Mapping Place: Supporting Cultural Learning through a Lukasa-inspired Tangible Tabletop Museum Exhibit

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ABSTRACT
Museums are exploring new ways of using emerging digital technologies to enhance the visitor experience. In this context, our research focuses on designing, developing and studying interactions for museum exhibits that introduce cultural concepts in ways that are tangible and embodied. We introduce here a tangible tabletop installation piece that was designed for a museum exhibition contrasting Western and African notions of mapping history and place. Inspired by the Lukasa board, a mnemonic device used by the Luba peoples in Central Africa, the tabletop piece enables visitors to learn and understand symbolic and nonlinguistic mapping concepts that are central to the Lukasa by creating and sharing stories with each other. In this paper we share our design process, a user study focusing on children and learning, and design implications on how digital and tangible interaction technologies can be used for cultural learning in museum exhibits.

Author Keywords
Tangible interaction; interactive tabletop; interaction design; cultural history; museum exhibit; storytelling; collaboration; learning.

ACM Classification Keywords
H.5.1. [Information Interfaces and Presentation]: Multimedia Information Systems---*Animations*; H.5.2. [Information Interfaces and Presentation]: User Interfaces---*Input devices and strategies*, *Interaction styles*; H.5.3. [Information Interfaces and Presentation]: Group and Organization Interfaces---*Collaborative computing*; K.3.1 [Computers and Education]: Collaborative learning.

General Terms
Design; Human Factors.

INTRODUCTION
Emerging digital interaction technologies are increasingly used in museums. In this context, multi-touch tabletops and tangible interfaces can offer collaborative experiences that assist the learning process through hands-on interactions with the subject matter. Interactive tabletops and tangible media have been used in museums to promote cultural and historical knowledge, but the learning effects of such endeavors require further investigation. Similar systems that teach STEM subjects are well-documented, and many lessons can be applied toward teaching the humanities. We identify a broad opportunity for the HCI community to develop an understanding of how tangible interactions can be effectively used to support learning and comprehension of cultural heritage.

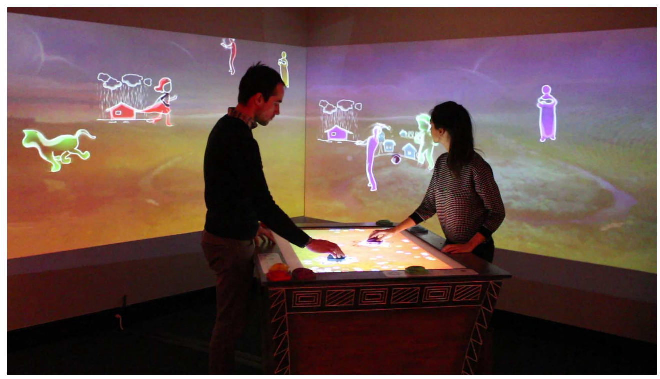

Figure 1: Lukasa-inspired tangible tabletop installation in the *Mapping Place* museum exhibition.

We worked with the Robert C. Williams Paper Museum in Atlanta, GA on an exhibition titled *Mapping Place: Africa Beyond Paper*. The museum holds special exhibitions and hosts workshops about papermaking and paper-related arts for school groups, especially elementary and middle school students. The *Mapping Place* exhibition (held from February 28 – June 6, 2014) invited visitors to contrast Western notions of mapping and maps of Africa with the way African cultures conceptualize and represent their own history and place.

Our part in the *Mapping Place* exhibition involved the design and development of an installation piece that aimed to re-envision and convey African notions of mapping history and place through digital and tangible media. Our goal as researchers was to better understand how tangible interaction technologies can be designed and situated within the museum context in a way that supports learning and comprehension of cultural and historical concepts.

