MobileMuseum: Smart, Portable, and Borrowable Museum Displays to Explore Interaction Patterns and Public Engagement

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Fig. 1. Motivated to increase access to (a) artifacts on display at a science museum, (b) we digitally-fabricated low-cost replicas, (c) and designed flip-able labels with embedded sensors, in a (d) public interactive mini-museum display to engage people hands-on with the tangible artifacts, and (e) allow it to be portable, borrowable, and 'smart' with multiple seamless sensors.

We explore how smart, portable, tangible, and borrowable museum displays can be used to expand museum outreach, and provide tools for measuring user engagement. Our prototype, MobileMuseum, is a portable museum display on wheels, housing digitally-fabricated replicas of artifacts from a national science and technology museum. To track interactions without cameras, we embedded photo and magnetic door sensors and RFID tags and antenna. Our deployment study was carried out for 2 months and included 4 different locations (2 recreational and 2 educational). Data collected from 6 sensors, 261 hours of field observations, 17 filled questionnaires, and 14 interviews helped us understand interaction patterns. Qualitative and quantitative findings revealed that self-monitored interactions encouraged deeper open-ended exploration. Social sharing increased among people in groups while lower foot traffic increased engagement duration. We present generalizable opportunities for self-monitored Interfaces that lends themselves to social circulation, 'honeybee-effect', 'order effect', and 'leftovers' from users.

CCS Concepts: • **Human-centered computing** → **Human computer interaction (HCI)**; *Empirical studies in ubiquitous and mobile computing*; • **Hardware** → Emerging interfaces.

Additional Key Words and Phrases: tangible user interface; seamless interaction; self-monitored; Public Interactive Display; museums; sensor; RFID; laser-cutting; 3D-printing; digital fabrication

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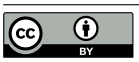

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1 Introduction

Museums integrate technology in a broad variety of ways to enhance user engagement, such as by creating interactive installations [92], Virtual Reality (VR)/Augmented Reality (AR)/Mixed Reality (MR) experiences or video projections [75], and mobile-guided interactions [7] of exhibitions and artifact displays. Researchers use technology to design interactive prototypes [92], utilize digital fabrication methods [91], and develop online collections [70, 99] or web galleries [12] using digital photography or 3D scans. Most Public [Large] Interactive Displays (PLIDs) rely on Graphical User Interfaces (including touchscreens, projectors, mobile apps, LED screens, and AR/VR), which are mainstream interaction modalities that museum professionals are familiar with. While prior HCI literature has extensively studied these types of screen-based pervasive [60] and public displays [50, 72, 95], tangible and embodied forms of public interaction remain comparatively underexplored. Tangible User Interfaces (TUI) offer a wider range of tactile manipulation, self-guided experiences, and social engagement with/through museum artifacts [35, 107]. These experiences are typically on-site, and remote access through virtual galleries lacks tactility. The challenge of offering tangible, off-site museum experiences that operate independently or extend on-site exhibitions remains underexplored. Their potential affordability, ease of deployment and maintenance, and ability to collect reliable, anonymous user data make them a promising low-cost, high-value engagement tool for museums.

Recent HCI research has increasingly merged museum collections with interaction design. Some studies proposed using visual markers (e.g., QR codes) for low-cost smartphone-based interactions [6], while others explored touchscreen wall panels as "the first step to a virtual museum" [25], and even robots to enhance visitor engagement [21]. Beyond screen-based systems, few have examined tangible museum experiences. For instance, [31] embedded sensors in artifacts for physical interaction, and LightHouse [63] investigated playfulness and self-expression. Yet, such pre-pandemic work remained accessible only to on-site visitors. Post-pandemic, scholars have called to "free the gallery from constraints posed by its traditional spatial and cultural configuration" [20] by reimagining collections as mobile objects and city-integrated experiences. However, no published studies have yet examined user encounters with mobile museums. Building on this work, our project aims to expand access by enabling more people to experience museum exhibitions beyond traditional spaces.

In response, in this paper, we address the following research questions:

- RQ1 - How will individuals interact with an off-site tangible museum experience?
- RQ2 - What social and spatial factors affect engagement with tangible interactive displays?

