Exhibition Design for a Tangible Archaeology Prototype - Excavating Local History

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Abstract

We present an interactive archaeology prototype with a tangible user interface and in-the-wild user study at a sciencue museum where the piece was exhibited. We also present an analysis of which building blocks the interactive exhibition experience consisted of. The prototype was studied at the museum for two days by observing the visitors at it (n=61) and through a user study where different elements of the interactive exhibition were assessed (n=9). The exhibition is discussed through a framework of five design elements: story, information, technology, presentation, and ethics. Our salient findings highlight the importance of careful design in balancing authenticity and usability, the storytelling experience and the importance of designing a suitable pace for interacting with the exhibition. We also provide discussion points for gamification and integrating ethical viewpoints when designing interactive cultural heritage exhibitions. Our research contributes to museum exhibition design and engaging visitors through technological experiences.

Keywords

Human-centered computing, interaction design, archaeology, museum exhibition, tangible user interface, gamification, cultural heritage

1. Introduction

Technologies are being applied in a variety of ways in museums and science exhibitions. Today, different types of interactive pieces have become commonplace in museums and cultural history exhibitions and increasingly go beyond information displays and touchscreens, offering tourists immersive experiences. Pai et al. [1] suggest that successful experiences with smart tourism technologies are a way to increase visitor satisfaction and revisit intentions. Several technology-mediated approaches to educating visitors about archaeology have been developed, such as using virtual reality (VR) [2, 3] and augmented reality (AR) [4, 5], photogrammetry and 3D printing [6, 7], as well as interacting with 3D content through touchscreens [8, 9]. In this article, we describe the process of designing and constructing an interactive archaeology-themed exhibition for a science museum and its two-day in-the-wild evaluation at the museum (Figure 1).

Gamification has been used to enhance service experiences and provide gameful experiences in various contexts [10], including learning about cultural heritage (CH) [11]. By reporting a field study, our research contributes to the field of gamification research, where a need for more in-the-wild studies has been pointed out [12]. Our chosen interaction method, using tangible tools when interacting with the exhibition piece, was selected instead of touchscreen-based interaction, based on our initial comparison study [13]. This resonates with prior findings on physicality, as it has been reported that physical gamified elements (e.g. points) are more meaningful than virtual ones [14]. In our design process, we did a field study and sought to provide an engaging and close-to-authentic experience with scientific information, enabling people to learn about local history while interacting with the exhibit. We focus on analyzing the different parts of the exhibit and investigating how they align with different design elements for an interactive museum exhibit. Our study consisted of a two-day experiment at a

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science museum, with an exhibit promoting local cultural history. The user study consisted of collecting feedback through two methods: by observing museum visitors interacting with the exhibit and a formal user study where participants completed tasks and a survey and were interviewed to evaluate the overall user experience.

This paper is organized as follows: we first present the related work on tangible museum exhibitions and museum exhibition design. Then, we share our design process with the tangible prototype, describe the user study methods used, and present the results. Finally, we reflect on the findings, present conclusions, and share the next steps for further research.

2. Related work

Here, we present previous work related to museums and tangible exhibits and explore how archaeological exhibitions have been designed previously. We also discuss the physical aspects of having tangible tools, how different elements are included in exhibitions and their role in the user experience.

2.1. Museum exhibition design

Previous research has demonstrated the potential of interactive technologies for engagement, and positive learning experiences has been demonstrated [15]. Also, human-computer interaction has been found to effectively recontextualize CH with different tools and approaches [16]. Huotari and Hamari have defined gamification as "a process of enhancing a service with affordances for gameful experiences in order to support user's overall value creation" [17]. Gamification has been identified as sitting at the intersection of hedonic and utilitarian motivations [18]. In the cultural heritage context, gamification has been used primarily for promotion and motivating users, leveraging various technologies such as AR and VR [19].

Recommendations for designing museum exhibitions have been presented by, e.g. Allen [20], who give recommendations based on their experience with science museum exhibitions. They highlight four essential aspects: "immediate apprehendability, physical interactivity, conceptual coherence, and diversity of learning modes". When designing museum exhibitions, social aspects should also be considered; for example, Coffee [21] writes that "the museum is a profoundly social experience". Thus, researching the social experience and context is crucial to designing the whole museum experience. This

Figure 1: The interactive archaeology prototype after all the artefacts were uncovered.

is supported by Hornecker [22], who compared two exhibit presentations at a museum and how they enabled co-experiencing and sharing the exhibitions. Their work highlights the importance of tangible elements and how the overall experience and elements are set up. This study noted different user behaviours in front of a screen, with children positioned right next to the screen and adults watching from behind in a shared experience. The social aspect has also been noted by Haywood and Cairns [23], who studied children's engagement in an interactive exhibit at a science museum and suggested three main themes: participation, narration and co-presence of others. These studies have highlighted the role of social dynamics, which is also found in the research of gamification (e.g. [18]).

