"It's just a toolbar!" Using Tangibles to Help Children Manage Conflict Around a Multi-Touch Tabletop

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ABSTRACT
In this paper we present a case study of children's collaborative behavior around a multi-touch tabletop interface. The study includes data from four sessions with four children over a period of three weeks. The children in our study exhibited a diverse set of collaborative behaviors including territorial control of screen real estate, conflict over interface elements, and turn taking behavior, all of which seemed related to specific aspects of the interface design. Most notably, we observed conflict relating to a graphical toolbar that the children could drag around the screen. After observing this conflict, we redesigned the interface so that children were forced to use a tangible object (a wooden block) to make the toolbar appear on the screen. This tangible object seemed to help the children resolve their conflict and to promote spontaneous turn taking behavior. This paper is an effort to understand why the graphical toolbar alone seemed to spur conflict and why the introduction of a tangible object seemed to help children resolve the conflict on their own.

Author Keywords
Children, multi-touch tabletops, collaboration, tangible interaction, learning

ACM Classification Keywords
H5.m. Information interfaces and presentation: User Interfaces – *Interaction styles; Input Devices and strategies.*

INTRODUCTION
Multi-touch tabletop technology offers a dynamic and appealing medium for designers to create collaborative learning experiences for children. However, the nature of children's collaboration around tabletop devices remains largely unexplored. In particular, subtle interface design decisions seem to have a large impact on children's interactions with each other as well as with the tabletop interface itself.

In this paper, we present a case study examining the behavior of a group of four elementary school children interacting with a scientific modeling application on both a multi-touch tabletop and a desktop computer. The study includes data from four sessions over a period of three weeks. We selected this group of children for our case study because they exhibited a diverse set of collaborative behaviors including territorial control of screen real estate, open conflict over interface elements, and turn taking behavior, all of which seemed dependent on specific aspects of the interface design that changed over the course of four sessions.

Most notably, we observed unexpected conflict relating to a graphical toolbar that the children could drag around the screen (Figure 2). After observing this conflict, we redesigned the interface so that children were forced to use a physical block (Figure 3) to make the toolbar appear on the screen. This tangible token seemed to help the children resolve their conflict and to promote spontaneous turn taking behavior. This paper is an effort to understand why the graphical toolbar seemed to spur conflict and why the introduction of a simple tangible object seemed to help children resolve that conflict on their own.

This case study is part of a larger design research study with the goal of adapting the NetLogo modeling environment [16] for elementary school students through the use of multi-touch tabletop devices. Our goal is to support collaborative exploration of scientific models on a tabletop surface. NetLogo is an agent-based modeling language that enables students and professionals alike to model complex systems and emergent phenomena [16]. One advantage of agent-based models is that they are accessible to learners without the need for great mathematical sophistication. Many important physical, biological, and social phenomena can be modeled and

TEI'11, January 22–26, 2011, Funchal, Portugal.

understood through simple computational rules that describe the behavior of agents in a complex system [17].

BACKGROUND

Research has long suggested that work in small groups can result in productive learning experiences for children (e.g. [9, 14]). Studies have further explored the role of computers in small group work [2,3,6,10,11,12]. For example, Inkpen, Booth, Gribble, Klawe and Upitis found that children who collaborated around a single computer display to solve puzzles showed improvements in achievement and attitude over peers who worked alone [6]. The effect of computer collaboration on achievement was especially heightened within groups of girls.

Multi-touch tabletops provide a large horizontal display around which children can interact simultaneously—in many ways similar to that of everyday interaction that happens around non-computer tabletops (for example children playing cards or board games). Tabletop workspaces (interactive or not) provide a high degree of peripheral awareness of others and their actions in the workspace [15], and researchers have begun to investigate the potential of multi-touch tabletops to support both co-located collaboration and learning [1-4, 6, 7, 10-13].

Many interactive tabletops are implemented using computer vision technology (e.g. Microsoft Surface), which makes it possible to interact with the computer using tangible objects as well as touch input. For example, Antle, Droumeva, and Ha [1] have conducted research involving pairs of children solving jigsaw puzzles in three different conditions: with a desktop computer and mouse, with a standard cardboard puzzle, and with a digital tabletop and tangible puzzle pieces. Their results suggest that the direct physical manipulation of objects with the tangible puzzle leads to faster and easier problem solving involving less trial and error.