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The design of our piece was inspired by the Lukasa from the Luba peoples of Central Africa. The Lukasa, or memory board, is a hand-sized wooden tablet that is studded with beads and shells and/or carved with ideograms [18]. The beads, shells and carvings are used to represent pieces of stories and thus serve to record the history, genealogy and cosmology of the Luba peoples. A board can only be interpreted by its creator and by specially trained members of the tribe. In our digital version of a large scale Lukasa, visitors create stories through a combination of tangible objects and multi-touch tabletop interactions (see Figure 1). With the authentic Lukasa inside glass case in the *Mapping Place: Africa Beyond Paper* exhibition, our piece aimed to give students a tangible way to explore the abstract concepts of the Lukasa through collaboration, story construction, and storytelling. To inform the design of the tabletop installation piece, we researched museum installations, tangible user interfaces (TUIs) for learning, and tangible narratives. We describe our design process as well as a user study conducted to understand how the context of the installation supports learning and sensemaking. Based on our results, we draw design implications for museum exhibits that use tangible technologies to support learning about history and culture.

RELATED WORK

Tangible interactions are increasingly used in museums to promote engagement and learning for visitors. Researchers are developing novel approaches to explore scientific concepts, math and programming, sustainability, interactive narratives, and historical and cultural heritage through interactive digital applications. We provide a brief overview of research and design in three areas: interactive museums, TUIs and learning, and tangible narratives.

Interactive Museums

Cultural museum exhibits are traditionally comprised of static historical artifacts, existing in physical spaces that are often far removed from their original environments. These artifacts cannot be touched, and their original uses must be imagined. Interactive exhibits seek to bridge the gap between the visitor and the exhibit though hands-on interaction, and are designed to give visitors the opportunity to engage with a variety of subject matter.

Much of the research that investigates the benefits of technology and learning focuses on STEM subjects [14], and indeed science museums have been early adopters of interactive installations. For example, an exhibit at the Boston Museum of Science encourages non-linear constructivist learning of computer programming through “passive tangible interfaces,” a combination of powered and unpowered components designed for low cost and durability [10]. Another tabletop application for museums teaches children about programming concepts by encouraging collaboration and storytelling, and uses puzzle pieces and blocks to mitigate the difficulty of interface interaction [16].

Although the learning objectives for interactive tabletops that are used to communicate cultural subject matter are less discussed in the literature, interactive tabletops are becoming more common in museums. Notable examples include those developed by firms such as Potion Design. Many of Potion Design’s installations explore history and cultural heritage, enabling visitors to interact with archival photos, videos, or 3-D reconstructions [17].

These types of interactive exhibits will continue to interest museum patrons, as technologies with tangible input devices and digital augmentation tend to reach a wider audience than traditional exhibits [11]. At the same time, research suggests that if the purpose of the technologically enhanced exhibit is not immediately understood, social discussion around the exhibit will deal more with the mechanics of the interaction rather than the content [12]. A closer look at how interactive technologies can be designed to promote positive effects of learning and comprehension is therefore necessary.

TUIs and Learning

Although many TUIs that aim to promote learning focus on STEM subjects, we believe that certain benefits associated with these TUIs may also be relevant for systems that strive for cultural learning. Specifically, we looked at tabletops that promote learning through collaboration or play.

Researchers have studied how the physical structure and shape of tangible interfaces enables exploratory learning and content creation. For example, TellTale [1] used a toy caterpillar whose body segments can record and play back audio clips to allow children to experiment with and learn about the structure and content of oral stories. Oh et al. [16] used puzzle blocks as tangibles in order to help young children with the difficulty of navigating interface interaction. The use of puzzle blocks as constraints further serves to clarify the purpose of their actions.

Multi-touch tabletop applications can also foster collaborative learning. Harris et al. [9] suggest that children engaged in multi-touch surface interactions will discuss the tasks at hand more than the children engaged in single-touch interactions. Benford et al. [4] analyze the design of interactive storytelling technologies, KidPad and Klump, as platforms for collaborative learning and development among young children. They suggest that TUIs can promote “shoulder-to-shoulder” collaboration; that is, with TUIs children benefit from watching the progress of their peers, which can in turn increase cumulative learning potential.