Often, archaeological objects in a digital format are presented as collections, whereas we aim for user interaction and engagement. Bruno et al. [2] introduced a method for users to access an archaeological 3D model catalogue in VR. While their system did not engage the visitor to uncover objects, it was a shareable VR experience, reporting up to 50 people watching simultaneously. Similarly, Barbieri et al. [8] developed an interactive 3D visualization with two locations, allowing users to view archaeological findings in their original context, to improve comprehension. Pollalis et al. [5] created an application for interacting with archaeological objects with AR glasses. In their prototype, the users curated their own exhibitions by placing virtual objects in the museum space. In regard to sensitive materials, museum experts face significant ethical responsibility when deciding what to display and how, which is sometimes overlooked [24].

2.2. Tangible cultural heritage exhibitions

Tangible CH has been researched from various angles. For example, Hornecker and Buur [25] presented a framework for tangible interaction, which consists of "systems that rely on embodied interaction, tangible manipulation, physical representation of data, and embeddedness in real space". In designing museum exhibits, Ciolfi and Bannon [26] describe an archaeology workshop, where hands-on activities were provided for school groups. Visitors excavated real sand to uncover objects hidden by the staff, conducting authentic archaeological tasks, such as documenting their findings and discussing the objects. Visitors considered this activity a "very engaging experience" that prompted collaboration between participants [26]. Related to the same museum, Hall et al. [27] described an exhibit where users uncovered replica artefacts and then completed a quest related to the museum's main collection.

A type of archaeology exhibit similar to ours was designed by Lu et al. [28], who provided tangible tools for excavation and cleaning objects. They highlighted the realistic interaction feedback and reported high user engagement with the system. Some of the issues they share relate to instructing the users on how to use the tools and presenting information effectively, as users paid more attention to the physical tools than the text. A more digital approach was presented by Liu et al. [3], whose VR game allows users to excavate objects inside VR using physical gestures for interaction. Inside the game, two tools are used to perform the excavation: a hammer and a shovel, and the user has to be careful in the operation in order not to cause harm to the archaeological object, which was discovered to support the user experience and learning. Concerning archaeology and digital games, Champion [29] has suggested that game mechanics should be found or developed to apply 3D models, e.g., for education. They also report that involving people in the game design process is collaborative and meaningful.

3. Interactive exhibit design

The design was built previously and studied in another article [13], and the experience was revised and improved based on the user feedback from the study. In the previous study, it was concluded that the prototype was preferred to be used with tangible tools instead of just fingers. The gamification included in our exhibition is subtle, mostly implemented as a setting and narrative, and interactive visualization and information. We opted out from having, for example, point systems or achievements, but rather the joy of uncovering the objects and learning more about them through the other related material of the exhibit, alone or in groups. To summarize, our exhibition included elements of the three aspects of gamification: hedonic, utilitarian and social [18].

3.1. Archaeological content

Figure 2: The tangible prototype before use.

Archaeology is a discipline that studies the past through material culture and strives to uncover the history and development of humankind. It includes different fields of archaeology, such as classical archaeology, maritime archaeology, and Egyptology, that focus on other areas and periods. Archaeological information accumulates in destructive ways, such as excavations, and non-destructive ways, such as inventory and preliminary studies. Today, archaeology uses technology in various ways to help in different parts of the research process [30, 31]. It should be noted that in archaeological research, one does not focus only on the artefact itself; the context of it matters the artefact can be interpreted, see e.g. [32]. Without the context that relates to the archaeological finding, nothing can be deduced from the object other than its physical properties and additional general information if similar discoveries have been made in the past.

When preparing the tangible archaeology prototype presented in this article, the historical content was curated by an archaeology expert (fourth author), who searched the CH databases for interesting artefacts found in the area. The expert also had experience conducting actual excavation field studies and participated in one during the design process (Figure 3). The design research group also visited an excavation site with the expert, which functioned as important background information for the exhibition design. The content for the exhibition prototype was selected to be of the local CH. The three archaeological items selected for the exhibit were found in the area of Salla (previously Kuolajärvi) in Finland and accessed through an online database FindSampo [33]. The objects were found between 2015 and 2019 and date back to the Iron and Viking ages.

3.2. Interactive exhibit

The interactive exhibit included three parts for the participants to explore: a roll-up displaying context for the topic, a tangible prototype, and an artefact information poster.

3.2.1. Context roll-up

The context roll-up provided general information about archaeology. The information presented was curated by an archaeology expert (fourth author). It was designed to be visually appealing and easily understandable to a diverse range of users, given that their identities were unknown beforehand. The text was presented in English and Finnish to cater to local and international users. The overall colour scheme was inspired by the hues found in the soil and artefact photographs used in the prototype.

Figure 3: Field research at an archaeological excavation site.

3.2.2. Tangible prototype

The tangible prototype includes a monitor with an infrared (IR) touch frame and two excavation tools (Figure 2). The 23-inch monitor and IR touch frame are mounted on a wooden frame. A plexiglass layer protects the monitor from damage. The IR frame detects any object that crosses its plane, turning the monitor into a touch screen. This allows users to use any object as a touch input, unlike regular capacitive touch screens.

