Towards a Classroom Ecology of Devices: Interfaces for Collaborative Scripts

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Abstract: The ShareIT Project has been investigating how interactive tabletops can support co-located collaborative learning. As interactive tabletops are still in their infancy, basic questions of how these interfaces support collaboration are still unanswered. To address these, we have been conducting conventional psychology experiments, where a small intervention is run with a significant number of groups and statistical comparisons can be made across conditions. While that is a useful research paradigm for understanding the potential of interactive tabletops by themselves, a different perspective will be needed to integrate them into a working classroom.

This position paper is about bridging that gap by envisioning interactive tabletops as part of a larger classroom ecology of devices. It examines the potential of different devices and different interfaces on those devices to support different parts of a collaborative script. Based on our work on interactive tabletops, I present three examples of how different interfaces can enable, encourage, and enforce collaboration. A better understanding of these interfaces ultimately leads to better tools to instantiate collaborative scripts.

An Ecology of Devices

The field of ubiquitous computing (ubicomp) has envisioned a future where multiple devices interact seamlessly to provide a fluid user experience (Greenfield, 2006; Weiser, 1999). We are approaching a time when that future can be realized in the classroom. Different technologies can work in tandem to form an ecology of devices that allows each to be used for purposes that best suits its interface and affordances. Handhelds are portable and can accompany the students. Interactive tabletops encourage small group work (Rick, Rogers, Haig, & Yuill, 2009). Electronic whiteboards best support whole class discussion (Moss et al., 2007). Different devices can become part of a coordinated system to support collaborative activities (e.g., Roschelle et al., 2007).

A Vision of the Future

Students go on a field trip where they use handheld computers (e.g., PDAs, iPhone, etc.) and attachable probes to gather environmental data. Students are paired up for this task, so that one can operate the handheld while the other operates the probe. Students are encouraged to switch roles. Students take pictures of flora and fauna and an interactive application helps learners identify them. When back in the classroom, students add their data to the classroom-computing infrastructure.

The next day, the teacher uses her electronic whiteboard to review the data with the whole class. Several research topics are identified as worth pursuing (e.g., how does soil pH and moisture affect plant life, how does plant life affect which bugs are where). The class is split into equal-sized groups to research these questions given the available data. Groups use interactive tabletops to analyze the data. These lend themselves particularly well to small group work as every group member has a good view of the data and can interact with it concurrently. Each group is also given a paper worksheet of questions to guide their work. Using the analysis tools, the groups examine the data to come up with some conclusion. They are then asked to create a presentation of their work. Analysis and creating a presentation takes several days. Many students take the presentations that they have home and work on them from their home PC.

On presentation day, each group presents their findings to the whole class on the interactive whiteboard with the teacher running a whole-class discussion and feedback section. Based on that feedback, the groups revise their original presentation and submit it to the teacher. The following day, students are split into different groups based on a jigsaw pattern. Their assignment is to use the interactive tabletop to create a mind map of the different concepts. Since each learner brings individual insight from having been in a different group, the students must work together to build a mind map that encompasses all the concepts.

Interfaces for Collaborative Scripts

A collaborative script organizes learning activities and classroom interaction along a predetermined trajectory to better support learning. The scripting can be done at either the micro level (how students engage a specific task step-by-step) or macro level (how learners are organized for the different phases of the learning activity). In the above example, the learning activity follows a macro script, from individual data gathering to whole class discussion to final small-group reflection. Macro scripts are useful as different configurations are better suited for different phases. For instance, brainstorming has been shown to be most effective when done individually (Dugosh & Paulus, 2005). Often, group work benefits from an inequity of knowledge or divergent positions of the group members (Dillenbourg & Hong, 2008). At other times, no inequity is needed for collaboration to benefit learning (Roschelle, 1996).

Creating, fine tuning, and executing educationally effective macro scripts is a difficult design challenge (Anastopoulou et al., 2008). While that is the ultimate problem, this paper addresses only a step towards a solution: How do we unlock the potential of each device to support collaborative learning? In the example, each step in the macro script is carried out with a computational interface that best supports it. Due to its large vertical display, the electronic whiteboard lends itself to whole class discussion. Due to its portability, the handheld computer can be taken into the field. Particular attention in this example has been paid to the potential of interactive tabletops to support group work.

Interactive Tabletops for Group Work

From handhelds to desktops, the dominant paradigm for computing has been a personal one—one user per device. Interactive tabletops offer the potential to break that restrictive mapping. Already, much of the research on interactive tabletops examines how they can support collaborative activities. As tabletops become commercially available, they have the potential to support group work in a way no other popular classroom technology has been able to do (Rick, Rogers, et al., 2009).

