New Interaction Tools for Preserving an Old Language

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Figure 1 Oroo' sentence "I have left a hunted boar (or part of it) for you in this direction" a) in jungle, b) sketched by a Penan artist, c) tangibles of symbols d) made in application with tangibles

ABSTRACT

The Penan people of Malaysian Borneo were traditionally nomads of the rainforest. They would leave messages in the jungle for each other by shaping natural objects into language tokens and arranging these symbols in specific ways – much like words in a sentence. With settlement, the language is being lost as it is not being used by the younger generation. We report here, a tangible system designed to help the Penans preserve their unique *object writing* language. The key features of the system are that: the tangibles are made of real objects; it works in the wild; and new tangibles can be fabricated and added to the system by the users. Our evaluations show that the system is engaging and encourages intergenerational knowledge transfer, thus has the potential to help preserve this language.

Author Keywords

TUI; fabrication; capacitive tangibles; preservation of language

ACM Classification Keywords

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INTRODUCTION

The Penan village of Long Lamai is nestled in the rainforests of Malaysian Borneo about 300km from the coast close to the Indonesian border. It is an example of a tribe that has successfully transitioned from a nomadic lifestyle to a self-reliant settled community. The village consists of about 100 families, each with their own home and gardens. Access to the village is by river: the villagers' small outboard powered boats ply the river from Long Banga, the local airstrip and hub, to Long Lamai in about 90 minutes. The village has a primary school, church, micro-hydro dam, gravity-fed running water and a telecentre. The telecentre, developed in liaison with Universiti Malaysia Sarawak, provides Internet access via VSAT (a satellite communications systems) and WiFi that is accessible in the centre of the village. A 3G mobile tower was set up recently. Many of the villagers have laptops and mobile phones.

The community settled in Long Lamai in the mid-1950's. This has brought many advantages, such as education for all children and better access to medical care. However, it has also resulted in the loss of traditional knowledge, in particular, Oroo', the focus of this project. Oroo' is the object writing [14 p25] language used by earlier generations to leave messages for each other in the jungle. The elders realized that Oroo' will be lost if they do not find ways to preserve and teach it to the younger generations.

Research engagement with the community has shown that only those over 60 who lived the nomadic life during their youth have a full command of the language [37]. This means that only a few individuals hold the key to retaining this language which is an integral part of their culture.

Similar challenges of preserving language and culture are evident in many parts of the developing world [28].

The Oroo' uses physical artefacts to create messages. The symbols are constructed from materials at hand: leaves, sticks, and vines, folded or carved and put together in specific spatial arrangements to convey messages such as "I have left a hunted boar (or part of it) for you in this direction" (Figure 1). Short stories consisting of many symbols are common. In many cases, sticks are used as a signpost and direction indicator and the other symbols are tucked into notches cut into the stick. Messages can also be left on the jungle path.

The goal for the community is to retain Oroo' as a living language that can evolve to incorporate new symbols. The elders have observed their children's fascination with computers. The elders are keen to exploit this and also learn about computers from the youngsters. Thus the community's goal is to have a software tool that will:

- Assist with preserving and maintaining Oroo' writing;

by

- Being engaging for the old and young alike so people are motivated to use it;
- Encouraging intergenerational knowledge transfer by being an enjoyable collaborative environment [31].

The language tokens (words) are instantiated with physical objects (such as sticks and leaves). With a tangible user interface these objects can be augmented to become tangibles. Hereby the system can closely match the real world context [20]. Furthermore, tangibles are known to be effective for playful educational experiences [22].

Thus, the research question addressed in this project is "how can tangible interfaces be used to support children's learning of indigenous object writing?" To answer this question we must design a system that is intuitive for users with low literacy and computer skills. It must work 'in the wild' and support the users by allowing them to add new tangibles. Yet at the same time it must be engaging, fun and educational for the old and young alike.

Most tangible research projects have been lab-based and the tangibles are designed and built by the researchers. They use camera input or sensors to detect the position of the tangibles. In this scenario, the system must literally work in the rainforest and members of the community must be able to add new tangibles to the system so that the language can grow and evolve. For example new objects have recently been designed for 'school' and 'church'.