The interaction design and game mechanics applied to a multi-touch tabletop application can be structured to achieve collaborative learning. Multi-touch collaborative games, such as Futura [2] and Youtopia [3], aim to foster an understanding of urban planning and the environment through a series of choices and actions that have environmental consequences. In games like these, the learning comes from conditional constructs, where the consequences of a player's actions are clear. In YouTopia and Futura, the game mechanics also foster collaboration where actions can be co-dependent, giving children different but complementary goals to discuss [3].

The tangible objects of the *Mapping Place* installation are an entry point for interaction as well as a way to direct the focus of each visitor. The form factor of the tabletop, situated in a large space, enables collaborative learning by creating an opportunity for multiple visitors to see and discuss each other's use of the system.

Tangible Narratives

A number of researchers have explored the use of tangible interfaces to afford natural physical interactions with digital stories. Many tangible narratives allow the personalization of users' experiences through creative storytelling. Tangible Viewpoints [15] employed tangible pawns on an interactive tabletop to navigate a multi-viewpoint story space, resulting in different story experiences based on the interactive choices made by the user. Tangibility also allows multiple users to simultaneously interact with a story, leading to a cooperative and social experience. As storytelling is a social experience, it enables development of language and communication skills and collaborative learning. TellTable demonstrated that children using a multi-touch storytelling application took inspiration from one another's stories, and planned their stories in advance, creating more complex and cohesive stories [5].

An important aspect of storytelling with tangible narratives is the absence of imposed linearity. The affordances designed for the applied technology will naturally create constraints, but these constraints can also be considered the tools of the storyteller, and a platform for imagination. In Triangles [8], users connected triangles to form patterns recognized by a computer. The Triangles were used as non-linear storytelling tools, with each configuration potentially generating visual or audio feedback. Conversely, when direct meaning is applied to the tangible objects, there is a sense of authorial control, even when the user's ability to sequence the objects suggests non-linearity. Essentially, the user is able to actively explore the story rather than openly construct the story. This is the case with RENATI [7] as well as The Reading Glove [20], each of which used RFID tags to trigger audio clips assigned to physical objects.

The *Mapping Place* exhibition draws on tangible narrative research in two ways. First, since it remediates a traditional storytelling artifact, we draw from tangible narrative techniques in order to create a successful storytelling platform. Second, we capitalize on the learning and comprehension implications of tangible narratives in order to create a piece that promotes learning, not only about the story that is constructed, but also about how stories themselves can be constructed and what those constructions mean to different cultures.

PROJECT GOALS AND EXHIBITION OVERVIEW

Our goals were (1) to create an interactive installation that remediates traditional African notions of mapping history and place through digital and tangible media and (2) to better understand how digital and tangible interaction technologies can support learning and comprehension of cultural material and concepts within a museum context.

The installation piece was part of the *Mapping Place: Africa Beyond Paper* exhibition, which also included European representations and maps of Africa on paper, from the late 16th to the 20th century, along with an authentic Lukasa on loan from the Royal Museum for Central Africa in Tervuren, Belgium (see Figure 2). The exhibition invited visitors to explore the ways that the changing representation and projection of space has shaped Western approaches to Africa. By bringing the mnemonic tradition of Central Africa to an engaging storytelling activity, the tabletop installation helped to bridge the gap between certain aspects of Western and traditional Central African cultures. The piece's implied story structure, tangible objects, and physical and contextual space were designed to cohesively function to enable children to create and share stories of their own.