While tabletops are starting to be available for the classroom market (e.g., SMART Technologies is selling a multi-touch tabletop aimed at younger children), many of the interaction paradigms and technical features are still in flux. One particular challenge is understanding how tabletop interfaces can support collaborative tasks, such as found in a collaborative script. Both a change in task and a change in interface can change the nature of collaboration (Nacenta, Pinelle, Stuckel, & Gutwin, 2007). In our recent research, we are trying to understand how the *task* and the *interface* can *enable*, *encourage*, and *enforce* collaboration (cf. Benford et al., 2000). What follows are three examples of this work.

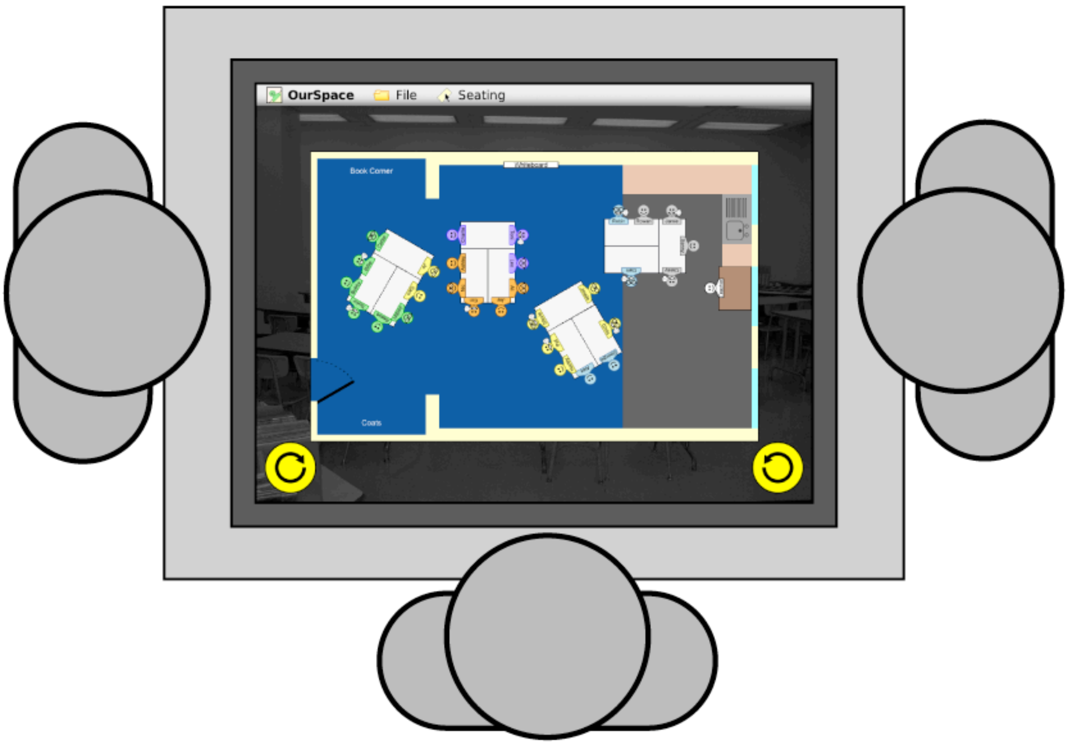

Figure 1. Three users position tables and students in their classroom using OurSpace.

OurSpace

OurSpace is a desk positioning and seating allocation application designed for three concurrent users (Rick, Harris, et al., 2009). A bird's eye virtual floor plan of the participants' classroom is placed in the center of the tabletop so that all participants, irrespective of their position, have good access to it (Figure 1). Participants use their fingers to drag icons of students and desks onto the classroom plan. When a student is dragged over an available desk seat, the seat is highlighted and the student is oriented toward that seat position; when dropped, the student icon snaps to that seat. Once a student is in a desk seat, he or she moves along with the desk;

students can also be dragged out of their seat to relocate them. To rotate desks, users drop them on rotation areas at the bottom left and right of the screen.

The research on OurSpace compared two interaction conditions: in the single touch condition, only one user's touch input registers at a time; in the multiple touch condition, all three users can interact concurrently. While turn-taking dialog was significantly higher in the single touch condition, no differences were found in either physical or verbal equity (Harris et al., 2009). This result contrasts with other research where multiple touch systems were found to be more equitable. Our findings suggest that minimal transition time and effort is critical to avoiding inequity with a turn-taking interface (Rick, Harris, et al., 2009). Turn-taking interfaces have the additional benefit of slowing down the interaction and making participants more aware of each other's contributions, which is useful for collaborative learning.