The research design draws on aspects of ethnography, participatory design, education design research and iterative software development. The system presented here has evolved through iterative design, implementation and evaluation. We contribute a novel system which encourages learning engagement using tangible and touch interaction. Furthermore, the system supports users' addition of new tangibles taking advantage of the affordance of tablet computers and the spirit of bricolage [7].

The structure of this paper is as follows. Next, we provide a background to tangible interaction. Following this, we describe our approach, the technical aspects of the project, the evaluations, and finish with a discussion and conclusions.

BACKGROUND

Tangible interaction has been explored for many years and in many contexts [9, 10, 25, 34]. This section provides an overview of the motivation for tangible interaction and the demonstrated benefits it brings [22]. It then focuses on research into tangibles on capacitive displays.

The ability to manipulate objects is a skill acquired very early in life. Using tangibles for computing operations takes advantage of this existing skillset [32]. Tangibles lower the level of interaction abstraction allowing users to apply their natural tool-based skillset to the digital environment. An integral part of this interaction is the rich sensory feedback users receive from tangibles in the form of visual, tactile and proprioception stimulus. In essence, tangibles combine the advantages of the physical and digital worlds by allowing digital information to be manipulated, controlled, and represented by physical objects [13].

Using physical objects is an intuitive way to explain things to others, to teach and learn at the same time [22]. Tangibles have been shown to increase explorative behaviour [6], reduce conflicts in cooperation [21, 26], encourage prolonged engagement [8, 15] and act as a useful aid to problem solving in comparison to standard graphical user interfaces [35]. Tangibles have also been used to aid in the preservation of indigenous oral stories [18, 29]. They have proved useful to encourage language learning with toddlers [12] and to aid learning programming [30].

Cameras were used to sense the tangibles in most early tangibles research – this approach is unsuitable for the environment of this project. We must adopt technology and techniques that will work in a remote rural environment [2]. There have been a number of projects that have explored using tangibles on capacitive tablets [3, 16, 27, 36]. These tangibles work by transmitting an electrical charge from the user through touch points on the tangible to the capacitive display [1]. The capacitive display detects the tangible as finger touches, and then a recognizer is used to distinguish between the tangibles.

SmartSkin is an early system that used capacitive sensing with a mesh shaped antenna to detect hands and objects [23]. Conductive materials were attached to blocks in patterns to allow objects to be identified. Yu et al. [36] present three tangible technologies for use on capacitive touch surfaces: spatial, frequency and hybrid. Their spatial tangibles employ touch point patterns for object identification. Frequency tangibles use a modulation circuit (with a power source) to generate touches of varying frequency. The hybrid tangible combines the spatial and frequency technologies. Chan et al. [5] introduce stackable tangibles, sliders and dials for capacitive screens. The stackable tangibles are able to sense changes in capacitance when blocks are placed on top of them – this in turn modifies the touch point pattern for identification. CapWidgets [16] are tangible dials designed for mobile capacitive screens. GaussBricks [17] also uses a tablet interface but this is supplemented by magnetic sensing of the bricks.

OUR APPROACH

We conducted a field-based participatory design project using tangible technology, and evaluated these with families to understand how tangible technology might provide a way of engaging younger members of an indigenous community with their traditional writing.

To our knowledge no research has explored learning tools suitable for object writing systems such as Oroo'. Furthermore while tangible user interfaces (TUIs) have been explored for verbal language learning and programming, they have not been investigated in the context of this type of language. In addition, the goal of having a tool that functions in the wild governs the equipment and interaction design choices.

This project blends a number of methodologies: ethnography [11], where the researchers work in the community, education design research [4] that builds on constructivist theories of learning, participatory design protocol [24] in which the users are active participants in the research, and iterative software development that focuses on user experience [19]. All engagements with the Long Lamai community follow an agreed protocol with co-authorship and approval of the community.

We report here three rounds of design, evaluation and redesign. The key parts of the project are designing a system that will work in the wild and support the addition of new tangibles. There are two aspects to adding tangibles – the community being able to fabricate their own tangibles, and being able to interactively add these new tangibles to the system.

The first prototype was developed by the researchers as a proof-of-concept. It was shared with three elders individually and with their input, a second prototype was produced. This was then evaluated with a group of elders, a family group and at a community meeting. From these interactions the third prototype requirements were specified and subsequently developed. This prototype was evaluated more formally with 6 family groups.