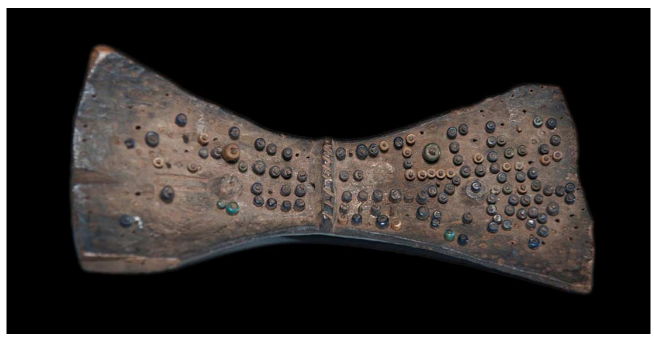

Figure 2: Lukasa board loaned by the Royal Museum for Central Africa for the *Mapping Place* exhibition. Photo taken by Sidarth Kantamneni for the Robert C. Williams Museum of Papermaking.

INTERACTIVE INSTALLATION OVERVIEW

The design of the interactive tabletop installation was inspired by the nonlinguistic symbolic mapping practices related to the making and reading of the Lukasa board. There are three steps involved in the tabletop interaction: making, mapping, and telling stories. Making stories involves drag-and-drop interaction of virtual beads to icons around one's tangible story shell on the interactive tabletop. Mapping stories involves arranging and visualizing the connections between story elements with the help of visual animations on an adjacent wall display. Telling stories happens through oral performance as visitors narrate their stories to one another around the table.

The installation consists of a multi-touch tabletop with tangible shells and two wall mounted projections. As visitors approach the table, they see digital beads scattered around the surface and a collection of physical objects shaped like shells on the edges. A visitor can pick up a shell and place it on the tabletop display to start building their digital story. The tangible shells are meant to encourage participation and storytelling by helping visitors differentiate their stories. Their shell becomes the central node of their story, and seven icons appear in a circular "menu" around it, representing possible components of a story about family and place: man, woman, boy, girl, pet, home, and city (see Figure 3). The visitors can arrange digital beads around the tangible shell by dragging them onto the icons to assign meaning to them. For example, if a visitor wants to tell a story about their mother and aunt, they can drag two beads onto the "woman" icon one after another. They may choose to represent their mother with a red bead and their aunt with a yellow bead in order to distinguish them.

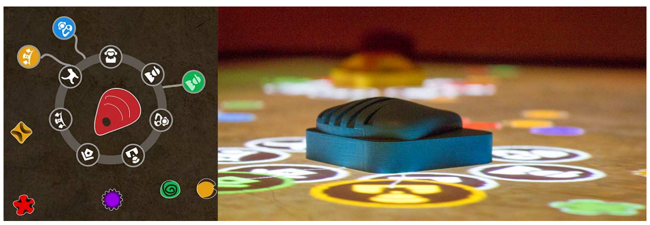

Figure 3: A circular menu of icons (left) appears around a tangible shell when it is placed on the tabletop (right)

As each bead is assigned meaning, a corresponding animation begins to play on a wall adjacent to the table (see Figure 4). When more beads are added, the animations are layered to create a story scene. The visitor can arrange the position of the elements in their scene as desired by moving the assigned beads around the central shell. The story is completed when the visitor removes the tangible shell from the table and the "menu" of icons disappears. Only the final arrangement of assigned beads remains and the visitor can verbally share their story with others around the table.

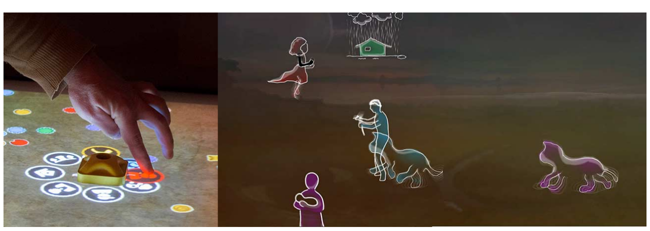

Figure 4: Visitor dragging beads to icons around a tangible shell (left); wall animation (right)

The visitors complete the interactive session by sharing their stories with one another around the table, accompanied by the playback of the animated scene on the wall. Multiple visitors can create stories on the table at the same time, each with their own tangible shell, resulting in a larger "story map" of the group's shared experience.