The screen shows soil that the user can remove in two layers by dragging a physical object over the screen. These layers cover three images of artefacts on a third layer below. The prototype includes two tools for removing soil: a brush and a spatula. These tools are placed to the right of the screen on printed images of each tool, with pressure sensors underneath. When a tool is lifted, an icon on the screen shows which tool is in use. A new image indicates when to pick up or return a tool, making it clearer for users. Users must use the spatula to uncover the first layer of soil, which allows access to the second layer, which can be removed with the brush. When 80% of the bottom layer covering the artefacts is removed, the artefacts glow to signal the user they are finished with the excavation.

A white reset button is located to the right of the tools. The software cycles through three different layouts of the artefacts displayed on the screen, allowing users to try the prototype multiple times while minimizing the effects of previous observations. The outer frame of the prototype is covered with foam board, rounded to create a natural look. Sand and faux rocks made from foam and paint add to the design. Natural elements, like fallen pine cones and foliage collected from a local forest, were added to enhance the outdoor feel. Also, wooden skewers and yarn form a fence around the screen, similar to those at archaeological excavation sites. The visuals on the screen are inspired by the photos from archaeological sites visited by the fourth author.

3.2.3. Artefact information poster

The artefact information poster is a foam board poster with an interactive flap. Users can lift it to reveal further information on the artefacts they discovered whilst using the tangible prototype. The poster shows e.g. the time period and use of the object. Having the artefact information separately from the tangible prototype minimizes the possibility of the next user observing the results or reward of the tangible prototype.

4. Method

Data was collected at a science museum over two days through two methods to gather broader insight (Figure 4). The exhibit was studied using field observation over two days. On the second day, a user study was held.

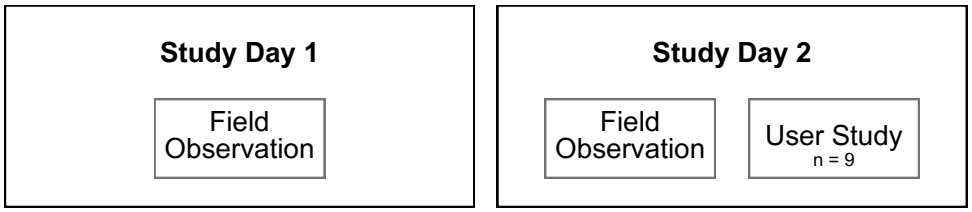

Figure 4: Study structure.

4.1. Field observation

On the first day, museum visitors passing by were asked to try the exhibit while three researchers observed their interactions with it. The researchers observed how the visitors paid attention to the exhibit, e.g. how they used the prototype. The field observation was divided into three sessions. Each session began with a clear evaluation matrix to prevent bias from previous evaluations. The visitors who tried the tangible prototype were asked to put a sticker on a plane to evaluate how the exhibit was, the axes being whether they found it boring or fun and if they learned a lot or did not learn anything. In addition to personal notes, the researchers used a printed template to tally up if the visitors read the posters, interacted with the prototype, and made a note of any comments that were noted any comments made out loud, in addition to any notes on the researcher's observations.

After one hour of observation during the first day, the prototype had to be changed from being on the floor to the table. This was done to enable more accessible participation, as we observed that many people seemed interested in trying it but did not want it or were unable to go on their knees. Thus, the prototype was moved onto a table for the rest of the day (3 hours) and the next day.

4.2. User study

On the second day, in addition to observing, three user study sessions (n=9) were held. The user study participants were recruited on-site and through word-of-mouth. Each participant was assigned a participant number. The participants took part in a four-part user study, comprised of answering a background questionnaire, trying the interactive exhibit and prototype, answering a survey, and taking part in a semi-structured interview.

First, they were greeted and were given an introduction to the topic. They were then asked to sign a consent form before answering a background survey. Following this, each participant was asked to read the roll-up and then interact with the prototype, uncovering three items each (Figure 5). Once this was done, they had a chance to learn information related to the uncovered artefacts from the poster, while the fourth author gave additional information and answered any questions about the artefacts.

The participants then answered a survey, evaluating their experience concerning five themes: story, information, technology, presentation, and ethics, with two tasks. First, by filling out an evaluation template that featured images representing the interactive exhibit: the support information, the tangible prototype, and the five themes (Figure 6). They were instructed to take notes and connect the given themes to different parts of the interactive exhibit by drawing lines between them. Second, the participants were asked to evaluate how important each theme was to the exhibit on a scale of one to five, with one being not important and five being very important. The participants could leave an open comment about each theme after the evaluation if they wished to.

To conclude the study, the first and fourth authors interviewed the session participants. The interviews were conducted in four sessions, with varying amounts of participants in each session. The number of participants picked to take part in each interview session was based on the flow of people visiting the exhibit, as the participants were not picked beforehand. All in all, nine people participated in the user study (Table **??**). All but one participant had visited the science centre before the user study sessions were held. The participants were asked to fill in a background information questionnaire.