SYSTEM DESIGN AND IMPLMENTATION

This section describes the technology behind the project. As there have been three rounds of development, we focus on the final prototype noting where appropriate changes made between prototypes. The software is written in HTML5 & JavaScript. It can be run directly from a compatible browser (Safari or Chrome) or saved as an app onto the user's home screen. A multi-touch tablet is required for the computer interface, we have tested on iPad, Android and Windows devices. In this section, we first describe the interaction design and tangible fabrication. This is followed by a description of the software and recognizer.

Interaction design

The software is designed so that the interaction is natural and intuitive. In particular, it must be suitable for the older members of the community (over 60): the only people fully conversant with Oroo'. Many of these people are otherwise illiterate and have had little exposure to computers. At the same time the software must be appealing and fun for young children so that the community's goals of retaining the language and supporting intergenerational knowledge transfer are met.

The system consists of the tangibles as shown in Figure 3, a multi-touch display and supporting software. To make an Oroo' in the system, the user presses a tangible onto the display (Figure 2a). An image of the symbol, the same size as the physical symbol is displayed directly under the tangible. The image can be moved by touching it and dragging it to a new location (Figure 2b). It can be rotated with two fingers (Figure 2c). To delete an image, it is dragged off the side of the screen (Figure 2d). Thus, the system supports add, change and delete with very simple and intuitive interactions.

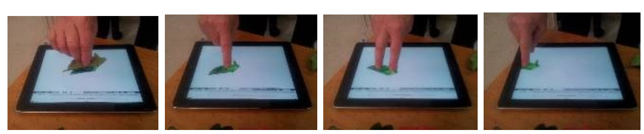

Figure 2 Interaction: a) add a symbol b) move c) rotate d) delete

Although registration of a tangible is required only once, we have also designed simple interaction for this. To register a tangible, the user first adds its pre-prepared image to the system by selecting the image file (from the standard file dialogue) and assigning it a name. When they select the image from a dropdown list in the menu bar (Figure 4) it is displayed. They associate the image to the tangible by aligning the tangible with the image and pressing the tangible onto the screen. The touch points are visualized to the user as feedback and when the user presses 'set', the association between the tangible and image is stored.

Tangibles

A tangible is constructed with a baseplate, capacitive touch tips, conductive clay, handles and the Oroo' symbol (Figure 3). The baseplate is a piece of rigid material that does not interfere with the electrical circuit. A baseplate can be of any shape, it has three 7mm diameter holes set in a unique irregular triangle. The holes house capacitive pen tips. Air-dry modeling clay is then used as a conductive medium to join the tips, hold the Oroo' symbol in place and provide a grip for the user. Depending on the shape of the symbol, a handle made of a metal screw covered in clay may be added to the top of the baseplate.

Figure 3 Tangible construction (from top left): a) pen tips with clay inside, b) conductive clay, c) MDF tangible baseplate with screw handle d) underside of the baseplate with pen tips in holes, e) a completed tangible.

Constructing tangibles that sense reliably has required considerable experimentation and extends the tangible design described in [27]. The materials, physical arrangement and construction all contribute to reliability. We found that the best materials for the baseplate are MDF (medium-density fireboard) or plywood – acrylic materials such as Perspex, hold a surface charge that interferes with the touch detection. Air-dry children's modeling clay is used as conductive material to glue the components together. However, the clay does not make suitable touch-points for the screen as it has too much friction; capacitive pen tips are a better medium. Metal screws covered in clay suffice as handles.

The tangibles are identified by the geometry of the touch-points (see Recognizer section below). It is best if these touch points are set close to the extremities of the baseplate in a triangle. Some of our initial baseplates had the three points in a straight line: it is more difficult to get contact with the surface on all three points with this arrangement because it is not stable. Furthermore, we found that the affordance of an obvious handle means that the users do not need to be instructed on how to hold a tangible. A handle also reduces the likelihood of unintended finger touches on the screen when pressing a tangible onto the surface.