As each group completes their session, their tabletop "Lukasa" is captured as a digital image and stored in an archive of all visitors' creations. These conceptual maps, which represent the stories shared by visitors, are displayed in a slideshow on screens at the back of the exhibition space. As with the Lukasa, without the original creators to give meaning to these maps by narrating the stories they represent, the recorded images remain little more than abstract symbols to subsequent viewers.

DESIGN PROCESS

The design of the piece was guided not only by the overarching goals for the project, but also by audience and site-related factors. Given that the piece was created for a museum setting, we anticipated that visitors would typically interact for five minutes or less. Furthermore, we expected the main audience to be primary or middle school children on school field trips. As a result, we realized it would be necessary to convey the Lukasa-inspired story-mapping concept through a short interaction that was both engaging and easy to understand. We considered storytelling and collaboration as important elements for learning about the Lukasa and developed our piece focusing on these aspects.

We considered three different ways of learning:

The first is to *learn by doing*, since the system's mechanics enable visitors to learn the underlying rules through interaction. We designed the system to resemble the meaning making process of the Lukasa board, where meaning is created through the selection and placement of beads on the wooden board. In our piece, visitors drag and drop virtual beads to icons in order to make their stories.

The second is to *learn by creating*. The system provides open-ended interaction, which allows visitors to decide their own ways to symbolize their story elements by using the components of the system. Visitors gain an understanding of the arbitrary, yet personal, symbolization process by devising their own ways to remember and tell the pieces of their stories.

The third is to *learn through interaction with others*. Visitors learn each other's ways of symbolizing story elements as they construct their stories side-by-side and share them with one another through oral performance.

The interaction, visual, and physical elements of the installation piece were designed to support these different ways of learning.

Interaction Design

The system design was inspired by the creation and storytelling process of the Lukasa board.

Embodied Interaction as Meaning Making

The drag-and-drop interaction resembles the meaning making process of the Lukasa board, where beads are assigned meaning as the creator selects them and arranges them together on the board. Similarly, virtual beads are scattered around the table as unclaimed story elements. Visitors can look at the different beads and push them around the table using multi-touch interaction; the beads respond with fluid movements, guided by physics. When a bead is dragged and dropped onto an icon, it connects to the central story shell and becomes a piece of one's story.

Personal Symbolization
The interface has four components that each visitor can incorporate to symbolize pieces of their story: color, icon, location, and movement. These story elements are reflected on the wall animation. The animations on the wall reflect the colors and story elements of the assigned beads, and can be arranged to create a scene by moving the corresponding beads around the central shell. By creating a composition of story elements, a visitor can differentiate his or her pieces of animation from others and also find his or her own ways of symbolizing story elements.

Personal Story-Map
The interaction with the tabletop results in a personal story map. We were informed by the original Lukasa board in which the spiritual capital is represented through beads centered around a cowrie shell. A tangible story shell becomes the center of each visitor's digital Lukasa, holding all the pieces of their story. As beads are attached to the shell and positioned around it, a thin line between bead and shell shows the association. Lifting the tangible story shell reveals and completes the story map.

Collective Storytelling
The entire tabletop becomes the group's digital Lukasa, holding multiple visitors' stories. Since sharing of the stories represented by the Lukasa was a tribe's ritual and performance, we wanted the stories to be shared as a collective experience. The wall animation visualizes the stories and encourages sharing with others. By looking at the wall, the visitor can point to, move, or change their story elements, making the experience performative.

Visual and Physical Design
The visual and physical design of the piece draws on Luba art in general and the Lukasa in particular. Inspired by the cowrie shells and studded beads typical to the Lukasa, we decided to design story elements as story shells and beads. The shells and beads are made in five different shapes and colors adopted from Luba art. The tabletop screen shows a texture of old wood, and the hourglass shaped table is made out of wood carved with geometric patterns. These design choices are intended to help people perceptually connect the digital tabletop to the Lukasa (see Figure 5).