When asked about the participants' subjective estimation of how much experience they have of

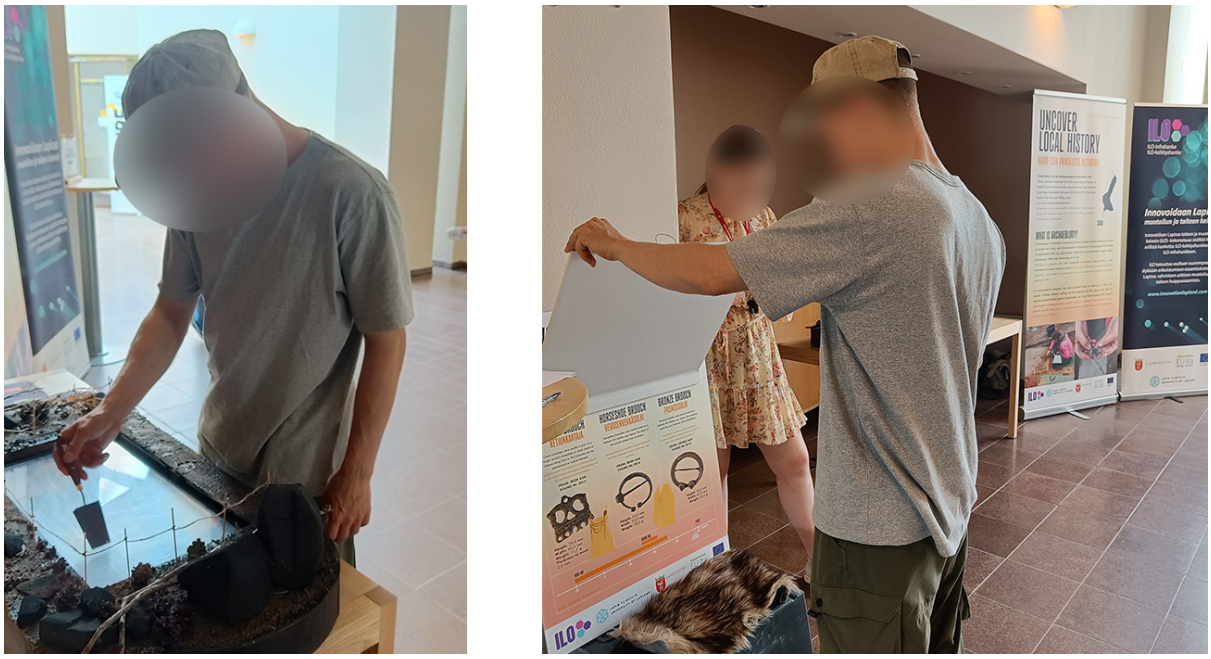

Figure 5: User study participant interacting with the exhibit.

Figure 6: A task for the user study participants to connect the different parts of the exhibition to the framework from their perspective.

Table 1
Details of user study sessions

Session Number	Participants	Age (years)	Gender	Length Of Interview
1	P1, P2, P3, P4	<18, 18-25, 46-55, 26-35	Woman, woman, woman, man	9 minutes
2	P5, P6	26-35, 36-45	Woman, woman	12 minutes
3	P7, P8	46-55, 26-35	Woman, man	12 minutes
4	P9	26-35	Woman	6 minutes

museums on a scale from one to five, the average was 3.3, with the highest estimate being five and the lowest two. One participant estimated they visit museums a couple of times a year, while another said they work in an art museum. A third participant said they have the national museum card and visit museums often with their child, who especially enjoys interactive exhibits and new experiences. When asked what the participants' subjective estimation of how much they know about Northern Finland's

local history is on a scale from one to five, the average was 2,8, with the highest estimate being four and the lowest two. Most participants commented that they had learned about the history of Northern Finland's location in middle school or at a university. One participant said they had learned about the history of Northern Finland from listening to their grandparents' stories.

5. Results

Here, we present the observation results and how the prototype was rated by the users on-site. We also share the results of the user study from the participants who filled out the questionnaire and participated in a group interview.

5.1. Field observation

During the two days of the exhibit, 61 passers-by were observed to pay attention to the exhibit. Of those interactions, nine people read the informational roll-up, 26 tried the prototype, 47 checked the artefact info from under the flap on the poster, 17 people's comments were noted, and 30 feedback stickers were placed. Of the 61 people who stopped by the exhibit, 55 were on the first day, and six were on the second day. The first 12 people used the prototype on the floor, while the rest used the prototype on a table. After the first hour, it was observed that many people showed interest in the exhibit but could not interact with the prototype, as it would have required kneeling. Kneeling for an authentic archaeological experience prevented participation due to age or mobility issues. The previous study was conducted at the University of Lapland campus, where only two participants noted that kneeling or crouching down was unpleasant but were able to participate nevertheless. The majority of participants in the previous user study were in their twenties (75%, or 15/20). We observed that in this case, families would often come to the exhibit, and the parents would encourage their children to try out the prototype. At the same time, the parents themselves would watch and join the activity by commenting or asking questions.