When children collaborate on multi-touch tabletops they negotiate meaning in a variety of ways. Often children will use physical behaviors such as blocking, "undoing", and grabbing to negotiate and collaborate [2]. Fleck, Rogers, Yuill, Marshall, Carr, Rick and Bonnett argue that these behaviors, in tandem with verbal discussion, can lead to effective collaboration in a tabletop environment [2].

In our research we have observed that children's existing repertoire of social protocols are not always sufficient to prevent conflict around interactive tabletops. Morris, Ryall, Shen, Forlines, and Vernier identified three conflict types emerging around tabletop interactions: global, whole-element, and sub-element [8]. Whole-element conflicts involve access to a single interface element such as the toolbar that is the focus of this study. Morris et al. suggest several coordination policies for resolving whole-element disputes on tabletop interfaces. Some of these policies relevant to our study include offering private or duplicate interface elements and creating personalized views for individual collaborators. In this paper, we consider an additional coordination strategy—the use of a tangible object to access a single, shared interface element.

A core concern of our research is the *fluidity of sharing* around our tabletop environment. According to Hornecker, Marshall, and Rogers, fluidity of sharing refers to the ease with which collaborators "can switch roles or interleave their actions" [5]. Fluidity of sharing can be compromised when users have a difficult time managing the tabletop real estate (territories). Research suggests that territories serve to coordinate tabletop interactions, and collaborators make use of three types of territories to help coordinate their interactions within the shared tabletop workspace: personal, group, and storage territories [13].

Another factor that affects collaboration is *orientation* [7]. Orientation on an interactive tabletop is the ability to move and reposition an item on the work surface. According to Kruger, Carpendale, Scott, and Greenberg, orientation serves functions of comprehension, communication, and coordination [7]. Orientation is important for negotiation in a tabletop environment as it communicates ownership and is used as a way to establish personal and group spaces.

Collaboration is also affected by group and table size. Ryall, Forlines, Shen, and Morris found that the size of a group greatly affected the way in which a physical shared resource was positioned [12]. While groups of two were able to orient a resource to a point of view that would satisfy both, groups of four had a harder time orienting resources and collaborating on a tabletop. Larger groups assign a person whose responsibility it was to manipulate the shared resource.

Figure 1. Our tabletop NetLogo interface

TABLETOP INTERFACE DESIGN

This case study involves a multi-touch tabletop interface that we designed for children to explore and create NetLogo models (Figure 1). We implemented the application on a Microsoft Surface, a commercially available interactive tabletop from Microsoft that allows multiple users to manipulate digital content using touch input. The Microsoft

Surface is a 30-inch horizontal display in a tabletop form factor, 22 inches high, 21 inches deep, and 42 inches wide.

During this study children interacted with two models from the NetLogo models library. The first model, *Wolf Sheep Predation*, explores the stability of predator-prey ecosystems. The second model, *Virus*, simulates the transmission and perpetuation of a virus in a population.

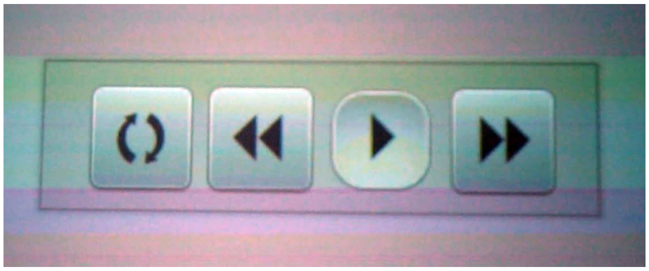

Figure 2. Graphical toolbar widget

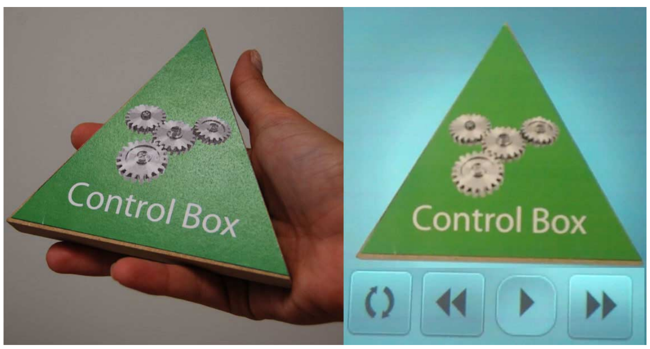

Figure 3. The tangible toolbar token is a triangular wooden block that children must place on the screen to make the toolbar widget appear (right).