The desk positioning and seating allocation task that the children were assigned was designed to be complex (i.e., with no simple solution). Thus, the collaboration was useful in creating a better solution as team members often approached the task from different perspectives. The tabletop interface enabled that collaboration. On the other hand, much of the work was done without much coordination. The multiple touch interface *enabled* the collaboration, but did nothing to encourage or enforce it. Eventually, as the design began to mature, the nature of the task required the participants to coordinate their actions. In contrast, the single touch interface *slightly encouraged* the groups to coordinate their actions from the beginning. This demonstrates how a slightly different interface can change the nature of the collaboration for the same task.

DigiTile

DigiTile is an adaptation of DigiQuilt (Lamberty, 2007) for the DiamondTouch table (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 are often symmetric. The application provides feedback on the mathematical concepts; for instance, the fraction of the entire tile that is a certain color is displayed on the button for selecting that color. While DigiQuilt uses a conventional PC to support a single user, DigiTile is intended to be used by two concurrent users arranged side-by-side (Figure 2). The learners are given increasingly difficult challenges to accomplish, such as creating a design that is half red or creating a design that is horizontally symmetric.

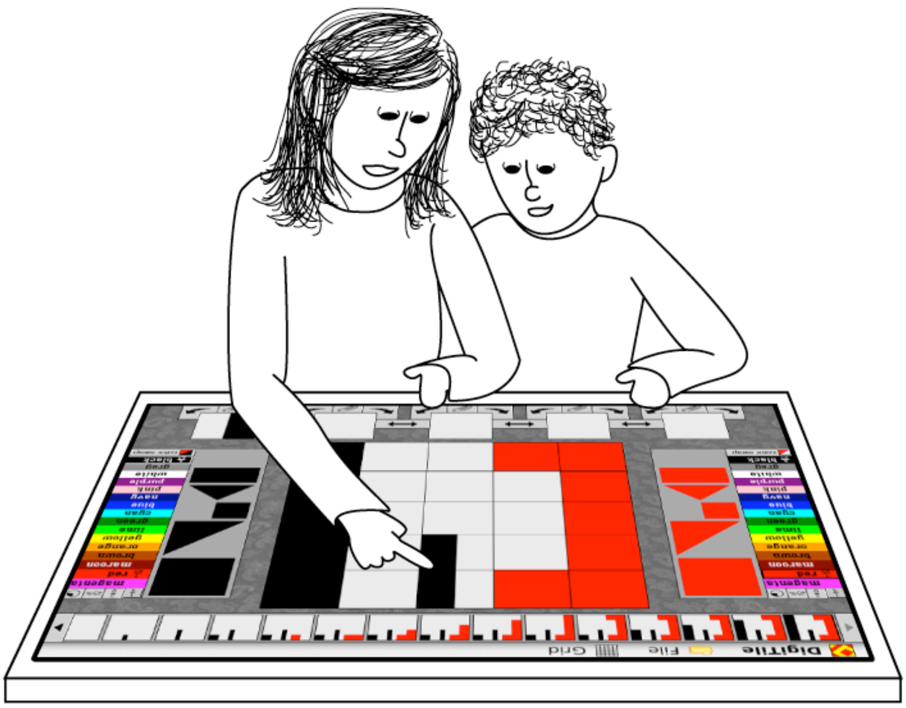

Figure 2. Two users collaborating on a DigiTile challenge of half red and half black.

Based on a thirty-minute session with DigiTile, learners achieved statistically significant increases in content understanding (Rick, Rogers, et al., 2009). While the interface allows both users to act independently, study participants frequently chose to coordinate their actions. They learned quickly that both participants adding to the tile independently causes confusion. One participant's contributions interfere with the partner's strategy. When participants discovered that uncoordinated contributions failed, they began to work together on one strategy at a time, often coordinating on strategies verbally. One participant might add pieces in a systematic manner while the partner watched the updating fractions and told the other when they had reached the goal. DigiTile's interface thus *strongly encouraged* collaboration. As with OurSpace, the task of completing a mathematical challenge benefits from collaboration. The learners benefit from articulating their understanding and providing feedback to their partners. While the task is not inherently collaborative, DigiTile's interface encouraged collaboration by making it nearly impossible to complete the task without it.

