. "Learners" switched between matcher and director roles in different rounds. The teacher's system was equipped with both *Look* and a paper list of Korean characters and corresponding English-language names. The teacher was instructed to try to figure out whether the groups were making progress and to help them if they got stuck. The experiment was conducted in a large meeting room with tables set in a U-shape. Students were not instructed on where to sit or whether they were free to move around. Nonetheless, learners sat facing one another or around a corner of the table while teachers sometimes stood next to one of them, sometimes say next to one of them, and moved from person to person.

Notes were taken by three observers to document the interaction. These focused on whether and how *Look* was used. Participants were asked to engage in a "think-aloud" process in which they articulated what they were doing and when to enable us to locate usability problems. Afterwards, students were asked to indicate both the positive (good) and negative (bad) aspects of what they had done.

Given its similarity to the Tangram and Match-my-graph games, it was not surprising that Matchers and Directors appeared to be engaged and consistently expressed enthusiasm. The teacher's role was the new component. These students did seem engaged, but not always in the ways we had envisioned. One teacher functioned much as we imagined, looking over the matcher's shoulder and beaming to a director to check desired the target order. This teacher beamed a lot in the middle of the game; however, the other beamed only at the beginning and end of each round. Thus, she was not monitoring progress the moment, but only global progress. Worse, neither teacher was able to intervene effectively during the interaction. Instead, they spoke with learners only after they had reported the end of their play. At that point, the teacher would check again with beaming and give feedback to students, such as concerning the incorrect placement of characters.

Subsequently, six triads of male undergraduate and graduate students at Virginia Tech were recruited through email requests to undergraduate and graduate researchers in Human-Computer Interaction (HCI) to perform an almost identical task. The average age of these participants was 24.7 years (Standard Deviation (SD): 3.7). All students were from the School of Engineering, primarily computer science and industrial systems engineering. Half of these triads had *Look* functionality for the teacher, and half did not. Each group participated in two rounds of KCM, rotating all participants between roles. Participants were videotaped and log files of the interaction were kept. Additionally, two kinds of simple learning outcome measures were obtained: participants were asked to pick out which ten characters they had worked with from a list of the complete 20-character Korean alphabet, and to match characters with English names.

Although there were too few groups for statistical tests to be meaningful, the number of errors in recognizing the characters was consistently less for the groups that had *Look* compared to those that did not. In round 1, the mean number of errors in recognition with *Look* was 7.33 (SD: .99) while without *Look*, it was 10.67 (SD: 2.18). In the second round, the scores were 2.67 (SD: 1.33) and 8.33 (SD: 4.84). Note that the standard deviations are also smaller for the groups with *Look* than for those without. Additionally, students in the *Look* condition were more accurate in naming the characters after round 1, though not for round 2.

Videotape and log files revealed that teachers with *Look*, updated and consulted their handhelds quite frequently. One teacher looked at the others' screens ten times during one round. He moved back-and-forth between looking at the matcher's and director's screens. Other teachers in the *Look* condition beamed to get the director's order and then sat next to the matcher and watched him work.

Although there was no reason to believe that the participants had any familiarity with pedagogical theory, and no instructions were given to the participants about the kind of pedagogy desired, participants in both conditions commented on the teacher's role. One, in the *Look* condition, said "The teacher must not help the students until the last minute. Extensive help from the teacher will reduce the learning." Another commented "We can keep going even if the teacher does not say anything." On the other hand, students in the no-*Look* condition, commented that the teacher was not particular useful. One said: "As far as the teacher's action, it was minimal, actually non-existent when I was trying to match for pictures." Another echoed something sometimes heard from students in project-based classes that "the teacher did not have to help in solving the puzzle, we just did it ourselves."

DISCUSSION

Thus, we have some support for the idea that Look functionality can be useful in conjunction with at least this task. The undergraduate and graduate student teachers appear to have used it in a way consistent with our pedagogical hopes and goals: lightly and to good effect. The middle school girls had more trouble. This may have been because their own notions of teaching were less mature, because they saw the student's role passive than did VT students, and/or because it was more difficult for them to imagine teaching in such a decontextualized situation.

One limitation of this work was that the learning task was confined to one factual task rather than a richer array of tasks including more complex inquiry-based learning. Another limitation is that the "teacher" was not motivated by the rich set of priorities and considerations that motivate a real teacher to intervene or not.

Strengths of the task include that it is in fact interesting for the participants, that there at least the two layers of learning (to recognize and name the characters), that it emphasizes the teacher's role, and that the recognition component is sufficiently complex to have produce a wide range of errors after two rounds.

Although these demonstrations are limited, we feel that there is enough evidence to go through the effort to incorporate *Look* functionality in a more contextualized teaching context. We do not expect *Look* to be used constantly, perhaps only twice or three times in a class section; however, we expect that it will disambiguate situations such as that reported in the initial paragraph of this paper that otherwise would not be clear.

