A case study of Tangible Flags: A collaborative technology to enhance field trips

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ABSTRACT
This paper describes research that investigates the use of a technology designed to support young children's collaborative artifact creation in outdoor environments. Collaboration while creating knowledge artifacts is an important part of children's learning, yet it can be limited while exploring outdoors. The construction of a joint representation often occurs in the classroom after the experience, where further investigation and observation of the environment is not possible. This paper describes a research study where collaborative technology was developed, used by children, and evaluated in an authentic setting — a U.S. National Park.

Keywords
Children, collaboration, cooperative inquiry, digital augmentation, mobile learning, tangible interfaces

ACM Classification Keywords
K.3.1 [**Computers and Education**]: Computer Uses in Education – *Collaborative learning*.

INTRODUCTION
Outdoor field trips give children the opportunity to explore an authentic context. Children on field trips are typically encouraged to observe and take notes while they explore their surrounding environment [8]. This may be followed by classroom activities where the children work together to create reports, posters or other representational artifacts using the knowledge they gained during the context of the immersive learning experience. However, this activity is limited because more detailed explorations of the physical environment cannot be replicated in the classroom. As a result, opportunities are lost for direct, iterative interactions in the physical learning space that combine collaboration in an authentic context with construction of explicit representations [9,12]. There is a noted lack of research on learning environments that make use of mobile technologies to support learning by experiencing, collaborating, and creating artifacts at the same time [18].

Figure 1 – The Tangible Flags technology in use.

This case study describes the design and evaluation of *Tangible Flags*, a technology to support and encourage young children (grades K-4) to concurrently explore, collaborate, and construct digital knowledge artifacts, while they are immersed within mobile, hands-on educational environments. On a field trip, each child (or team) is given a set of Tangible Flags and a wireless tablet computer with a radio frequency identification (RFID) scanner attached. Tangible Flags are computationally enhanced using RFID tags (see figure 2) and when scanned, provide access to digital information. While on a field trip a child can attach a Tangible Flag to any interesting item in their environment and can draw a picture or take notes relating to the flagged item using software on the tablet computer. The digital artifact is saved on a remote server via a wireless network. Children can use this same tangible interaction to access digital information created by others and annotate that information in a shared space.

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An evaluation of this technology was conducted in conjunction with the U.S. National Park Service at an outdoor park. The evaluation study involved park visitors participating in an authentic park program adapted for the use of the technology.

Related Work

The use of portable computers as data collection and visualization tools have been shown to promote inquiry for children (grades 5-8), but has not sufficiently addressed the need to support collaborative efforts during exploration [16]. The Ambient Wood project [14,18,19] has illustrated the power of enabling collaboration in context. The use of digital augmentation of the environment can promote reflection and is more effective if children (age 11-12) initiate their own inquiry into the environment instead of viewing pre-situated content [19]. HyConExplorer [4] addresses the need for children (grades 6-7) to produce their own material related to the learning activity by linking child-authored contextual information to the environment using location information. However, such an abstract connection between information and location can be confusing for children [3]. A more concrete link between digital information and context may be necessary, especially for younger children. Tagging methods such as optical barcodes or RFID have been used in a variety of research to associate digital information with the physical environment [10,15,22], yet none of this research has addressed the learning potential of providing young children with tools to tag their environment and embed digital information.

Research that does not address the contextualization of information can still provide insight into supporting collaboration in young children's creative efforts. One study indicates that children (age 9-11) participate more in collaborative interactions when they are provided with concurrent multi-user interaction and suggests that a lack of physical activity may negatively impact the overall effectiveness of collaborative activity [20]. Tools to support children's collaboration have demonstrated the importance of concurrent interaction for joint artifact creation [2], and the importance of mobility and tangible interfaces in fostering collaboration [5,11,21]. We feel concurrent interaction is an important complement to mobility when designing tools for children to augment the physical environment with digital information.