When constructing a tangible, care must be taken to have an effective electrical circuit between the touch-points and handle. To keep the connection between the pen tip and clay, a small ball of clay is placed into the tip, but care must be taken not to make the tip stiff because then it is more difficult to have all three points in contact with the surface simultaneously. We experimented with adding various materials to the clay or inside the pen tips (such as copper wire, and iron crumbs), but none of these provided better connectivity and some were counterproductive.

Images

An image of the symbol is shown on the display when the tangible is recognized. New images can be added to the software. The process for this is to take a photo of the symbol. Off-the-shelf photo editing software is used to remove the background and scale the image to the right size for the display resolution.

To simplify the first-time user experience, a set of default images are automatically downloaded when the application is installed. New images can be added via the menu 'choose file' button (Figure 4).

Software

The software is built in KineticJS, which is an HTML5 Canvas JavaScript framework. The framework supports images as objects with multiple methods and properties including rotate and move. After download, the software is designed to be used offline so it can be used anywhere in the village or in the surrounding jungle. A set of default images is included in the install. Subsequently client-side storage is used. For the first and second prototypes, we adapted the browser's LocalStorage mechanism to store the tangibles' images. However, this has very limited capacity, so the third prototype uses a Javascript Database.

Figure 4 shows the software menu. The top-left dropdown list contains a list of all available images. Those that have a tangible registered to them are marked with a tick. To add new images, the software allows users to choose a file, associate a name with it and set the size of the image. The "Clear" button clears the canvas and the "Reload" reloads the software from the server.

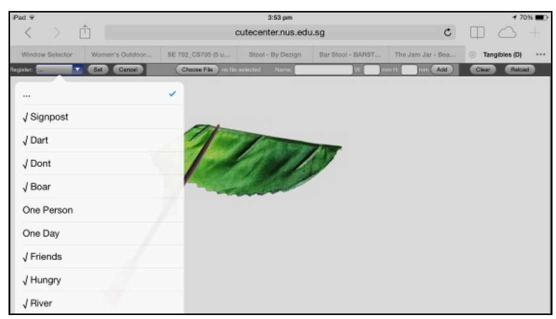

Figure 4 User Interface showing available images

When a tangible is recognized on the surface (see below for recognizer), the image associated with the tangible is retrieved from the database. The position and orientation of the image is computed so that it will lie directly under the tangible and the image is then displayed in that place.

The system also supports finger-touch image move, rotate and delete. We considered using the tangibles as interaction devices for these actions. However, a finger touch maps naturally to the real world experience of repositioning a physical symbol. Also, we found that while press actions are reliable with the tangibles, move and rotate are not; it is hard to maintain the contact of all three points while moving the tangible. The first two prototypes included move and delete. Rotate was added to the third prototype. Scaling of the images was discussed during the second prototype evaluation but the users considered it unnecessary.

Recognition

There are two steps to the recognition: first registering a tangible by recording its unique touch pattern (the triangle arrangement of pen tips) and associating this with an image; second, matching tangible interactions to existing registered tangibles.

We initially implemented a recognition algorithm based on [3] but found it was overly complex for the problem space. Three touch points are more than sufficient for the number of tangibles required therefore we use simpler triangulation techniques.

For registration, the image is displayed at a fixed offset and orientation on the display. The tangible's three touch point positions are recorded relative to the image position. The recognition algorithm calculates the distances between each pair of touch points, the centre of the triangle and angles of the triangle. The point which creates the biggest angle of the triangle is found. This largest angle is used to re-orientate the image later. The position and orientation of the touch points links the tangible to the image. Note this algorithm requires the points to form an irregular triangle for the orientation to work correctly.

To recognize a registered tangible, the same computation of relative points is executed. By traversing through the list of registered tangibles, the recognizer compares the distances to find a match. An error tolerance of 4mm is allowed. If a match is found, the recognizer calculates the translation of the tangible from its originally registered location by comparing the centre of the original tangible and the centre of the new touch points. Finally, the algorithm calculates the relative orientation compared to the original position by comparing the position of the largest angle relative to the centre of the triangle.

EVALUATION

Three rounds of evaluation were carried out. The first 2 were conducted on our first visit to the village. The third was on a subsequent visit a month later. Each round assessed different aspects of the research question. The first evaluation focused on whether the community elders felt that the tangible system could meet the basic requirement of aiding the preservation of Oroo'. In the second evaluation, we had people of various ages interact with the system. Thus, we were able to assess whether it was engaging to different user groups and informally observed knowledge transfer. The final evaluation concentrated on the efficacy of the system as an intergenerational collaborative environment. All community participants in the 3 rounds were Penans from the village.