The visual materials such as icons and animations are intended to help people visualize and share their stories. These are meant to be general enough so that they can fit to any type of story. The table is placed diagonally towards the center of the two display walls in the gallery to encourage visitors to look at the wall animation while interacting. Instructions are placed on each side of the table to inform visitors how to interact, and what each icon represents. Figure 6 shows a group of visitors interacting with the table during the *Mapping Place* exhibition.

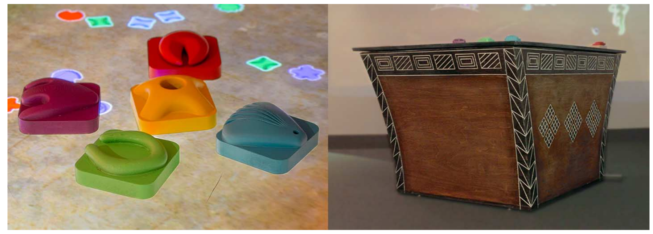

Figure 5: Tangible objects (left); tabletop (right)

Technical Implementation
The tabletop uses diffused surface illumination (DSI) to evenly light the surface with infrared (IR) light. It runs the Community Core Vision (CCV) engine to recognize touches and ReacTIVision [13] fiducial markers on the bottom of the shells. CCV stitches the images from four Playstation™ Eye cameras modified to see IR, which enables us to create a large interactive surface that can more consistently recognize smaller objects and fingers.

The front-end application was developed in Unity3D. The Unity scene stretches across three projected screens: the table surface and two projectors aimed at the walls. Unity3D controls the physics of the beads on the surface and the behaviors of the animations. Unity3D and CCV communicate using the TUIO protocol.

The animations were drawn and rendered in Adobe Flash and Adobe After Effects. Each frame was exported as an image to be colored and layered in Unity3D upon interaction.

The form of the table and the tangible shell objects were designed in SolidWorks. The table was cut at the Advanced Wood Projects Lab at Georgia Tech from plywood using a CNC (computer numerical control) router. The tangible shell objects were 3D printed on a Dimension SST 768 in the GVU (Graphics, Visualization and Usability) Prototyping Lab. The objects were then finished by sanding and painting the plastic.

EVALUATION
We conducted a user study to understand how the interaction with the tabletop primes students for learning abstract concepts, and how the understanding of such concepts affects interaction. Based on the goals of the exhibit and our background research, we developed the following research questions:

- Priming for learning – Does the interactive experience prime and affect understanding of the subject matter?
- Supporting sensemaking – Are visitors able to apply their knowledge to the experience? Does grounded knowledge affect how the visitors interact with the piece?

- Encouraging group interactions – Does the application support collaborative activities in groups?

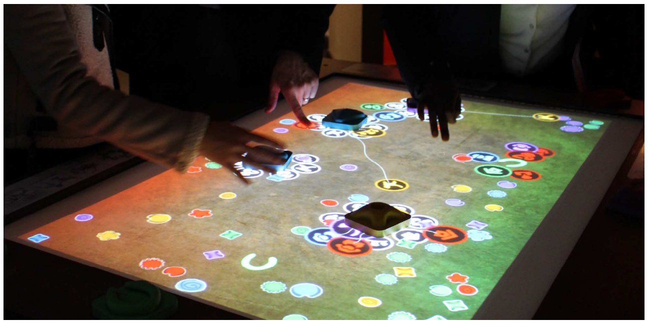

Figure 6: Interaction around the tabletop

Participants and Evaluation Sessions

The user study involved fourteen participants 8-13 years old, four female and ten male. Eight were homeschooled children and seven were primary school students. We arranged the students in four groups of 2-5 students to visit the museum and participate in a focus-group interview. The user study took place at the gallery where the exhibition was held.