Most research in supporting children on educational field trips is geared to children grade 5 and up [4,16,19]. By these grades, children are expected to be able to take notes and create reports somewhat independently. However, younger children also participate in field trips, where they make drawings, write notes or answer questions while observing. They are learning note taking and observation skills, but need more scaffolding and input from their educators. Prior to Piaget's formal operations stage (about age 11), children have problems with abstractions because much of their thought process is tied to concrete experience [13]. Children in grades K-4 have need of a more direct link between the real world and information on a computer. We believe Tangible Flags provides this direct connection.

APPROACH

At the University of Maryland's Human-Computer Interaction Lab, our philosophy is that children can and should be active design partners in developing technology for children. We use a method called *Cooperative Inquiry* that has adapted ideas from participatory design and contextual inquiry to meet the unique challenges of working with children [6]. Child and adult members of an intergenerational design team observe technology used by children and capture activity patterns, using sticky notes, drawing or writing in journals. An example of a technique used in the brainstorming process is sketching ideas to create mock-up prototypes using child friendly art supplies. The iterative process used in Cooperative Inquiry with both children and adults yields an in-depth understanding of how technology can improve the lives of children.

Preliminary Design

We worked with two teams of children in developing Tangible Flags; a group of 6 children, age 6-10, who joined us in our lab after school twice a week and a class of kindergarteners at the Center for Young Children, University of Maryland's on campus research pre-school. We made observations of the kindergarten classroom's actual field trips, and both teams participated in mock field trips. We experimented with marking the environment using flags consisting of a pipe cleaner attached to a popsicle stick. We named these *Tangible Flags* because the children planted them like flags and used them as a mock tangible interface for accessing digital artifacts. Our goal was to see the impact of the Tangible Flags concept on children's collaborative effort and ability to re-locate or elaborate on their findings. These initial flags were not computationally enhanced, so adult researchers helped the children correlate Tangible Flags with various media, such as notes taken or pictures drawn by the children, or audio and video recordings created by the children. These preliminary sessions informed our design in several important ways:

- **Awareness during exploration -** Tangible Flags influenced how the children explored on numerous occasions. They made decisions on where to explore based on the existing placement of Tangible Flags, both their own flags and the flags of others (e.g., exploring or not exploring an area because they could see who had already been there). We recognized the importance of this awareness and decided to make Tangible Flags more readily visible.
- **Unique flags -** Without actually accessing the digital artifact, children did not always accurately recall which Tangible Flag they had used to embed a given piece of information. We decided that it would be helpful to make each Tangible Flag unique (such as by color and

a number) and provide access to digital artifacts previously created without requiring the child to return to the location of the Tangible Flag.

- **Drawing and writing -** Access to audio and video recordings is sequential and sometimes led to children waiting on others to finish accessing the media. Writing and drawing was done concurrently.

The preliminary design sessions helped confirm that children could use physical tags as an abstraction to embed digital information into their environment. Access issues when using sequential media also highlighted the importance of concurrent interaction.

Design Concepts

We identified three important concepts for our design: physical connection to the digital information, increasing contextual awareness, and concurrent interaction.

Physical Connection to Digital Information

The simple interaction of placing a Tangible Flag is an age appropriate activity for young children and the physical act may reinforce the relationship between the real world environment and more abstract digital information displayed on a computer. In our design, a child first must discover and scan a Tangible Flag placed by another to gain access to the associated digital information. We feel this discovery experience provides a strong mental connection because the child is situated to compare the artifact with the real world environment that it represents. Once a Tangible Flag has been scanned, access to the corresponding artifact is available through the computer's GUI. The artifact can now be accessed from any location, but the original creation or discovery experience provides a mental association to the real world context. This may aid children in relating their current thought process to the digital information or to again locate the Tangible Flag in the physical space.

Increasing Contextual Awareness

While both individual and collaborative learning activities are appropriate for young children, individual exploration may result in missed opportunities for collaborative learning. Children may not be aware of each other's discoveries and may not effectively share knowledge. Making the actions of an individual obvious can promote awareness of activity amongst collaborators [14]. Readily apparent Tangible Flags can provide children with an awareness of other children's exploration and artifact creation activities, which can be directly translated into access to artifacts embedded via those Tangible Flags. To increase awareness, sets of Tangible Flags can have different colors to indicate the original author. Numbered flags create an association to digital information and may help children to later access to digital information using the computer interface instead of the Tangible Flag.

