Tiny Tabletops: A Research Agenda

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Abstract: Everyday computing technology is transitioning from desktop computing to interactive surfaces. At the forefront of this technological revolution are multi-touch tablets. Each year, tablets become more affordable, more capable and more widespread. Now is the time for research to shape how they will be used to support learning. In this position paper, I propose a learning sciences research agenda for tablets around the proposition that tablets can be used as tiny tabletops. There has already been extensive work documenting how interactive tabletops support co-located collaborative learning. Tablets and tabletops share many of the fundamental properties, such as direct input and multiple access points, but the interactive surface of tablets is significantly smaller. How does that affect the use? That is the question that guides my current research. In this paper, I connect my current work on the Proportion tablet application to my previous work on the DigiTile tablet application to provide a concrete case of a tiny tabletop research agenda.

From Desktop Computing to Interactive Surfaces

Desktop computing—controlling a graphical user interfaces with a keyboard and mouse—was developed in the 1960s and came to prominence in the 1980s. Input technology and processing power to interpret more complex data (e.g., real-time image processing) has improved since then, leading to technologies that support natural user interfaces—where the computer processes complex input to correctly interpret user intent to create a more intuitive interface (Wigdor, & Wixon, 2011). Interactive surfaces of various sizes (handhelds, tablets, tabletops and whiteboards) are a particularly prominent category of these technologies. Modern day touch devices are highly accurate, fast and able to simultaneously capture concurrent input (i.e., multi-touch).

Interactive surfaces have two critical advantages over desktop computing: direct input and multiple access points. Direct input means that an end user can directly manipulate the software interface and applications using touch, pen and / or by moving tangible objects. In comparison to using a mouse to control a cursor, the cognitive distance between intent and execution is shortened. In situations with multiple participants, a potential learning benefit is that hand, arm and body movements are visible. Multiple access points means that multiple concurrent interaction points are sensed by the hardware and utilized by the software. This enables multi-point gestures (e.g., pinching to zoom out) and using two hands simultaneously. Furthermore, access points can be distributed among multiple participants, thereby enabling collaboration.

From Tabletops to Tablets

One of the most consistent findings in education is that collaboration makes learning more active, engaging, and effective (Cohen, 1994; Webb, & Palincsar, 1996). With many students and one teacher, peer-to-peer co-located collaboration is well suited to the average classroom. Unfortunately, PCs—the most prevalent classroom computing technology—are ill equipped to support such collaboration. Because of their support for direct input and multiple access points, interactive surfaces have expanded how technology can support co-located users (Figure 1). In particular, research has demonstrated the benefits of using interactive tabletops to support co-located collaborative learning (Dillenbourg, & Evans, 2011; Higgins, Mercier, Burd, & Hatch, 2011).
Interactive tabletops have a long and prominent history in research (Buxton, 2011). As a result, researchers have been able to investigate their potential to support learning. In contrast, multi-touch tablets are fairly new, with the Apple iPad arriving in 2010. Currently, there is little published research on how they can support learning. Market analysts predict that the market for multi-touch tablets will overtake PCs (desktops and laptops combined) as early as 2013 (UPI.com, 2012). Already, there is significant commercial interest in introducing tablets into the classroom as electronic textbooks. The argument usually made is that electronic books will be significantly better (more up-to-date, more engaging, easier to manage and cheaper) that they will soon justify the initial hardware investment. If these devices are going to enter the classroom, now is the time for researchers to come up with models of how they can be used to support constructivist learning.

Here, I propose that learning sciences researchers take their cue from the existing body of research on interactive tabletops and investigate their potential to support co-located collaborative learning. After all, tablets are very similar to tabletops: Both are interactive surfaces that support direct input and multiple access points. The major difference is that tablets are significantly smaller (e.g., the iPad tablet has a 9.7” diagonal display, whereas the Microsoft Surface tablet has a 40” diagonal display). Can tablets similarly enable co-located collaborative learning? If so, how does the smaller screen size affect the collaboration? To give a clear illustration of how tabletop research can inform tablet research, I summarize my work on the DigiTile tabletop application (Figure 1a) and show how it influenced the research on the Proportion tablet application (Figure 1b).

The DigiTile Tabletop Application
DigiTile is an adaptation of DigiQuilt (Lambery, Adams, Biatek, Froiland, K., & LaPham, 2011) to the DiamondTouch (Dietz, & Leigh, 2001) interactive tabletop (Rick, & Rogers, 2008). Like DigiQuilt, it is a construction kit for learning about math and art by designing colorful mosaic tiles. In addition to being aesthetically pleasing, these tiles lend themselves to mathematical analysis. The designs embody fraction concepts and can be symmetrical. While DigiQuilt was designed for a single user, DigiTile was designed for two concurrent users positioned side-by-side in front of the interactive tabletop (Figure 1a). Learners move pieces from the left and right palette to the central tile as they work on various mathematical challenges. The fraction of the tile that is a certain color is displayed on the button for that color. For instance, is shown on the red button in Figure 2a.

In a study, learners worked on three tasks. First, to familiarize them with the interface, they replicated the pattern in Figure 2a. Second, using a 4-by-4 tile, they were to create a tile that was three-eighths orange and three-eighths brown (one dyad’s solution is shown in Figure 2b). Third, using a 5-by-5 tile, they were to create a tile that was one-tenth red, two-tenths blue, three-tenths yellow and four-tenths green (one dyad’s partial solution is displayed in Figure 2c). In comparison to a control group, DigiTile users showed significant gains in fraction understanding after a 30-minute session (Rick, Rogers, Haig, & Yuill, 2009).