After visiting the exhibit, the observed visitors were asked to evaluate their experience by placing a sticker on a coordinate plane, in which the vertical axis ranged from 'I learned a lot' to 'I did not learn anything' and the horizontal axis from 'boring' to 'fun' (Figure 7). Based on the evaluations on the coordinate plane, the participants found the exhibit and prototype fun and informative. Twelve visitors found the exhibit and prototype fun but did not learn that much. One visitor thought the exhibit and prototype were somewhat boring but learned a lot. None of the visitors expressed that the exhibit and prototype were boring or uninformative.

5.2. User study results

First, we present the results of the interviews and later surveys in which the user study participants were asked to evaluate different aspects of the exhibition.

5.2.1. Affinity wall

During the user study, participants were interviewed, and their responses and discussions were analyzed using an affinity diagram method, first using an affinity wall for notes and finally putting together a diagram [34]. Initially, interview results were summarized and then organized into groups on a board according to common themes. The first and second authors iteratively categorized and organized notes into different themes that emerged during the process. Ultimately, the following categories were established: Ethics, The Role Of The Archaeologist, Storytelling, Tools, Local History, and Content.

The Ethics category included thoughts on how the artefacts were discovered and processed, what to do if one discovers on their own, and how the topic of ethics was challenging to grasp. Several participants wanted further information on what to do if they made a discovery in real life, as they were instructed not to move the objects so archaeologists could properly analyze the artefacts. Participant

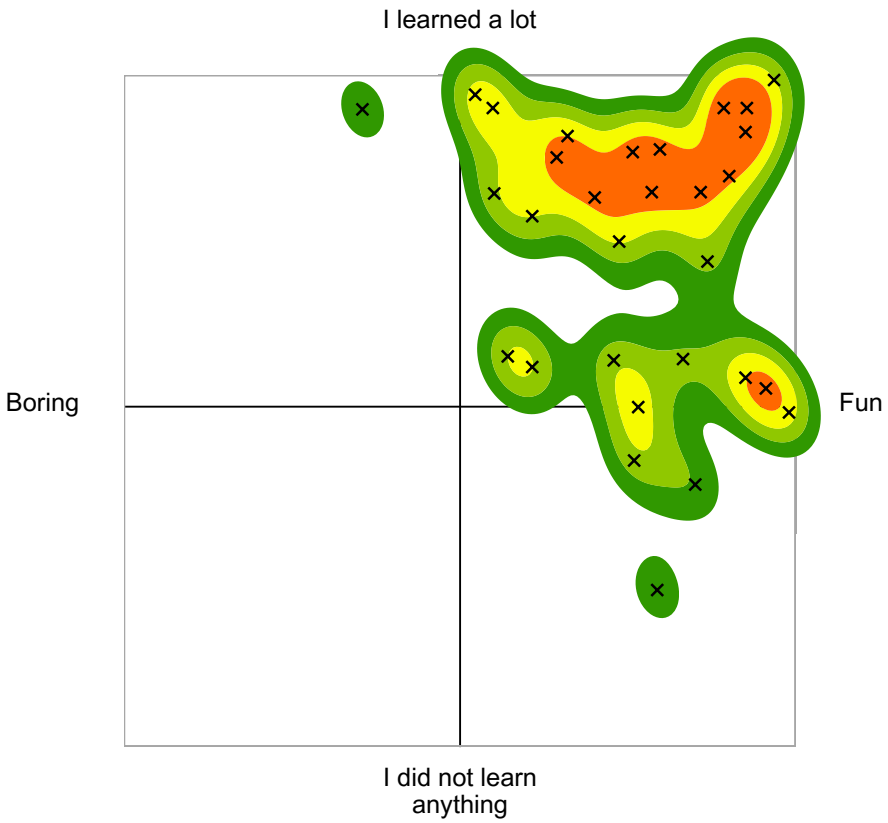

Figure 7: Passer-bys' ratings of exhibition.

8 (P8) commented that there could be ethical issues if the artefacts were discovered or related to an Indigenous culture.

The Role Of The Archaeologist category included thoughts about archaeologists being familiar with TV programs or films, wanting to know who made the discoveries (amateurs or professionals), and that being the archaeologist made the discoveries more interesting and meaningful, in this case, discovering them via our prototype. Several participants inquired about who originally discovered the artefacts used in the prototype and if there was any information on their background.

The Local History category included thoughts on where the prototype could be used, the history of the artefacts, and whether the artefacts being discovered locally or regionally affected their experience. Overall, the participants thought having local and regional history brought to the forefront was great. P1 and P7 both commented that if the discoveries were made in a completely different region instead of locally, it would not feel as impactful or important to them. Several participants commented on how they did not know much about local history, but one participant (P6) explained that all they knew about the topic was from stories they had heard from their grandparents. The participants were interested in the culture and history behind the artefacts, such as who would have used them and why. Illustrations of how the artefacts could have been used in the past were included in the poster, with a participant (P9) commenting on how that helped deepen their understanding and interest in the topic. Participants suggested the prototype could be suitable for different kinds of museums and also local fairs or markets that were themed around history or traditions.