Currently the interface consists of three components. The first is a window that displays a visual representation of the simulation. Children can drag this window around the screen and resize it using a pinch gesture. Initially positioned underneath with simulation window is a collection of sliders that children use to adjust a model's input parameters. Finally, a toolbar widget containing a collection of buttons to control the simulation is provided. The interface also incorporates a collection of tangible blocks that serve as entry points into NetLogo programming activities. For example, children can place a Create Turtle block on the table (Figure 1) to add agents to a model and a Forward block asks the existing turtles to move forward on the screen.

Control Toolbar

Children control NetLogo simulations using a toolbar widget (Figure 2). Pressing the play button on the toolbar starts a model simulation, which can then be controlled using fast-forward, rewind, pause, and reset buttons. In our initial design, we placed the control toolbar near one corner of the tabletop and allowed it to be dragged around the screen using a single finger. In the first session of the case study the children never repositioned the toolbar, apparently assuming it was fixed in place. In the third session, the children realized that the toolbar could be moved around the screen, which in turn created disputes over where the toolbar should be placed, and who controlled it. As a result, between the third and fourth sessions, we redesigned the interface to include a tangible toolbar token, a triangle shaped wooden block shown in Figure 3. In this iteration of the interface, children were required to place the physical block on the tabletop to make the toolbar widget appear on the screen. The toolbar widget always appeared alongside the physical token and moved with it on the screen.

METHOD

Participants

For this case study we observed a group of four children, three girls (ages 8, 9, and 11) and one boy (age 10) recruited from a suburban private school in the United States Midwest. As compensation for participating in the study children received a $5 gift card to an ice cream shop.

Procedure

The children participated in a series of three workshops over a period of three weeks. Each workshop lasted three hours. During the workshops children collaborated around a desktop computer, a multi-touch tabletop, and a physical board game. We prompted the children with challenges such as: "work together to find settings that will create a sustainable ecosystem." All workshop sessions were video recorded.

Case Study Sessions

From the three workshops with the children we selected four interaction sessions to highlight in this case study. These sessions consisted of the children working together with minimal adult interaction to explore a NetLogo model.

Session 1: Tabletop with Fixed Toolbar

In the first session the children worked on the tabletop to explore the wolf-sheep predation model. We asked the children to try to create stable populations of wolves and sheep. In this session the children apparently believed that the graphical toolbar was fixed in place—they never moved it from its default location on one corner of the tabletop. During this session one girl who was closest to the toolbar dominated its use. The other children would frequently reach across the table to press one of the buttons. This session lasted 21 minutes, 4 seconds.

Session 2: Desktop Computer with Single Mouse

In the second session the children worked with the same NetLogo model using a desktop computer and a mouse rather than the tabletop. In this session children passed the mouse from person to person, sharing control. This session lasted 15 minutes, 11 seconds.

Code	Description
Reach Over	Reaching over the workspace to try to use the control (successfully or not). 
Blocking	Preventing another child from using the control using one's body, arm, or a finger.
Possible Blocking	Positioning body to establish territory. However, due to lack of verbal or intentional cues the intention to block is uncertain.
Verbal Complaint	Expressing dissatisfaction over how the control is being use or how another child is acting with respect to the control (e.g. "I want to use it now!").
Grabbing	Physically taking the control away from another child. This includes dragging the toolbar on the screen or taking a physical input device (mouse or tangible block). 
Passing Control	Passing the control to another child.
Tucking Away	Holding a physical control to prevent others from taking it. 
Asking for Control	Asking to use or hold the control (e.g. "Can I try it?")

Table 1. Coding scheme

Session 3: Tabletop with Floating Toolbar
The following week, we presented a virus model to the children and asked them to make the spread of disease faster, slower, extinct, and perpetual in the model. In this scenario, children noticed that the toolbar could be dragged around the screen. This realization seemed to spark an argument over control of the toolbar. This session lasted 18 minutes, 7 seconds.

Session 4: Tabletop with Tangible Control Bar
In an effort to control the argument, we introduced a tangible object in the following week. To make the toolbar appear the children had to first place the tangible object on the screen. In this session the children were able to develop a turn-taking protocol that appeared similar to what we observed in the second session with the computer mouse. This session lasted 5 minutes, 24 seconds.

Coding
We coded the video with a scheme based on [2] and shown in Table 1. The coding scheme was modified to accommodate particular interactions we were interested in, such as reaching across the table to take control of the interface element. The coding scheme provides a descriptive account of the interactions observed around the element of control in each interface. In the first and third sessions the element of control was a toolbar widget (Figure 1). In the second session the element of control was a mouse. And, in the fourth scenario the element of control was a tangible control box (Figure 2). The frequency of each code was found by counting the number of instances over the duration of the session.