Concurrent Interaction

Children in an open, exploratory environment may not work together collaboratively all the time, even when assigned to pairs or teams. As seen in both our preliminary design sessions as well as previous research [2,20], concurrent activity is very important in keeping children engaged during collaboration. Tools to aid children in collaborating in mobile environments need to support both individual and collaborative activity and enable children to seamlessly switch between exploration, individual and joint artifact creation by allowing children concurrent access to the digital medium.

PROTOTYPE SYSTEM

We elected to use a tablet computer as it emerged as the best portable system for young children. Handheld computers have limited screen space and the stylus can be too small for a child, while a laptop is not easily used while moving and a mouse does not support freehand input as well as a stylus. We wished to use freehand input because the younger children in our target age may have limited writing or typing skills. With freehand input, children can write or draw in a way that is more natural. We found Compaq tablet computers have a smooth pen interaction and the pen is thicker than most, making it easy for children to use. The size and weight of a tablet computer was a concern for small children, but we decided this was less problematic than input issues. Children can always set the computer down or take turns carrying it when in a team, and we have seen children do both in our experience.

Hardware

The RFID tags are passive devices consisting of thin, flexible copper traces printed on paper, each having its own unique ID. Tangible Flags are built by embedding a RFID tag inside a flag made of art materials (see figure 2). Our flags evolved in the course of our design and testing, starting with colored felt and pipe cleaners that could be attached to objects. But we found that the children wanted larger, more visible flags. Our final version uses a large, yellow border for visibility and no longer includes a string or pipe cleaner, which often became tangled.

Figure 2 – Tangible flag initial (left) and final (right) designs.

The RFID reader can detect RFID tags from a range of 4 to 6 inches. We knew from our previous work [7,11] that young children could consistently interact with tangible interfaces built around this RFID system. The RFID reader is attached to the computer in a prominent location so that children have a clear indication which part of their computer is used to scan Tangible Flags (see figure 3). In our first prototype, the reader had a cover that looked like a bull's-eye. During cooperative inquiry design sessions, our

child design partners suggested changing the cover's color to match the color of a child's set of Tangible Flags.

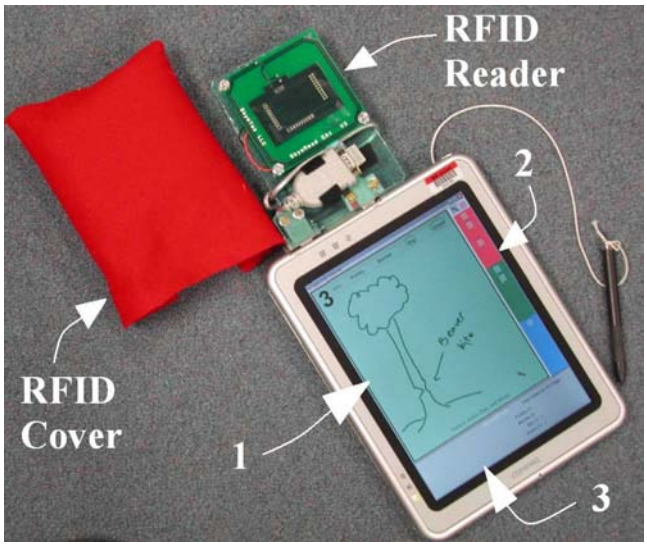

Figure 3 – Tablet PC with RFID reader and cover, showing the GUI interface.

Software

Software for Tangible Flags consists of two components, one or more clients and a server, both written in C#. The networking software is written using Microsoft's .Net remote procedure call library. The client interface software is written with Piccolo, a 2D zooming graphics library [1]. Client computers connect to a server that is running on a computer accessible through the wireless network. The server maintains data objects for each Tangible Flag. It forwards data changes to every client.