First round

The first prototype had a default set of three pseudo symbols simply to provide a point of discussion (Figure 5). Other tangibles could be added by the process described above. Three members of the community explored this prototype.

Figure 5 First prototype tangibles from top left: twisted grass, leaf and stick.

Individually, each was given a short demo with the default tangibles and then used the system to explore its functionality. While they could not make Oroo' from the pseudo symbols, they were able to place, move and remove symbols. They then made a new tangible with our guidance. A discussion followed about the potential of the system.

The first participant was, Garen, the village elder who has been instrumental in much of the research carried out with the community. His first reaction was of awe, followed by "We can make Ooro' with this". It was followed by lots of questions such as "Can they be recorded in a database? Labelled?"

Figure 6 First round sessions 1 & 2

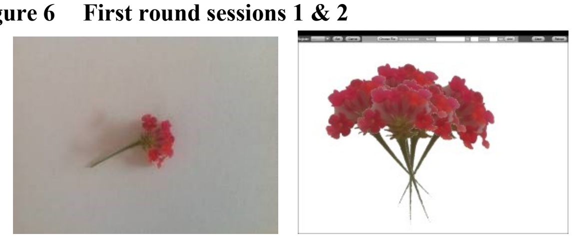

Figure 7 Flower image added to system and used to make a bouquet

Garen then took us to the second participant's home. She too was captivated and quickly called her adult son over to participate. He made his own tangible with a flower and made a bunch of flowers (Figure 7). They were both very interested in this approach. The final person to evaluate this prototype was an artist who is currently illustrating Oroo' (Figure 1b). He too was immediately captivated.

The participants' consensus from this first evaluation was that the system was excellent and could be used for Oroo'. However, in order to be more realistic, the tangibles needed to be made of actual symbols. Two of the participants had, with our guidance, added a new tangible to the system suggesting that this part of the system is adequate. In preparation for the next round, Garen made 4 real symbols and we reused the grass from the previous round (Figure 8).

Second Evaluation

The second prototype was technically the same as the first but now had 5 real symbols as exemplars. Three different groups evaluated the next prototype: a group of 3 elders, a family group and the villagers at a community meeting. This round tested again the suitability of the system for Oroo' and how people of various ages engaged with the system.

Figure 8 Second round tangibles from left to right: boar, signpost, don't, 3 days and dart.

Figure 9 Family group in second round.

The 3 elders, were age from 40 to 70. After a demo, they quickly started making different Oroo's. All three used the tangibles and discussed among themselves how they could be useful. They were intrigued with the technology and said they could see the system being very useful.

Surprisingly we learnt two new things about Oroo' during this session. First, the twisted grass – representing 3 days – could only be used with a person symbol, which we did not have. Also, the position of the different parts of the symbol on the signpost is meaningful. For example, placing the 'boar' on the top of the signpost has a different meaning to tucking it in one of the notches further down, and how tightly a symbol is tucked into a notch is also significant. These titbits of information were new to the researcher who had been working with the village documenting the language for 18 months.

After some discussion, it was decided that, with the 10 most regularly used symbols, the tool would provide an excellent base for evaluating whether the system is effective as a collaborative environment to teach Oroo' to children.

Later, the headman, his wife, son and son's friend tried the system. Their engagement and delight was evident (Figure 9). We observed everyone actively participating and enjoying the experience. Also, there was a lot of collaboration and teaching going on between the adults and children. They discussed the symbols and the way they fit together to make Oroo', all the while using the system to demonstrate the language.

The final session of this evaluation was a community meeting in the evening. About 25 members of the village were present with a balance of young and old, and genders (Figure 10). We placed the iPad in the middle of the floor and people gathered around. After a short demo, people used the system for the next hour. There was a lot of interaction between the people directly using the system and those observing. There was laughter while adding boar and dart symbols at different orientations and moving the dart around to pierce the neck, heart, eyes, tail, etc. Basically, the amusement was on where the dart should hit the boar for an effective kill.