To investigate how children collaborated at the tabletop, the video data of successful groups was analyzed for distinguishing patterns (Rick, Marshall, & Yuill, 2011). Surprisingly, successful groups had vastly different group dynamics. One dyad worked independently, but shared their findings with each other through continuous narration and physical mirroring. Another dyad shared a unified task focus, taking turns actively moving pieces and observing / commenting. A third dyad worked largely independently in the same space, occasionally actively collaborating. While DigiTile supported different group dynamics, there were also common elements. First, the large space of the tabletop allowed learners to work concurrently (and independently if they chose to do so). Second, even when children were not seeking to actively communicate, partners were able to be aware of their actions through peripherally monitoring their movements and draw inspiration from them. Third, children were able to augment verbal communication with pointing gestures to better communicate ideas. Fourth, users switched smoothly between acting and observing.
The Proportion Tablet Application

For this application, the tablet is positioned vertically on a table in front of two learners, aged 9–10 (Figure 1b). Learners work together to solve a series of ratio / proportion problems. The interface has two columns—one on the left and one on the right. For each problem, the children must size the left and right columns in proportion to their respective numerical labels. Through using Proportion, they gain competence in proportional reasoning.

Proportional reasoning is a challenging mathematical domain (Lamon, 1993). One problem is that it is usually taught and tested with mathematical notation through word problems; these provide neither real-time feedback on task progress nor tools to scaffold users. Proportion provides several interfaces to scaffold users (Figure 3). Without any support (3a), learners must estimate the ratios. Embodied proportional reasoning, relying on rules-of-thumb (e.g., larger denominator means smaller amount) and estimation (e.g., 9 is about twice as much as 4), are particularly important for learners to relate their everyday experiences to mathematical concepts (Abrahamson & Trinic, 2011). With a fixed 10-position grid (3b), learners have precise places that they can target, thereby using their mathematical understanding of the task to quickly solve problems. One strategy is for users to select the grid line that corresponds to their respective numbers. This works well for simple ratios (e.g., 4 : 9). For the common-factor problem shown in Figure 3b, that strategy does not work. As illustrated, the children tried a novel strategy of positioning the columns based on the last digit of the number. Of course, this did not work and they were able to realize that this was not a viable strategy. With relative lines (3c) that expand based on the position of the columns, learners can use counting to help them solve the problem. They can also learn more embodied strategies, such as maximizing the size of the larger column to make it easier to correctly position the smaller column. When the lines are labeled (3d), other strategies can be supported. For instance, in the fraction-based problem shown, a useful strategy is to arrange columns so that whole numbers (e.g., 1) are at the same level.

Proportion provides two levels of real-time feedback. If the ratio of the two columns is close to the correct answer, a small star with a “close” label is shown. If the ratio is within a very small zone, then it is pronounced as correct, a large star with a “correct” label is shown, and the application moves on to the next problem. When designing this feedback, it was important that learners not just solve the problem based on the feedback without strategically engaging the problem. Hence, the close feedback was designed to give no information about which direction the correct answer lies. However, learners need enough feedback to make progress when they are testing out or discovering a new strategy. To better support this, the sensitivity of the zones is adjusted for the problems. The first time a new strategy is needed, the zones are relatively large, allowing learners to more easily stumble upon the solution. As the sequence progresses, the zones become smaller, making it uncomfortable for learners to simply employ a stumble-upon strategy. The zones are larger for estimation tasks (Figure 1a) where precision is difficult even when learners employ a correct strategy. Conversely, the zones are smaller when the interface should support precision, thereby coaxing learners to take advantage of those tools.

Proportion has been through two rounds of user testing to improve the interface and fine-tune the sequence of problems. The interface and the curriculum have been polished to where children will be able to use Proportion without external support. The curriculum contains 215 problems split into 21 sequences addressing proportional reasoning tasks from comparing simple whole numbers (1 : 5) to complex fractions (11/2 : 4/3). This broad range was chosen to better support the research. At an average of 25 seconds per problem, learners would be able to finish the entire problem sequence in about 90 minutes; however, that is not how Proportion will be used. As time on task is a dominant factor in learning success, this work aims to control for that variable. All groups will work for an hour. Even high performing groups are unlikely to finish as the problems go well beyond the targeted grade level.
A Tiny Tabletops Research Agenda

Inspired by work DigiTile and other work on supporting co-located collaboration with interactive tabletops, research with Proportion aims to shed light on two broad research topics. First, it will investigate how children communicate to collaborate. The DigiTile work demonstrated that children readily use their interactions with the interactive surface to communicate with their partners. This work aims to tease apart the role of verbal and gestural communication. In particular, it will investigate how scripting the collaboration to encourage verbalization impacts learning and task performance. The smaller display may make it more difficult for children to point to specific elements to communicate their meaning.

Second, it will investigate issues of equity of collaboration for tablet-based collaboration. One of the significant benefits of tabletops is that they encourage equitable collaboration (Rick, Harris, Marshall, Fleck, Yuill, & Rogers, 2009). One reason for this is that the large surface makes it difficult for users to access all parts of the surface; therefore, users tend to concentrate their interactions in areas closer to their position at the tabletop. Such separation is not possible for a tablet: Every user has good access to all parts of the interactive surface. Instead of relying on the affordances of the hardware, the Proportion software was designed to foster a specific ownership pattern, leading to equitable interaction: Learners sit side-by-side in front of a display with two columns arranged side-by-side; hence, it is implied for the left user to manipulate the left (orange) column and for the right user to manipulate the right (blue) column. Yet, this convention is not necessitated by the technology. What happens when the convention breaks down? How does this affect the equity and effectiveness of the collaboration? Work on interactive tabletops has demonstrated that such physical conflict can highlight cognitive conflict and thus lead to conceptual change (Pontual Falcão, & Price, 2011).

References