We started the user study with a pre-task activity asking students about their storytelling practices, and to share a story with the other participants. The pre-task activity was meant to prime students to think about stories and find out if they had prior knowledge about the Lukasa. We contrasted two different ways to teach students about the Lukasa board, with a lesson either before or after the tabletop interaction. Two groups of participants had the lesson first, interacting with the tabletop later, while the other two groups used the tabletop first. The ten-minute lesson was given by the researchers in a classroom and explained the socio-cultural background, the usage, and the cultural meaning of the Lukasa board. The lecture was accompanied by slides containing texts, images, and a video. The lesson was followed up by a mid-task interview to assess the participants' understanding of the Lukasa board. The mid-task interview was in the form of a semi-structured discussion. We asked participants to explain what they had learned, and to compare and contrast the Lukasa board to other storytelling practices and artifacts such as books, maps, or oral narration. For the ten-minute interaction session with the tabletop, we asked participants to make stories about their family and neighborhood. The interaction was followed with interview questions asking about the ways participants used the table to make stories. Once the participants had been exposed to both the lesson and the tabletop, we ran a post-task interview to investigate how the tabletop influenced the sensemaking process for learning about the Lukasa. We asked participants to discuss the similarities and differences between the tabletop application and the Lukasa board.

Methods

During the interaction session, participants were asked to talk aloud while we recorded video and took field notes. We transcribed the video and evaluated the data from the interactions and interviews by coding based on grounded theory. We compared the two groups to understand the learning effects of the lesson and the tabletop interaction, and their influence on one another. Grounded theory is a qualitative analysis method often used in social science research involving discovery of theory through analysis of data [6, 19]. Our use of grounded theory was primarily to discover a metric for coding emerging data and to find repetitive patterns. The codes were grouped into similar concepts, and into categories. This method was appropriate for our study as we did not have a theoretical framework to test but rather wanted to understand the meaning of our observed data. We used the analysis software NVivo to code and analyze our data. We eventually narrowed down the codes and categories as summarized in Table 1.

	Category	Codes
Priming for Learning	Definition	Object, Use of, History,
	Memory	Cultural Memory, Memory Aid
	People	Exclusive Knowledge, Oral Performance
	Symbolic Representation	Symbolic, Iconic, Nonlinguistic, Movement
	Literal Representation	Visual Representation, Storytelling
Supportive of Sensemaking	Storytelling	Intentional, Random, Frustration
	Symbolic Representation	Color, Movement
	Literal Representation	Visual Representation, Icons, Location, Time
Supportive of Group Interactions	Collaboration	Joint Action, Joint Attention, Communication

Table 1: Codes and categories extracted from the data.

Results

We conducted qualitative analysis of our coded data based on our goals and the research questions mentioned above. Deeper observation and patterns in the data that emerged during coding gave us insights into the use and effects of the interactions.

Priming for Learning

Based on our analysis, it appears that the interactive experience does affect understanding and does prime students for learning the concepts in the lesson. Students who interacted with the table first drew on that experience during the lesson.

"In Lukasas, the symbols represent things, and based on probably visual similarities. They probably make the

symbol look similar to what they are explaining." – Participant with interaction first

Students who received the lesson first also applied the lesson to the interactive session, contextualizing the experience.

"It [The tabletop application] helped me understand how something could symbolize things. Like for example, this boy icon can symbolize something but then I can tell different stories out of it." – Participant with lesson first

Some design elements of the application led to unintended interpretations of both the interactions and the content in the group who interacted with the installation first. Since our application visualized the story compositions through animations and characterized icons, participants who interacted with the tabletop first were more likely to interpret the visual components of the symbols literally instead of using them as abstractions of more specific meanings. Even though they still learned about the Lukasa, they understood the idea of symbolization based on visual similarities rather than abstraction of story elements.

Supportive of Sensemaking

We found that having contextualized knowledge supports sensemaking through interaction. That is, grounding the interaction with a prior lesson helped participants focus their interaction in order to grasp the concept. In our study, participants who received the lecture first were able to abstract and symbolize their story elements and use color to indicate relatives, groups, and emotion to tell their stories during their interaction.