Client

A client displays the data for the user, accepts user inputs, and communicates data changes with the server. The interface screen consists of three areas (see figure 3).

1. A working area displays the data associated with one Tangible Flag.
2. The flag area displays a thumbnail for every Tangible Flag the user has scanned.
3. The ScratChat area is a common writing area not associated with any Tangible Flag.

The working area has a light background color and number that matches a Tangible Flag. Users can write or draw on this page using the tablet's pen, much as they might on a piece of paper. They can erase their own inputs, but not those of others. Each client's pen writes in the same color as the Tangible Flag set and computer cover. Different clients can concurrently interact with the same Tangible Flag page.

The flag area displays a thumbnail for every Tangible Flag a user has scanned. Selecting a thumbnail activates the working area for that flag. Animation is used to swap pages between the flag area and the working area. Scanning a Tangible Flag with the RFID reader also selects its page; children can use either interaction to access different Tangible Flag pages.

The ScratChat area provides a means for instant communication with all other clients. Writing in this area automatically disappears after a short period in order to prevent it from becoming cluttered and to emphasize its use as a message space, not a note taking space.

EVALUATION: Case Study at Rock Creek Park

Rock Creek Park [17] is a National Park in Washington, D.C. that has a number of cultural and natural resources, including trails through natural areas. The National Park Service has a variety of programs scheduled for visitors, one of which is a ranger-led forest walk with a scavenger hunt, a popular activity for families with children in early grade school. We felt this program would be a good first test for Tangible Flags. Our research team adapted the scavenger hunt program for the Tangible Flags technology. We selected the "Edge of the Woods Trail", which is a quarter mile loop through the woods with a small pond and meadow near the center. A scavenger hunt was selected that had a focus on the variety of trees and other plants that can be seen along this trail. Some of the plants along the trail include holly trees, pawpaw trees, chestnut oak trees, raspberry bushes and devil's walking stick.

Participants

The park visitors who wished to participate were split into three groups with one or two children in each group; families were kept together. While the program was advertised for children ages 6 and up, we also accepted younger siblings. Parents accompanied their children and were given no specific restrictions on interaction, except to limit efforts to help their children with the technology. If asked to write inputs by their children, parents were instructed to place an asterisk next to any adult input. Each group was assigned a color: red, green or blue. A 4th grade girl (age 9) who had previously used the technology was given the blue computer. The red group was pre-kindergarten boy (age 4) and a 2nd grade girl (age 6), who were siblings. The green group was a 1st grade girl (age 6) and a 2nd grade boy (age 7), who were unrelated. The children were given a 10-minute demonstration of the technology before the activity began.

Study Activity

The activity started with an introduction to the area by the ranger and some guidelines on what to look for. After a short demonstration of the technology, groups independently explored the trail. After about 20 minutes of the exploratory walk, the ranger led all participants on a guided walk of the trail.

After the introduction, each group was given a set of three Tangible Flags of their color and one computer — we chose three flags to limit the activity to about 45 minutes. This was a good duration for keeping the children's attention during our pilot study and when working with our child

design partners. The children were asked to find things on the trail that had one or more of these characteristics: big, green, prickly or having berries. This was an intentionally broad activity in order to give the children more flexibility to explore and discuss as a group what to flag. After they placed a Tangible Flag, the children were asked to write or draw some description of the object (see figures 4-7). In order to elicit input from everyone in a group and reduce monopolized use of the computer, children were given specific assignments on what to describe: color, shape, size or texture. Children were also asked to scan any other flags they discovered, add their descriptions, and to write or answer questions.

On each page for a Tangible Flag, there were vote 'widgets' at the top where each group could vote if an object were 'prickly', 'green', 'big' or had 'berries'. Children could vote for any or all and could see other groups' votes. On the left side of the ScratChat window was a summary that showed all votes across all Tangible Flags, for each category. This feature was added to encourage the children to take more interest in what other groups were finding. Voting was an important feature during our sessions with our child design partners.