Conversation topics were also coded. Students' conversations included two primary topics: *science-talk* and *control-related* conflict. *Science talk* is any stretch of time in which at least one child is discussing the workings of the model. This includes conjecture, discussion, and predictions about the model, as well as observation of individual agents in the model. For example, as one model converges with too many sheep:

> A: Overpopulation
> J: Not enough wolves. Then the animal who eat wolves dies too... It's a clog in the circle of life.
> A: Chain reaction.... Oh, that is a lot of dying at once.
> N: What about the animals that eat wolves? They can start eating sheep instead.

Control-related conflict was coded as any verbal comment or physical behavior that was related to the ownership or use of the model controller. For example:

> A: [Reaches over] [Grabs control]
> J: [Verbal Complaint] Stop!
> T: [Verbal Complaint] J. said I could have a turn!
> J: No, I didn't!
> T: [Asks for control] May I please?
> J: It's just a toolbar!
> N: [Reach over]
> T: Then why do you want it?
> A: Yeah?

J: Because it belongs here
A: It doesn't have to; it doesn't have to... Look [Reach over] [Grabbing control]
N: [Verbal Complaint] Alex! Stop!
A: It can move! Doesn't HAVE to be there…

In some cases the situations overlapped; for example, two students discussed the model as the other two were engaged in control-related conflict. We calculated the total amount of time for each category by adding the duration of each segment per session. We then divided these sums by total session duration.

We also report the frequency of interruptions in science talk due to control-related conflict. For example, we coded this exchange as an interruption in science talk:

A: It’s lasted pretty long
N: Yeah. That was pretty sustainable, right?
A: [Reaches over and takes the toolbar]
A: Miiiine.
N: They won’t all die if you have it down here
J: [Takes the toolbar back from A]
A: MIIINE! [reaches over to grab the toolbar]
J: STOP!

RESULTS

Flow of Interactions

We calculated instances per minute of each behavior type in each session (Figure 4a-c). The results suggest that children adopted distinct collaboration styles in each session. The interactions in the first and third sessions were initially similar. The differences emerged in the 9th minute of the third session (Figure 4c) when children discovered that the toolbar widget could be moved around the screen, and an open conflict emerged. This transcript covers the start of the argument:

A: [Reaches over; realizes the toolbar moves]
A: [Reaches over; tries to take toolbar]
N: Wait, wait, wait—we need this at 6.
T: They will all die if you have it down here.
A: [Drags control away] Mine! Mine now.
J: [Reach over and drags control away]
A: [Reaches over]
J: [Blocks A with hand]
A: [Gasps] Mine!
A: [Reaches over again]
J: [Blocks again]

In the first tabletop scenario, when children did not know that the toolbar could be moved, they reached across the table to press buttons an average of 2.27 times per minute (SD = 1.95). Whereas, in the third scenario, when children found out the toolbar could be moved, they reached over to use it 3.1 times per minute (SD=3.43). The higher amount of reaching over, as well as higher standard deviation, probably reflects the dispute over toolbar control, which escalated at the ninth minute.