The category for Tools included thoughts on the tangible tools, brush and spatula used in the prototype. The participants enjoyed the simplicity of the tools; they were easy to use. All participants commented that they liked using the physical tools instead of their fingers, which is the most common way to interact with digital screens. The spatula tool sometimes got stuck on the screen or was not registered as well by the technology used, so most participants concluded the brush tool was the best.

Table 2
The final affinity wall.

Ethics	**The Role Of The Archaeologist**	**Local History**
Can be a difficult concept to understand for some.	Being the archaeologist makes it more interesting and meaningful.	Not as well known, good to bring forth.
How were the artefacts discovered and processed?	Who found these artefacts: an amateur or a professional?	Regional and local history is deemed interesting; it is more influential.
What do I do if I make an archaeological discovery? What is the follow-up?	Archaeologists are familiar from TV.	Whose history is it? Who were the original owners, and who found it?
		What is the culture behind the artefact? What was/is it used for, and by whom?
		The tangible archaeology demo could be used, e.g. at events showcasing history, like local markets.
Tools	**Storytelling**	**Content**
Simple (positive)	Having a story could make it more immersive.	Was nice that there was a guide to explain the topic further.
The brush was nicer than the spatula, but both were nicer than using your finger.	It does not matter if the story is real or fake as long as it is believable and balanced.	Could be more in-depth.
The spatula got stuck sometimes.	Having a story could help you learn more about the people behind the objects, which is interesting.	Include more possibilities to figure out things or guess on your own (e.g., what are the objects).
Using the tools felt more authentic (than using your finger), but are these tools actually used in archaeology?	The people and culture behind the objects are the most interesting.	More visuals (photo, video).
Liked having physical tools (compared to digital tools).	Bring forth the archaeologists, or people who made the finds, more.	Interesting and attention-grabbing appearance.
Having physical tools helped me understand the topic.	Having a knowledgeable guide was a big positive, as it was a more human approach and more interesting.	Could benefit from further gamification.
There were some mishaps with the technology not working properly.		Continue the experience at home (e.g., flyer, model, miniature... to take home).
It was OK that it felt a bit fake or like playing.		

P9 commented on how it was satisfying to use the brush tool and see the object being uncovered in real-time. Another one noted that: *"It was good that the tools were like real archaeological tools, instead of controllers"* (P8). One participant commented that the tools helped them feel more like an archaeologist but wondered whether these tools were used in the field, but continued to say that perhaps it was all right if they felt a bit like toys in this context (P6).

The Storytelling category mainly included thoughts on whether or not the concept could benefit from a story alongside the task. All participants thought having a story would be beneficial and help further understand the topic, task, and artefacts. The story could either be around the original owner or use case of the artefact or around the archaeologist who made the discovery. The consensus was that it did not matter if the story was real or fictive as long as it was believable. P6 commented that if the story were about, for example, a Viking princess, it would take away from the prototype and its

authenticity. Finding the balance between fact and fiction would be critical. The participants found the culture and history behind the individual artefacts the most interesting. During our prototype, we had the fourth author, an archaeology student, work as a guide of sorts and answer any further questions the participants had during their experience. Having a knowledgeable guide was deemed a huge positive as it helped the otherwise digital prototype have a more human approach, and the participants found the overall experience more interesting as they could ask any questions they thought of on the spot and get an answer.

The final category was Content, which included thoughts on the support information presented. The overall consensus was that having the context roll-up, artefact information poster, and tangible prototype as a trio was useful. Most participants did not read the context roll-up, but several commented on how it helped draw them in and give them a general idea of the exhibit. The participants thought the exhibit was enjoyable but lacked depth. They suggested including a story, pictures, photos, or videos to enhance the experience. For example, P1 suggested having *"Maybe more of a story around the objects"*. Some participants wanted a more challenging exhibit to encourage critical thinking, for example, allowing them to figure out what the artefacts were before giving the information to them. Adding features to gamify the experience could also make learning more interesting compared to just reading. A participant (P8) suggested having some physical elements in addition to the screen; *"It would have been fun if the objects were next to the screen, for example, as 3D prints"*. Several participants expressed their desire for the exhibit to provide a flyer containing details on archaeology, particularly on the proper protocol to follow in case of an archaeological find. They also suggested having a souvenir to take home, such as a miniature or replica of the discovered artefacts showcased in the prototype.

5.2.2. Survey tasks

The participants were presented with two tasks to fill out individually: they were asked to fill out the evaluation template (Figure 6) and evaluate how important the five themes were. The number of connections on the evaluation template was tallied to determine which areas excelled in each theme (Figure 8).

The context roll-up display received the highest marks in the Information category, with eight out of nine participants drawing connections. Many participants noted that the information presented on the roll-up was concisely summarized. The poster received four connections to the Information theme, while the prototype only received one, leading us to believe the participants did not find the prototype to be very informative.