During the exploratory walk, the ranger did not accompany any of the groups; instead she moved along the trail to see what the different groups did. The ranger was given a tablet computer that was running in a special 'observer' mode, which has a thumbnail in the flag area for all Tangible Flags. Without scanning, the ranger could see all the notes written by each group and could write questions or responses on the Tangible Flag pages (the ranger's writing showed as black). In addition, the ranger had placed two Tangible Flags along the trail before the activity began, on which she had written some questions. After about 20 minutes of independent exploration, the park ranger gathered all the groups together for a guided walk of the trail, looking at all the Tangible Flags that had been placed.

Results

The server software logged exactly when each client scanned a Tangible Flag as well as all inputs in a Tangible Flag's page. In addition, a researcher accompanied each group with a video camera.

Group	Exploratory Walk	Guided Walk
Red	4	7
Blue	5	7
Green	4	4

Table 1 – Number of Tangible Flags (out of 8) with inputs from each group at the end of a walk.

Each group had the potential to discover 8 Tangible Flags (besides their own) during the exploratory walk, three for each of the other groups and two the ranger had placed. During the exploratory walk, every group added inputs to each flag they discovered. By the end of the guided walk, every group had scanned every flag, but only red and blue groups added inputs during the guided walk. In addition to the two ranger flags, the ranger asked a question on two of each groups' flags as they were placed during independent exploration, so 6 out of the 8 flags discovered by any group had questions from the ranger.

We present four examples to illustrate how the Tangible Flags technology supported the children's creation of joint artifacts while independently exploring. These examples show children choosing their own points of inquiry, discovering Tangible Flags left by others, elaborating on the inputs of others, accessing artifacts concurrently, and adding relevant inputs without returning to the location of a previously visited Tangible Flag.

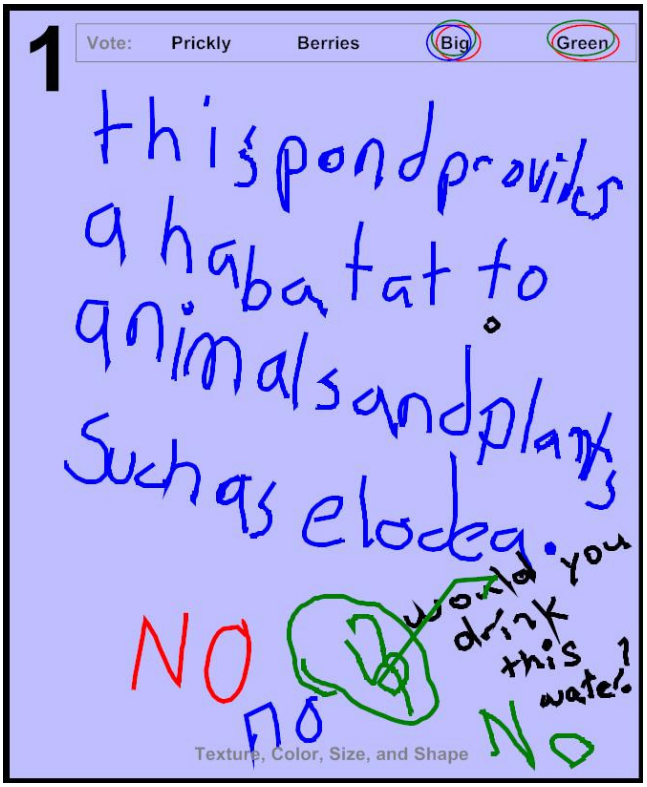

Figure 4 – Example 1 placed next to the pond.

Example 1 (figure 4)

The blue group girl chose to place a Tangible Flag next to the pond and wrote "this pond provides a habatat *(sic)* to animals and plants such as elodea." After she had moved on, the red and green groups arrived at the pond simultaneously and both groups discovered the flag. The green group boy elaborated on the writing by drawing a picture of the pond. At this time the ranger also started writing a question, "would you drink this water?" The red and green groups concurrently answered the question, each using their own computer. Near the end of the exploratory walk, the blue group girl examined the blue flags using the flag area and added her response (bottom center of figure 4) without returning to the pond.