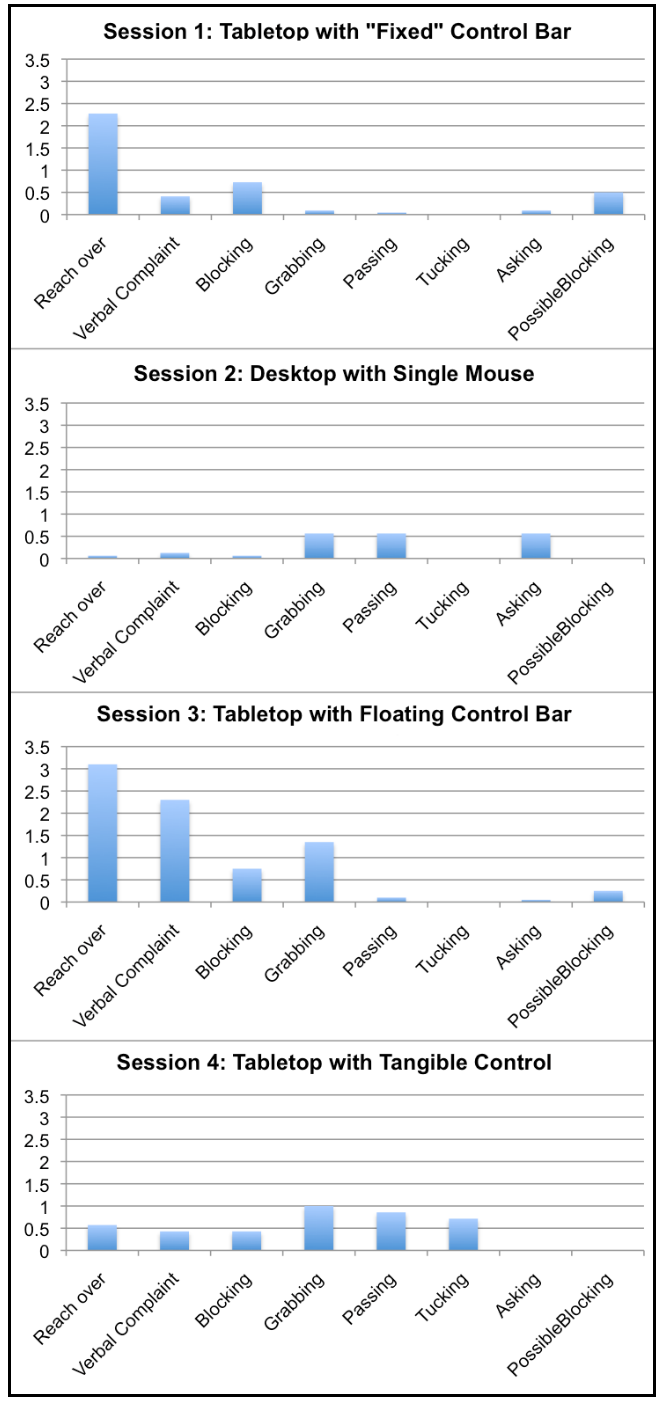

Figure 4. Average instances of behavior codes per session: (a) tabletop with “fixed” toolbar widget; (b) desktop computer with a single mouse; (c) tabletop with “floating” toolbar widget; and (d) tabletop with tangible control box.

The open conflict in the third session also brought about a higher amount of verbal complaining. In the third session the children complained 2.3 times per minute (SD= 4.31) compared to 0.41 times per minute (SD = 0.67) in the first scenario. The action of grabbing the control in the two sessions was also different. While in the first session there was a small amount of grabbing (0.09 grabs per minute; SD

= 0.43), in the third session the number went up to 1.35 grabs per minute (SD = 2.56).

Once the tangible object was introduced (session 4, Figure 4d), the flow of interactions changed substantially. Compared to the third session children passed the control more (0.86 times per minute, SD = 0.9), reached over less (0.57 times per minute, SD = 1.13), and blocked less (0.43 times per minute, SD = 0.79). The children also displayed a new behavior, that of taking the tangible object off of the table and tucking it away under their arms to prevent others from taking it (0.71 times per minute, SD = 0.76). The fourth session seems to more closely resemble the second session in which the children used a desktop computer with a single mouse. In the second session the most prevalent actions were grabbing, passing, and asking. Children grabbed the control 0.56 times per minute (SD=0.51), passed the control 0.56 times per minute (SD=0.72), and asked for the control 0.56 per minute (SD=0.72). We attribute the prevalence of these actions to the turn-taking behavior children spontaneously adopted in the mouse session.

Session	%Science talk	%Arguing and complaining	Interruptions / minute
1	100	1.64	0.429
2	91.38	4.49	0.198
3	72.72	16.63	0.828
4	80.64	4.12	0.556

Table 2. Percentage of science talk and arguing & complaining in each session. The final column shows the frequency with which science talk was interrupted due to arguing and complaining. Note: at times the children argued while simultaneously discussing the NetLogo model. Thus, percentages do not necessarily add up to 100.

Science Talk and Argument Sequences

We also analyzed the total amount of time spent in science talk during each session compared to the amount of time spent arguing or complaining over control of the toolbar. In the first session, when the children assumed that the toolbar was fixed in place, argument sequences were rare at less than 2 percent of the student work time; this session also included the largest percentage of science talk time. When the children moved to a desktop display with a mouse controller, the percent of time spent on science talk decreased by almost 10%; in addition the proportion of conflict increased to approximately 4.5%. The tabletop display with the tangible control showed similar results with further dip in science talk, to 80%. The most prominent results appeared in the third session when the children realized that the toolbar could be moved. During this session students' science talk dropped to nearly 70%, while their conflict level rose to over 16%. Table 2 presents the results of science talk, control-related conflict, and frequency of complaint-lead interruptions. In comparison to the tabletop with a fixed control bar (session 1), the rate of complaint-lead interruptions nearly doubled with the floating control bar (session 3). The lowest rate of conflict related interruptions occurred with the desktop display (session 2).