Figure 10 Community meeting in second round.

Finally, there was a general discussion about what was required for the next prototype. There was agreement that the 10 symbols identified by the elders would provide an excellent platform to teach the basics of the language. For the interaction, the only change requested was to include finger touch rotate.

A bug in the recognizer meant that sometimes the image was rotated 180 degrees. While this obviously needed fixing, it also made us more aware of the importance of spatial relationships and orientation in the language. We also decided that the triangular base-plates worked best.

The participation of these various groups, established that the system was easy to use as well as engaging for people of different ages and that it represented Oroo' closely enough to emulate real Oroo'. We also defined the requirements of the third prototype as: fix the recognizer, add finger touch image rotation, and add the identified 10 basic symbols to the software as the default set.

Third evaluation

After completing the third prototype with the 10 default symbols, we returned to test it with the Long Lamai community. As we had learnt that realistic symbols are very important, the first step was to get Garen to make a set of appropriately sized symbols (Figure 11a) that were attached to the tangible bases. The set of tangibles used in this evaluation can be seen in Figure 11b.

Figure 11 Third round: a) making symbols b) symbol set with representations for people, objects, geographic features, directions, time and conditions.

The focus of this evaluation was on the engagement and intergenerational knowledge transfer goals. If these goals are met, the system will help with retention of the language. With the approval of the village headman (as required under the protocol of engagement), 6 family groups were recruited to participate in the study. The user study was based on standard methodologies but was more naturalistic than a lab study.

Each of the 6 family groups that participated in the study consisted of a child accompanied by their parent(s) or an adult relative, and in one case a child who had been a participant in an earlier group. We selected adults who know the Oroo' language. The children, 4 male, 2 female, were aged 7 to 16.

Most of the adults had used the system on our previous visit, we updated them on the project and checked that they remembered how to use it. They were given a few minutes to practise adding, moving, rotating and deleting symbols.

Following this, the adult and researcher together pre-tested the child's knowledge of the 10 Oroo' symbols. They were shown images of the symbol on a computer screen and asked to name the symbols they knew (see Table 1).

The adults were then asked to teach the symbols to the child using the Tangibles, and to use them with the software to make Oroo' stories. Later, we encouraged the child to use the system to make their own Oroo' stories. At the end of the session (about 60 minutes) we retested the child on the symbols (Table 1) and interviewed the adults.

Three sessions were conducted in the telecentre and the other three, at the family's home. Since most of the families are busy with agricultural activities during the day, the experiments were conducted between 6pm and 9pm. All sessions were video recorded and photographed. A member of the community was on hand to translate as required and took notes in Penan during the session; the notes were later translated to English for analysis.

RESULTS

In this section, we first report on the intergenerational knowledge transfer and then engagement. We refer to people involved in each group as G*n*[**F**ather|**M**other|**C**hild] e.g. G1F is Group 1's Father; G5C is Child in Group 5 .

The goal of intergenerational knowledge transfer was accomplished as the children all learnt a number of symbols during the session (see Table 1). Recall that the prototype includes the 10 most common symbols. In the pre-test, one child knew 2 symbols, the others knew none. In the post-test the mean was 8 correctly identified symbols.

Our first group (G1) included father, mother and son (Figure 12a). During the post-test G1C correctly remembered 9 symbols out of 10. G1F retaught the forgotten symbol. The 4th group (Figure 12b) the teachers were G1F & G1C while the student G4C was the nephew and cousin of G1. G4C, born and raised in the city was visiting Long Lamai with his parents. During this session we asked G1C to teach the Oroo' symbols to G4C. After introducing all the symbols, G1C asked G4C to repeat the names by looking at the tangibles; he correctly remembered 6 symbols. We observed how the children worked together well and noted that G1C had retained knowledge of the symbols he had learnt 2 days earlier, and how to put them together to make an Oroo' story.