WordCat

WordCat is a word categorization game for two users positioned side-by-side (Figure 3). It is based on the SCOSS (Separate Control Of Shared Space) model of interaction, where learners work on the same task individually but must agree on a solution before they can proceed (Kerawalla, Pearce, Yuill, Luckin, & Harris, 2008). In WordCat, the challenge is to sort twelve words into the four central bins (three words per bin), so that each of the columns and each of the rows form categories related to the meaning or the shape of the word. In the example in Figure 3, the solution categories will be colors versus animals and words that begin with g versus words that begin with b. The words appear one at a time; the same word appears in the left yellow bin and in the right blue bin. Users then drag the words from the bin to the position in the central table where they believe it belongs. The left user can only move yellow words, while the right user can only move blue words; this rule is enforced by the tabletop interface. If both the yellow and blue version of a word have been moved to the same central bin, one green version of the word with bold text shows up. Once users are in agreement on all given words, a new word appears in the left and right bins.

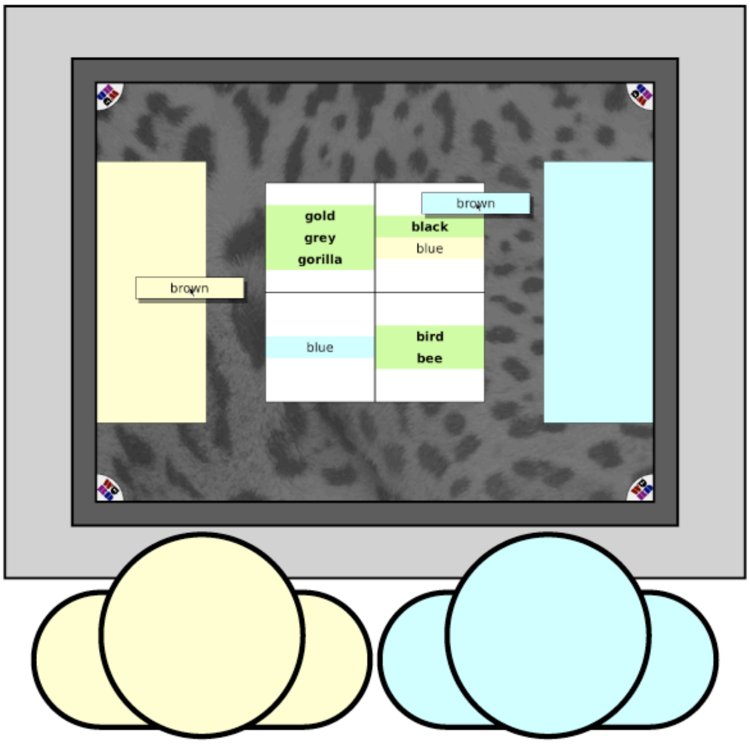

Figure 3. Two users placing word tiles in WordCat.

Unlike in OurSpace and DigiTile, one user cannot complete the task by themselves. Both users must move pieces into the same positions before a new word is added. Thus, WordCat's SCOSS-based interface *strongly enforces* collaboration. Inherently, the word categorization game does not require collaboration; however, it does benefit from collaboration as players help each other out. Along the way, they must convincingly articulate their hypotheses to try to convince their partners to go along. While WordCat's interface is quite strict, adjustments can be made to the interface to lessen the strength of the enforcement. For instance, new words could appear even if agreement had not been reached. Alternatively, all twelve words could appear in the respective bins at the start of the task. While the collaboration would still be enforced eventually (i.e., both partners must agree in the end), it would be so to a lesser extent (since the users could work largely independently until the end).

Conclusion

As these three applications demonstrate, the interface affects how the task is carried out. It affects the nature of the collaboration and thereby the learning that occurs. To effectively utilize interactive tabletops in a classroom ecology of devices, it is important to understand these interface differences and how to design for them. Yet, that is only a partial challenge to integrating interactive tabletops into a classroom.

First, novel technologies tend to be expensive and it is unlikely that one classroom could afford more than one or two interactive tabletops in the near future. Thus, the challenge will be to script learning activities that are not unduly limited in effectiveness by the limited number of devices. Second, creating application suites that utilize multiple different devices is a challenge. Since they have different hardware and different interfaces, different devices often do not support the same applications. Third, sharing data seamlessly between different devices in the classroom and outside the classroom (e.g., children taking presentations home to work on them there) is both an implementation and usability challenge. Fourth, the problem only becomes more challenging as different devices (e.g., public displays, digital desks that allow document capture, tangible bits) are added to the classroom ecology.

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Acknowledgements

This work is part of the ShareIT project funded by the EPSRC, grant number EP/F017324/1. I would like to thank my collaborators in that project: (alphabetically) Victoria Bonnett, Kimberly Bryant, Sheep Dalton, William Farr, Rowanne Fleck, Caroline Haig, Amanda Harris, Samantha Holt, Eva Hornecker, Paul Marshall, Shems Marzouq, Richard Morris, Nadia Pantidi, Yvonne Rogers, and Nicola Yuill. We thank MERL for loaning us the DiamondTouch.