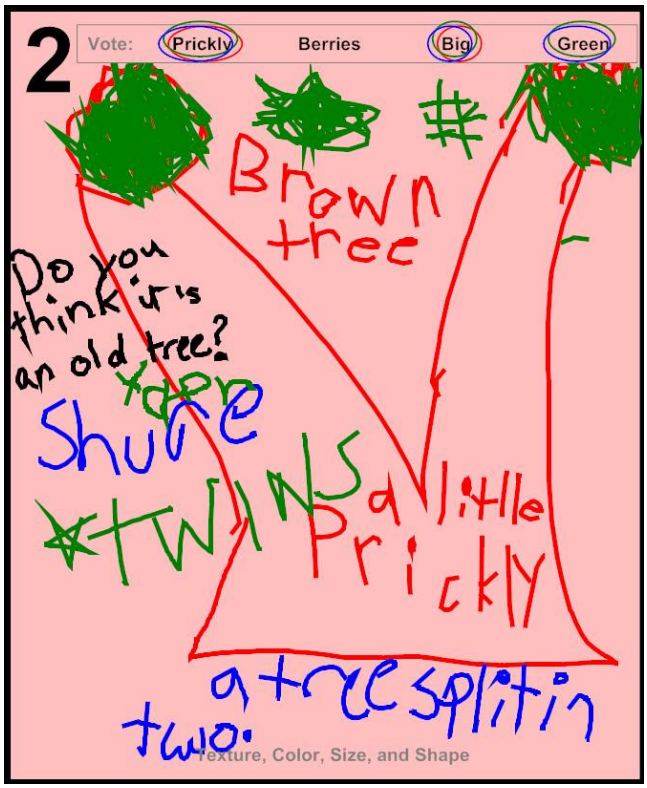

Figure 5 – Example 2 placed under a chestnut oak tree.

Example 2 (see figure 5)

The red group chose a large oak tree with split trunks as being of interest. The red group girl drew a picture of the tree and wrote 'brown tree' and 'a little prickly'. After the red group had moved on, the ranger added a question "do you think it is an old tree?" The blue group girl discovered the Tangible Flag and answered the ranger question "shure *(sic)*". She elaborated on the drawing by writing "a tree split in two." Some time later the green group discovered the flag. Based on a comment from the green group boy, a parent added "twins" for the green group (note asterisk in figure 5). During the guided walk, the green group boy answered the ranger question with "yaeh *(sic)*" and elaborated on the drawing by coloring leaves on the tree.

Example 3 (see figure 6)

The green group liked the pawpaw tree, which has very large leaves. The green group boy started the drawing of a leaf and added all the veins seen on the left side. The green group girl then finished the drawing, adding all the veins on the right side. After the green group had moved on, the ranger added a question "Why is this leaf still green?" The red group discovered the Tangible Flag and the girl answered the ranger question with 'it's dying'. The red group boy said aloud "it has not changed color" and the girl added his comment (bottom right of figure 6). After the red group had left, the blue group girl discovered the flag and answered the ranger question with "always green". During the guided walk, the green group girl responded aloud "it's still growing" when the ranger read the question aloud. The red group girl wrote the green group girl's response on the page (bottom left of figure 6).