"I put the lady into red because she got really angry at the baby for crying so loud." – Participant with lesson first

In contrast, those without the prior lesson did not try to symbolize story elements and made literal interpretations of the visual elements such as how the animation looks to explain their story.

"The man is trying to kill the cat so it is running away. Poor cat." – Participant with interaction first

Supportive of Group Interactions

The collaborative activities of those who received the lesson first were limited to learning how to use the system without further effort for collaborative story construction. Because the Lukasa is a personal story construction device, knowledge of the Lukasa board appeared to constrain the interaction and individualized the story construction. Conversely, participants who completed the interaction first demonstrated a greater tendency to collectively explore the system and collaborate on story construction.

"I have a dad and a boy, you have a mom and a dad. You have a cat and I have a cat. So I am going to get rid of my dad. We have so many cats! Now what can we do with everybody's cats?" – Participant with interaction first

Limitations

The museum setting introduced its own set of limitations. The museum we worked with and the teachers of visiting school groups were not able to significantly alter the curriculum they provide to focus on the Lukasa and mapping concepts due to both schedule and curricular constraints. These factors limited both the pool of subjects and the curriculum we were able to work with for our study and made it impossible to conduct our study with visiting school groups.

As a result, we recruited participants separately from school groups, running a focused small-group one-time-visit user study. Admittedly, group dynamics and user diversity affected our observation. Recruiting a larger number of participants would mitigate such concerns and generate quantifiable data for analysis. Expanding the curriculum or conducting follow-up studies could provide additional insights. In addition to the lecture, other activities such as drawing or crafting a personal Lukasa could be done jointly with tabletop interaction.

DESIGN IMPLICATIONS

The evaluation produced implications for interactive technology design for museum exhibits.

Learning through Sensemaking

A culture's embodied practices and perspectives can be taught through an interactive system that embeds that culture's logic and structure. Digital technologies can enable visitors to perform and realize the ideas behind conceptual and historical practices through engaging and playful interactions.

However, in order to support effective learning through a short interactive experience, these interactions should be based on contextualized knowledge. Effective sensemaking happens through interaction and reflection of meanings. Through hands-on experience, visitors can reconstruct and personalize the content they have learned. Without such knowledge, the interactions risk remaining simply a fun experience that provides limited understanding of the concepts at hand.

Storytelling for Collaborative Learning

For children, tangible narratives are an opportunity to create a dialogue where cultural ideas and values can be shared. Tangible narratives have been shown to encourage exploration, play, and collaboration through storytelling. Multiple users are able to simultaneously interact with a story, leading to a cooperative and social experience. This can be a good method to encourage learning and foster a collaborative learning environment in cultural museums.

Contextualized Use of Technology

Interaction and visual design should reinforce learning goals and actively attempt to avoid implying unintended meanings. Aligning an installation with learning goals is a good way to give students a way to critically engage with certain types of content, especially if it is part of a larger curriculum. However, without some grounding, design decisions can mislead students and lead them to make unintended interpretations of the content.

CONCLUSION AND FUTURE WORK

The Lukasa-inspired interactive installation demonstrates one way in which emerging digital interaction technologies can be used to revisit and support learning about historical and cultural concepts in ways that are tangible, embodied, and performative. The implied story structure, tangible objects, and physical and contextual space of our piece were designed to cohesively function to enable children to create and share stories of their own. Our user study showed that grounding the experience in contextualized knowledge can enhance comprehension of abstract concepts and subject matter. Future work can explore the how a system's design reflects the content and context of cultural interactions, highlighting how design for the humanities may compare or contrast to design for STEM subjects. There is still much to be done to understand how tangible technologies can best support learning in cultural museums and our future directions include further design, development, and evaluation work in order to generalize our results across a broader range of subject matter and a larger participant pool.

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