DISCUSSION

The children seemed to have a clash of expectations regarding appropriate social protocols in the tabletop sessions. Because tabletop interaction was new to these children, we speculate that they were unsure what set of social scripts or norms applied. Some of the children assumed turn taking scripts, asking to participate, passing the control, and complaining when those scripts were not applied. Others assumed territories and fought for having sole control of the tabletop.

In the first session with the "fixed" toolbar, the children established clear territories, and they struggled to position themselves in places where they had easy access to the control. We felt that the ongoing conflict compromised the fluidity of sharing because one child monopolized the territory where the interface element was located. Once the children noticed the toolbar could be moved, the struggle for territory control escalated into an open conflict—the frequency of reaching over and grabbing increased and verbal complaints interrupted the children's scientific conversations.

Morris et al. suggest several coordination strategies for conflict resolution including the use of duplicate control boxes at different points on the table [8]. Although, we didn't evaluate this option with our interface, we feel that it has potential downsides for the types of activities we hope to support. Duplicate control boxes might reduce a child's ability to observe the models and their awareness of complex structures. Duplicate controls could cause arguments and confusion as children press different controls at different times, as well as provoke a race for who will press the control first, detracting from the attention to the model. Using a fixed control bar works well, except that it implies an assigned "boss". As children had difficulty assigning roles themselves, this concept also caused some conflict. Ultimately, using a tangible object to access the control bar might be a good option for designing collaborative tabletop interfaces for children as it recalls familiar protocols children are accustomed to.

When we introduced the tangible control in session 4, there were less territorial disputes, and arguments. This is because the tangible control affords removal from the table, separating control of the interface element from the tabletop territories. It introduced a familiar idea into an unfamiliar interactive setting, and, allowed children to recall turn-taking scripts: a "passing the baton" protocol. Thus, we speculate that the tangible object acted as a catalyst for more fluid sharing. In the end of the fourth session, we asked children why they stopped fighting over the control. Their responses included:

> A: Because people were just like dragging it... like I was about to click it and they'd drag it towards them, and

stuff, but like this... If you are holding on to the control box, no one can drag it.

T: And, you can also take turns too.

LIMITATIONS & FUTURE WORK

There are limitations to this research that should be considered in the application of results to future designs. First, the study analyzed data from one case study, with a small number of children over a period of three weeks. It is possible that the children could have established similar turn taking protocols on their own, independent of our design change. It is also reasonable to assume a novelty effects (especially in the early tabletop sessions) that might have begun to wear off near the end of the three-week period. Likewise, fatigue and boredom could have played a role in the later sessions. We also did not try a tabletop interface design that offered the children multiple toolbars to share on the screen as suggested by Morris et al. (2004) [8]. As discussed above, we feel that this particular design decision would not be ideal for this type of collaborative learning; however, this is only based on our design intuition.

In the future we would like to explore different forms of coordination strategies and examine the resulting effects on collaboration with a larger, more diverse group of children. We also expect to perform a conversational analysis of children's scientific talk around the tabletop interface with a focus on the ways in which the threads of social negotiation and scientific talk intertwine.

CONCLUSION

Interactive tabletops are an increasingly popular tool for the design of learning experiences. In this paper we present a case study of four children interacting with four variations of the same interface. These interfaces included: (1) a multi touch tabletop interface with a fixed toolbar widget, (2) a desktop computer with a single mouse, (3) a tabletop interface with a floating toolbar widget, and (4) a tabletop interface with a toolbar widget accessed by a tangible object. We present evidence that the use of the tangible object in the fourth session was successful as a prompt for children to share control of the interface. In contrast, the floating toolbar widget in the third session seemed to spur conflict and interfere with the children's scientific discussion. We argue that through the use of the tangible object children were able to invoke familiar turn taking protocol—the mouse served a similar function in the desktop session. The use of the floating toolbar widget, on the other hand, resulted in conflicting expectations of appropriate social behavior on the part of the children.

ACKNOWLEDGMENTS

We would like to thank the Center for Connected Learning and Computer-Based Modeling at Northwestern University. We are also indebted to the children that volunteered to take part in this research and to Ana Duarte, and Gabriel Olson for all the support in this research study.

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