Participant	Gender	Age	Symbols identified	
			Pre-test	Post-test
G1C	M	8	0	9
G2C	M	7	0	6
G3C	F	8	2	5
G4C	M	8	0	8
G5C	M	12	0	10
G6C	F	16	0	10
Mean			0.33	8

Table 1: Child pre-tests and post-tests of Oroo' symbols

Some adults taught the symbols one by one and then asked the child to repeat the names of the symbols and check for retention of earlier symbols. Then they taught the child how to make a story using the system. One father commented "I first went briefly through the symbols. Taught him how to use the tangibles and then asked him to create a story. After a few minutes we both were working on creating stories together". In another case, the adult came up with the story "I'm going to the river and I'm alone. It takes me one night to go there and I'm hungry," for the child to make.

One adult first taught the child the natural materials that are used to make the symbols (such as different types of leaves). Then he taught the child how to bend, fold and connect components and how different transformations of materials can create different symbols (e.g. the same leaf folded differently can be a 'wild boar' or 'I'm hungry'). He also checked the child's understanding of the symbols before teaching the Oroo' stories. After this, they used the tangibles and software to make stories.

Another adult integrated the symbol teaching and story making together. Showing the child a symbol, explaining its meaning he told the child when it is used. He asked questions while forming a story with the symbols.

After the teaching, the children used the system together with adults to form more complex Oroo' stories. Figure 14 shows 2 of the stories constructed during this phase.

Figure 12 Group 1 and 4 in Evaluation 3

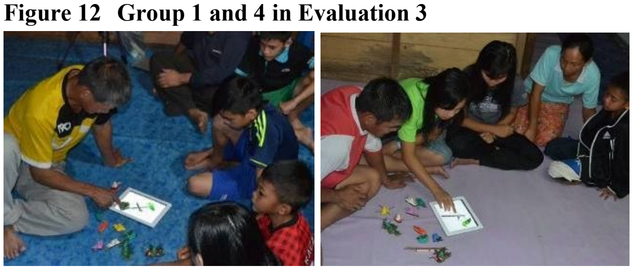

Figure 13 Groups 5 and 6 in evaluation 3.

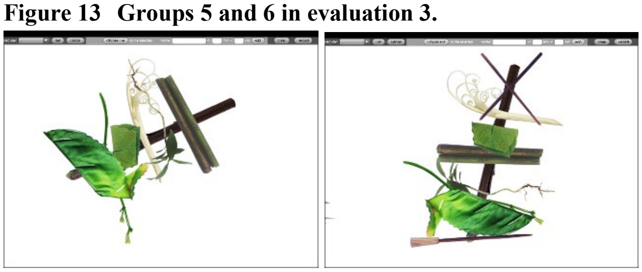

Figure 14 Oroo' stories made by children.

Engagement and enjoyment are central to all successful learning. We were pleased to observe that the children and adults alike were fully engaged and having fun. The tangibles provided them a platform to interact. For most of the participants using a tablet was a new experience. Just as with the adults in the earlier evaluations, the appearance of Oroo' symbols on the screen was magic for the children. Most used the system as if playing a game. While the adults were teaching, the children were eager to learn the symbols quickly, remember them and wanting to play with the software and tangibles as soon as possible.

In the one child-to-child session, we observed both children appeared to really enjoy themselves. They worked with little guidance while G1C taught and then they made stories together.

During the interviews at the end of the sessions the adults commented on the engagement aspects of the system.

G1F "I think this system is really good because children always love to play games and they learn very fast by playing. I feel they use this system as playing a game".

G2F "I'm excited to see this kind of system. It's nice and I think it is perfect. It is helpful".

G3F went a step further and said this tool works much better with the children than the old method of going to the jungle and teaching the Oroo's. He said "This is easy. It is fun using this system. Children do not want to go to the jungle and learn this stuff. I think after using the system they would like to go to the forest and try out the same things in real life".

However, G5F still believes the best way to teach the Oroo's is to go to the jungle and learn them by practice but he also doubted that the younger generation would go to the jungle unless there is a need. He said that apart from farming activities, the younger members of the community rarely go to the jungle now.

DISCUSSION

The overarching goal of this project is to provide a software tool that will aid in preservation of the Penan's sign language. This is accomplished by providing a highly engaging environment where intergenerational knowledge transfer can take place.

Preservation of indigenous languages and culture is urgent as the two-edged sword of globalization impacts small communities across the world [28]. Many of the endeavors focus on oral stories and story-telling rituals. Oroo' is not a language of storytelling nor is it primarily an oral language – it is *written* in that it takes a physical form and purpose it more functional. Few of these languages still exist, for example most of the tribes of Borneo had a similar language but only the Penan still remember theirs.