The tangible prototype had the most connections to both the Appearance and Technology themes, with the poster getting one connection to Technology and the context roll-up none. P9 commented that *"the gamification was good and something new"*. Having a different perspective on the Technology theme, P2 commented how the photos of the artefacts on the poster show *"the craftsmanship of that time"*. All parts of the exhibit were quite evenly evaluated in the Appearance theme, with the roll-up having four connections, the prototype six, and the poster five. P8 commented that the *"environment built around the screen on the prototype made the experience more comprehensive."*

The poster had the most connections to the Story theme, with six participants indicating it out of nine, while the roll-up had four and the prototype one. A participant (P8) wrote: *" The illustrations of outfits using the artefacts shown in the prototype were very explanatory"* concerning the story. Some participants, however, wrote that they would have wanted more information or storytelling about the people and culture behind the artefacts. Only two participants connected the Ethics theme to anything related to the exhibit; one connection to the context roll-up and one to the artefact information poster. P1 wrote a question mark next to the theme, and P9 commented that they *"did not notice"* anything related to ethics in the exhibit. P5 noted a general comment that they liked it when they were first given background information about archaeology and later got to try excavating themselves.

The second task given to the participants was to evaluate how important the five themes are in exhibits of this nature, in general. The participants evaluated each theme's importance on a scale of one to five, with one being not important and five being very important. After each theme, the participants

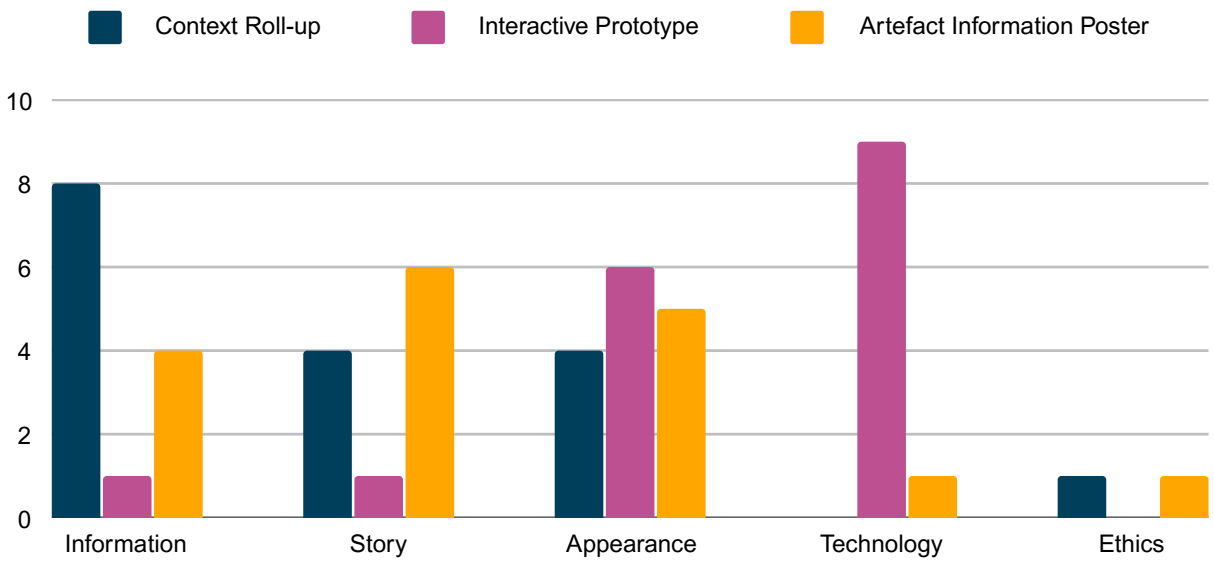

Figure 8: User study participants (n=9) evaluation of exhibition elements.

could add a comment if they wished. Based on the comments, not all the participants understood the task. At least three participants seemed to evaluate the themes based on how well they had been taken into account in this particular exhibit. Not all participants wrote comments, and not all participants evaluated each theme with a number or at all. However, all the themes were evaluated on average at over four, meaning the participants seemed to find all the themes as important to take into account when designing an interactive exhibit.

Appearance ranked highest, with the average evaluation being 4,7. While P7 did not give a numerical evaluation for the theme, they commented that *"an interesting appearance tempts you to new topics"*. Also, P9 evaluated the theme's importance at five and commented that appearance is *"an important part of presenting information"* and that it *"must be clear and visually pleasing"*. P1 suggests that the researchers at the exhibit could *"wear some cool Viking outfits"*, introducing an interesting notion that also the researchers at the exhibit are part of the exhibit just because they are there.

The Information theme's average evaluation was 4,6. This theme had the least comments. P9 commented that information is *"an important part of an exhibit, but it can not be too heavy"* and that *"you should not have too much all at once"*.

The Technology theme's average evaluation was 4,4. One participant (P7), who evaluated the importance of the theme at five, commented that *"if the technology does not work, nothing works"*, which a comment from P8 echoes: *"If the technology does not work, you end up concentrating on the wrong things"*. P5 commented that, in their opinion, technology can add functionality, which is good, but adding technology just for the sake of adding technology does not bring the exhibit any added value.