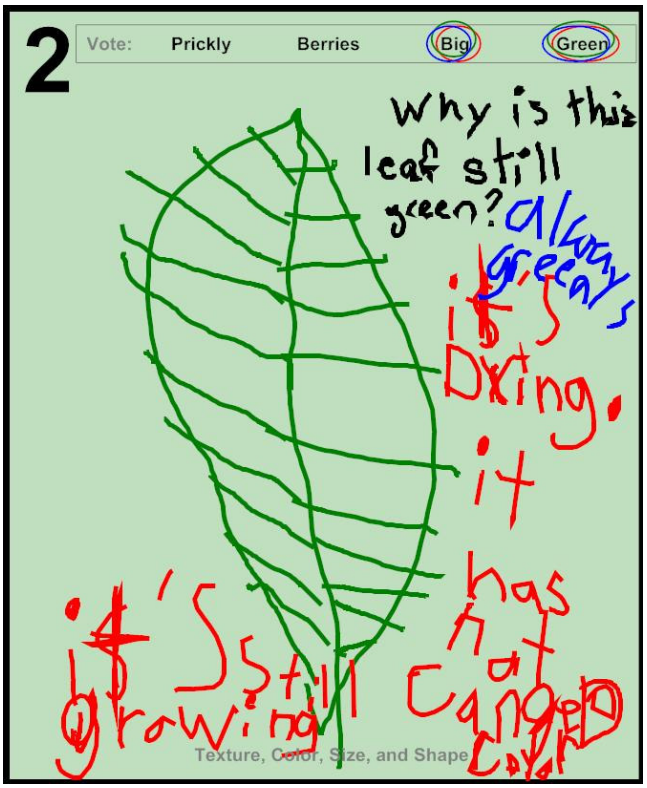

Figure 6 – Example 3 placed under a pawpaw tree.

Example 4 (see figure 7, next page)

Prior to the activity, the ranger placed a Tangible Flag near a devil's walking stick tree and asked, "What might the prickly bark protect this tree from?" The blue group girl discovered the Tangible Flag first and answered the question with "damage and animals". After the blue group had left, the green group discovered the flag and the green group girl elaborated by drawing a picture of the prickly bark of the tree (bottom left of figure 7). The green group boy responded aloud with "enemies" when the question was read aloud by a parent. The parent wrote this comment (note asterisk in figure 7). After the green group had left, the red group discovered the flag. The red group girl elaborated on the blue girl's answer with "rabbits". When the red group boy said aloud "wolf", "fox", "deer" and "worm", the red group girl added "wolf" and "fox", and then she added "raccan *(sic)*". During the guided walk, the red group girl corrected the ranger's writing ('s' on upper right of figure 7) and her spelling of raccoon.

Other Observations

While exploring, two children used the flag area to access the pages for Tangible Flags from other locations and added input to the corresponding artifacts. This indicates that children can use the context of the original discovery to collaborate while exploring independently. During the guided walk, the red group girl followed along with the

Tangible Flags by using the flag area while the other children scanned the flags even when the flags had been previously discovered. This indicates that using tangible interaction may be a natural method for children to access digital information embedded in the real world.

During the guided walk, a scribble war broke out on one of the artifact pages. The children marked over each other's writing using concurrent interaction and wrote argumentative comments to each other. This suggests that children may need additional support to moderate and negotiate the creation of joint artifacts, especially with concurrent interaction. The children also used most of the space on many of the pages, indicating that the design may need modification to accommodate larger groups.

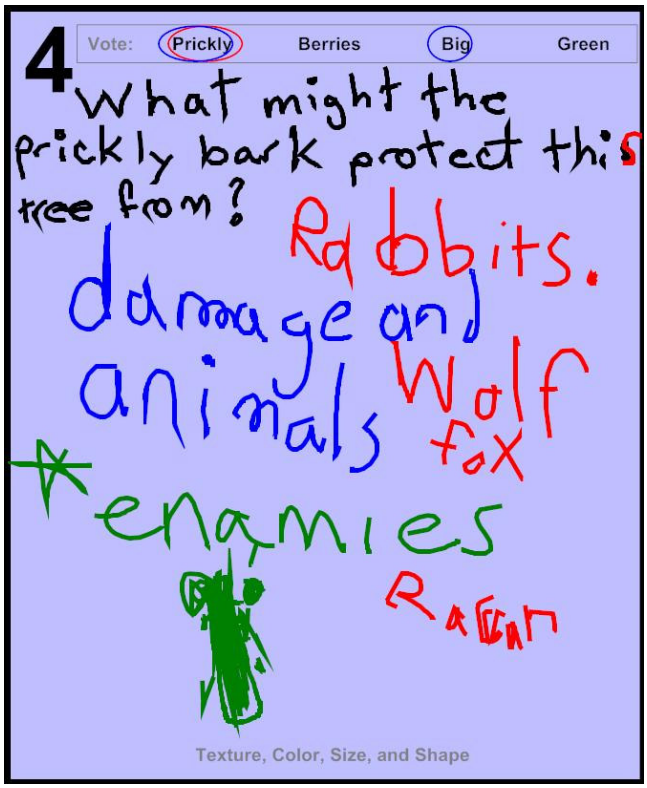

Figure 7 – Example 4 placed under a devil's walking stick tree.