An additional direction has to do with the of future IR beaming. We worked with IR in the NetCalc project and therefore in this one because it solves a raft of classroom management problems. When the teacher or the teacher's machine functions as a central server, any problems tend to involve the whole class and be disruptive. Point-to-point beaming allows localized control but participants with no need for the system to know who is working together. We have found it to be extremely useful and easy for small group interaction. However, it is unclear that IR will continue to prevail on inexpensive handheld machines, compared to radio-frequency (RF) communication. Thus, our research has to extend to include RF. With its nearly synchronous properties, teachers should have an easier time seeing activity in progress with RF. There will be no need for static snapshots. However, RF-based *Loo*king may still be time consuming and problematic because of the need for machine to know which other machine or machines to be *Look*ing at. RF alone may not suffice to make the teacher's assessment of the learning situation as automatic as with a desktop display.

CONCLUSION

One of the fundamental design goals of this project was to support the role of the teacher in learning situations as a "guide on the side" in relationship to handheld wireless computing. We investigated using Look functionality for weak guidance in classroom activities, in which the teacher could come to understand the intellectual state of small groups at work. The result of user experience with our prototype and a few triads with a non-Look control, gives preliminary indication that Look can be used to enhance classroom communication and understanding; however, the case is not closed, creating interesting design challenges in the social or technological realm or both.

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REFERENCES

Blaye, A., Light, P., Joiner, R., and Sheldon, S. (1991) Collaboration as a facilitator of planning and problem solving on a computer-based task. *British Journal of Developmental Psychology*, **9**, 471-483.

Clark, H.H. (1996a) Arranging to do things with other. Plenary Speech, ACM Conference on Computer Supported Collaborative Work, April 19, 1996; Vancouver, BC.

Clark, H.H. (1996b) *Using Language*. New York: Cambridge University Press.

Davis, S.M. (2002) Research to Industry: Four Years of Observations in Classrooms Using a Network of Handheld Devices. Proceedings of the IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE'02), Vaxjo, Sweden., 31-38.

Ferraris, C., Brunier, P., and Martel, C. (2002) Constructing Collaborative Pedagogical Situations in Classrooms: A Scenario and Role Based Approach. Proceedings of CSCL 2002, Boulder, Colorado., 290-299.

Kaput, J., and Hegedus, S. (2003) Exciting new opportunities to make mathematics an expressive classroom activity using newly emerging connectivity technology. In N. A. Pateman, B. J. Dougherty & J. Zilliox (Eds.), Proceedings of the 27th Conference of the International Group for the Psychology of Mathematics Education held jointly with the 25th Conference of the PME-NA (Vol. **1**, pp. 293). Honolulu, Hawaii: College of Education, University of Hawaii.

Kaput, J.,Roschelle, J., Vahey, P., Tatar, D. and Hegedus, S. (2003) Five key considerations for networking in a hanndheld-based mathematics classroom. In N. A. Pateman, B. J. Dougherty & J. Zilliox (Eds.), Proceedings of the 27th Conference of the International Group for the Psychology of Mathematics Education held jointly with the 25th Conference of the PME-NA (Vol. **4**, pp. 71-78). Honolulu, Hawaii: College of Education, University of Hawaii.

Luchini, K., Quintana, C., Krajcik, J., Farah, C., Nandihalli, N., Reese, K., Wieczorek, A., and Soloway, E. (2002) Scaffolding in the Small: Designing Educational Supports for Concept Mapping on Handheld Computers. CHI 2002, 792-793.

Moher, T., Ding, X., Wiley, J., Conmy, D., Hussain, S., Singh, P., and Srinivasan, V. (2003) Combining Handhelds with a Whole-Class Display to Support the Learning of Scientific Control. Proceedings of CHI '93 (Amsterdam, The Netherlands, April 1993), ACM Press, 882-883.

NRC (2000) *How People Learn: Bridging Research and Practice*. Washington, D.C., National Academy Press.

Rieger, R. and Gay, G. (1997) Using Mobile Computing to Enhance Field Study. Proceedings of CSCL 1997, Toronto, Ontario, 215-223.

Roschell, J. (1996) Learning by collaboration: Convergent conceptual change. In T. Koschmann (Ed.), *CSCL: Theory and practice of an emerging paradigm*, Mahwah, NJ: Lawrence Erlbaum Associates, 209-248.

Soloway, E., Grant, W., Tinker, R., Roschelle, J., Mills, M., Resnick, M., Berg, R., and Eisenberg, M. (1999) Science in the Palms of their Hands. *Communication of the ACM*, **42**, 8.

Tatar, D., Roschelle, J., Vahey, P., and Penuel, W. R. (2003) Handhelds Go to School: Lessons Learned. *IEEE Computer*, **36**, 9, 30-37.

Vahey, P., Tatar, D., and Roschelle, J. (2004) Leveraging Handhelds to Increase Student Learning: Engaging Middle School Students with the Mathematics of Change. Proceedings of the Sixth International Conference of the Learning Sciences. Santa Monica, CA. June 22-26, 2004.

Wilensky, U. & Stroup, W. (2000) Networked Gridlock: Students Enacting Complex Dynamic Phenomena with the HubNet Architecture. Proceedings of the Fourth International Conference of the Learning Sciences, Ann Arbor, MI. June 14-17, 2000.