The Story theme's average evaluation was also 4,4. P3 commented that adding a story makes you want to learn more about the topic. P4 suggested that using video to present the story could connect it more with the technology used in the exhibit. P9 wrote: *"At least for me, storytelling makes the topic more interesting and makes it easier to absorb the information given."*

On the other hand, ethics ranked lowest, with the average evaluation being 4,3. P7 commented that they could not think of how ethics would be important to take into account in an exhibit, except in the case of grave finds, in which case the findings *"belong to the buried."* Both P3 and P8 expressed that it is important to consider when discussing history.

6. Discussion

6.1. Usability versus authenticity

In our interactive exhibition design, we considered authenticity to be an important user experience goal. The choice of tools, the visualizations, and the overall setup were sought to provide as an authentic feeling of an excavation as possible. Thus, the original idea was to place the prototype on the floor level, similar to an actual excavation site. An interesting finding, however, or a reminder, was that the drive for authenticity should not overrule the usability requirements. We noticed this when initially setting up the prototype on the floor. The in-the-wild study soon showed that the authentic manner of doing archaeology on the floor level proved to be unusable for many people, especially as many of the museum visitors were rather elderly. The non-ergonomic setup also discouraged some people from trying the prototype at all. We soon re-iterated the setup and placed the prototype on a table. This highlights the role of accessibility, which was something found important also in the study by Pai et al. [1]. Also, as noted in our observations, the role of social dynamics could be recognized in how groups interacted with the exhibition, as sometimes the guardians accompanying children would prefer to stay back and facilitate the use instead of directly interacting with it. This differs from the use of e.g. VR, where the experience is not always so collective.

6.2. Interaction pace and the framework of five design elements

The in-the-wild study highlighted how important it is to think about the pace of interaction when visitors come to the exhibition. It was very important to have the contextualization of the exhibition piece, created with a roll-up poster, before the actual interactive prototype. This helped the visitors to engage with the topic and to prepare mentally for the excavation site. It also provided a smooth transition towards the interactive part of the exhibition setup and the possibility for many users to explore it at their own pace. Moreover, we noticed that it was important to provide extra information after the interactive part, as visitors were then curious to learn more about the pieces that they had found. This aligns with prior research, where increased motivation and enjoyment have been discovered through gamification [10]. Also, gamification was something pointed out by participants, even though it was not mentioned by the researchers. Overall, the pace of the interaction when visiting the exhibition is important to plan properly and allow enough time for different phases of the visit.

The interactive exhibit was analyzed through a framework of five design elements: story, information, technology, presentation, and ethics, as shown in Figure 8. The three parts of the overall exhibition emphasize different design elements, and we found this to be a successful solution. Especially in the beginning, contextualizing the exhibit by providing a story and information was important. The ethical elements were concentrated at the beginning and end of the overall experience, where visitors had time and were not actively engaged in physical interaction. We believe this was also a good design solution. The findings of this study have given us reflections for our design framework that considers the ethics of Indigenous digital heritage [35].

6.3. Integrating ethics viewpoints

When evaluating our framework in this user study, we found that not many users paid attention to the ethics or would even name any ethical issues related to the topic. Perhaps this is apparent in other exhibits, but here, it was difficult to point out by the participants. After they were given examples or heard others' peoples thoughts in the group interview, they could understand the necessity of having ethical reflections on exhibitions and heritage. Ethics was also not mentioned as being directly related to the prototype by anyone. Still, it was more discussed with the information or related to the context, such as if the user should be given knowledge of ethical archaeological practices or any cultural issues related to objects or sites. While ethical issues are necessary for the personnel designing the exhibits [24], they might not be so visible to the visitors.

For our user study, an archaeological expert was present and could give the participants an explanation of the items and context, as well as answer their questions. We speculate that the participants' experience could have been different without the knowledgeable guide. This is also an interesting possibility for integrating ethical viewpoints in the exhibitions, as a domain expert can answer the questions of origin and retrieval of the artefacts more thoroughly.

6.4. Limitations and future work

We acknowledge that our research is limited by the short duration of the in-the-wild study and the number of participants. However, we believe the study setup provided valuable insight and lessons learnt on how to organize interactive CH exhibitions with a tangible user interface in practice. An exciting element to address in future studies is an even deeper integration of tangible elements into the concept design. While our exhibit included tangible elements in the form of tools and the setup, the participants were not able to touch and feel the uncovered objects, which were only available as digital images. We seek to explore this more in the future.

7. Conclusion

We have presented an interactive archaeology exhibit and reported an in-the-wild user study with a tangible prototype. Our findings show the different elements contributing to the user experience with the exhibition and highlight the role of contextualization, the importance of balance between usability and authenticity, and the role of pacing the experience. Different design elements, i.e. the story, information, technology, presentation, and ethics, were emphasized in different parts of the exhibition, which helped in pacing the interaction and engaging the visitors with the topic. Our findings can support the design of interactive and engaging museum exhibitions.

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