We witnessed a high level of engagement from both adults and children. This heightened engagement is consistent with other tangible research [8, 15]. The evaluations validated that knowledge transfer occurred between adults and children and that the system is also suitable for children working together. Tangible interfaces are known to function well as collaborative environments [21, 26].

Our evaluation does not demonstrate that the system results in more learning or higher engagement than the adults simply teaching the children at home without the system. This would require a comparative evaluation which is outside the agreed protocol of engagement between the researchers and community. Several adults commented that it's unlikely their children would engage in traditional ways of learning the Oroo' language. However, they are enthusiastic about using our system as they found the tangibles engaging and interesting for children and thought it shows great potential to keep the Oroo' language alive.

Another alternative would be a standard computer game. The evidence from existing research is that people learn more when using tangibles [22]. This is because tangibles engage more of the user's senses. The tangibles require more manipulation that a standard interface thus engaging the user's kinesthetic and proprioception. As well as this the manipulation may also create sound. In this case, the tangibles also provide richer textures to see and touch, and natural materials retain their smell. So all of the users' senses are more richly stimulated than with a standard computer system [13].

One of the adults in the third evaluation study suggested making the tangibles from artificial materials. He noted that natural materials such as leaves dry and decay and are not long lasting. He asked if we could find appropriate artificial materials, the tangible would look real and could be used for a longer period of time. Artificial flowers and trees are a viable source of realistic looking durable symbols (we have found the range of different artificial plants available is quite staggering).

Artificial materials would certainly be longer lasting. However, the sensory experience would lose some of its richness. For example, the fact that natural materials decay is integral to this language. The rate of decay of a leaf is well understood by these people: they know whether an Oroo' is a few hours, a day or a week old simply by glancing at it.

The way that the tangibles are designed means that it is easy to replace the symbol. One could imagine taking the system into the rainforest and getting the children to seek out the appropriate materials, and then craft them into the symbols. The symbols could then be attached with the appropriate bases and used in the system. Likewise, as the community becomes more familiar with the system they can, at any time add new symbols, thus expanding the vocabulary. However, for convenience they can also have symbols made from artificial materials.

We found that it is important the symbols are realistic – but the image does not need to match the tangible. Many of the signs can be made with different types of leaves – it is the folding or arrangement that is significant. Having a different leaf to the image did not cause a problem. However the mismatch disrupts the magic of having the exact symbol appear below the tangible. More investigation into the cognitive effects of the degree of match between the physical and virtual symbol would be interesting.

There was a range of suggestions for future enhancements. One suggestion was to implement the rules of Oroo' language in the next prototype. As we understand it, there are rules for the placement of the Oroo' signs on the signpost including order of symbols, place, and orientation. As an example, one elder demonstrated the importance of how the notches are made on the signpost. A possibility would be to use other tangibles for marking different types of notches.

These rules and subtleties of the language are not well documented. The system has already helped to uncovered language rules. Although this was not the aim of the current project, an area to explore is how such a system could be used to automatically capture the rules and nuances of the language.

CONCLUSIONS

The comments made during the evaluations suggest a high level of acceptance and enthusiasm for the system. These are perhaps best summarized by a comment from G1M. She said "Most of the adults of the community see the need to preserve the Oroo' language. This system will definitely help fill this space".

The tangibles are a core part of this system. We have extended tangible interaction research to realize a system that works in the wild and allows the user to dynamically add new tangibles. The core functionality of the system could be applied in many other scenarios, for example geometry games. The system could also be extended to automatically guide users and check results.

Unexpectedly the system revealed details about the Oroo' language unknown to the researcher documenting the language. This suggests that tangibles can have a role in discovery of knowledge. One area worthy of exploration is to extend the system so that it learns the language rules automatically.

The last word we give to one of the parents. He said "New technologies are coming to the village. Previously we didn't have the Internet, laptops or smart phones but now people are using them. Tablets will also be popular in Long Lamai in the near future. From the child's point of view, they are learning Oroo' symbols fast and remembering what they learn. The system seems really effective therefore, I think it will perfectly fit in to the community."

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