DISCUSSION

These examples and observations help to illustrate the potential of the Tangible Flags technology, which includes:

A Concrete Connection between Real and Digital

The children naturally used the tangible interaction to access digital information; both while exploring and during the guided walk. In all four examples, children answered questions or elaborated on content created by others. During that process, a Tangible Flag helped focus the children's attention on the relevant places in the environment and situated the digital information in the real world in an age appropriate manner. In example 1, the blue group girl accessed a Tangible Flag she had placed while at a different location. Because she had originally placed the flag and created the artifact, she could answer the ranger's question with the benefit of a first hand visit to the pond.

Awareness and Collaboration while Exploring

All groups discovered at least half of the Tangible Flags left by others (Table 1), providing them with awareness of where other groups had explored. Children viewed the digital information for all flags they discovered, providing them with awareness of other group's artifact creation activities. They gave input on every Tangible Flag they discovered while exploring, usually answering ranger questions and sometimes elaborating on each other's work by adding drawings (example 1) or comments (example 2). Tangible Flags helped give children an awareness of where other children had explored and enabled them to easily access information left by others, promoting collaboration.

Concurrent Interaction

Children concurrently accessed the joint digital artifacts; in example 1 by answering questions at the same time and in example 3 by writing down verbal comments while other children viewed the same artifact on a different computer. Concurrent interaction enabled children to freely explore and access artifacts without taking turns, which may have helped keep their attention during artifact creation activity. Future interface designs need to scale for larger groups of children and provide tools for resolving conflicts in the shared space.

Flexibility to Explore

Each group was able to move about independently and find things that interested them. In examples 1, 2 and 3, the children chose objects in the environment they felt matched the activity. During the exploratory walk, the ranger was able to engage the children by writing questions based on the children's choices, even as the children continued their investigation of the environment. In example 4, the pre-placed Tangible Flag enabled the ranger to draw the children's attention to an important part of the environment she wished to highlight. This gave a good balance of directed input from the ranger combined with open exploration by the children. The children had more ownership of the guided walk than they would have without the technology, since they played a part in determining the highlights of the walk.

CONCLUSION

Iterative processes of collaboration and creation of written descriptions can help focus observation and promote interpretation and reflection. Situating this process in the learning environment enables further investigation by the children when new questions are raised as a result of their collaboration and efforts at description. Using Cooperative Inquiry methods, we designed Tangible Flags technology to support children (grade K-4) in collaborative artifact creation during field trips. We have combined concurrent interaction in a shared digital space with tangible interaction; to both situate the context of digital information and support children's awareness of others' activity.

Children can use the Tangible Flags technology to independently explore in a mobile environment, while jointly authoring digital information, which is directly connected to the real, physical world. The technology also enables adults to participate fluidly and guide the educational activity. Our initial study in the authentic environment of a National Park suggests that the Tangible Flags approach to supporting field trips may be very appropriate for children in early grades.

Future Work

After a field trip, educators use group discussions in the classroom to help children reflect. To aid this educational process, Tangible Flags can have optical codes, which will appear in digital photos or video taken by the teachers. Software can then display the digital information associated with Tangible Flags side by side with the children's field trip activities, enhancing classroom discussions.

We plan to conduct a longitudinal study of Tangible Flags working with a kindergarten class. This comparison study will engage the children in observation and note taking activities, some using Tangible Flags and others using paper. The study will conclude with both methods being used in a classroom field trip.

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