Our work aims to expand museum outreach by making exhibitions more geographically and financially accessible within local communities where people live, work, and play. Drawing inspiration from mobile museums, museums on wheels, and the miniature Free Little Art Galleries (FLAGs) [65], which supported art engagement during pandemic restrictions, we explore how museums can extend their reach through remote, community-based installations. We adapt these strategies in our prototype, the MobileMuseum, combining rapid prototyping, digital fabrication, and embedded sensors. Traditional museum displays often enclose artifacts behind glass, limiting physical interaction. In contrast, our open-door, portable museum houses replicas designed for

hands-on engagement while seamlessly integrating sensors to measure interaction and accessibility (see Figure 1). Taken together, our contributions include:

(1) Conducting a situated deployment study of the MobileMuseum in 4 different locations (across a city that is 200KM away from the museum) collecting insights from 261 hours of field observations of 391 individuals and 56 days of sensor data records.
(2) Conducting a qualitative user interview study with 14 participants to gain deeper insights, informing a set of design opportunities for the HCI community.

2 Related Work

Museum experiences augmented with technology can be *interactive* through screen-based modalities [41, 56, 74], often combined with tangible elements [6, 21, 25] or made fully *immersive* through tangible interactions [20, 30, 31]. However, these experiences remain bound to museum galleries, while off-site access typically relies on online or virtual modes [52, 66]. We join others in identifying the need for creating tangible, in-person "in-vivo" museum interactions [20, 82, 119] that extend beyond the museum's physical walls [11].

2.1 Technology in Museums

Museums have traditionally been spaces for collecting, preserving, and exhibiting cultural and historical artifacts with interactivity limited to choosing which path to take while touring the space [13]. However, with the rapid advancement of technology, museums are increasingly adopting new digital tools and interactive technologies to enhance the visitor experience and engage audiences in new and innovative ways [51, 84, 116], such as having visitors contribute their own thoughts on exhibition artifacts [6]. Previous literature has looked at museums through the lens of interactive storytelling [67], new media technologies by creating interactive installations [98, 113], and educational media [115], amongst others. HCI researchers are also increasingly working with museum professionals to co-design more engaging museum experiences [21].

Numerous studies have been conducted to investigate different aspects of the museum experience [29, 96, 108]. Research within the HCI community usually focuses on achieving one of three different pillars of the museum experience including: increasing engagement [4, 28, 29, 109], increasing personalization [102, 108] or maximizing the learning experience of individuals [81, 96]. To achieve any of the desired outcomes, several techniques have been followed, either through the addition of digital elements or tangible ones in-situ or off-site. From touchscreens and virtual reality exhibits [24] to mobile apps and augmented reality tours [5, 15, 23, 54, 69], technology has become a ubiquitous presence in modern museums.

2.2 Interactive Museum Experiences

2.2.1 On-site. Research emphasizes interactive digital experiences [58], such as auditory exhibits (where each artifact has a voice and character that speaks directly to the visitor [83]), portable digital guides [16], and apps [41]. Falk and Dierking [45] highlight how exhibition experiences are shaped by personal, sociocultural, and physical contexts, extending meaning-making beyond traditional institutional walls. In earlier work, Falk showed that non-linear layouts increase exploration [44]. Tangible museum interactions include tabletops with tangible tokens [26, 74, 77, 94] and AR-based interactions (whether through hand-held blocks [73, 90] or physical 3D replicas [22, 27]). Large-scale tangible exhibits have also been explored [92]. Comparative studies show tangible interactions are less disruptive [103] supporting manual manipulation and exploration [105, 106]. Tangibles have been used to support social engagement, as in Kurio's time-travel narrative game [119] or

story-triggering replicas [79, 82]. Recent work also examines how visitors creatively appropriate tangible displays beyond intended uses [63].

2.2.2 Off-site. Off-site work has primarily focused on online and virtual experiences [52, 66, 121], though maintaining online engagement remains challenging [87]. Virtual galleries allow personalized tours [10] and inclusive experiences connecting remote and on-site visitors [104]. Beyond digital formats, tangible memorabilia (e.g., storybooks [70], wristbands [91], and postcards [**?**]) extend engagement after visits. Studies on gift-giving [118] and the *Museum in a Box* project [1] highlight tangible outreach potential, though high costs and logistics limit accessibility (including inconvenience of shipping, and bearing responsibility for loss and damage). While on-site and off-site digital systems have value, digital-only experiences can be disruptive [76], whereas tangible interaction often promotes collaboration and exploration [80].

2.3 Sharing of Tangibles

Tangible interfaces have been part of exhibition design even before TUIs were formalized [9]. Advances in digital fabrication, such as 3D printing and CNC [49], now enable replication and dissemination of tangible artifacts. Researchers also explore tangible publications for sharing prototypes [101], alongside community-driven sharing initiatives for books [3], tools [64], and art [2]. Studies investigate how sharing systems align supply and demand for tangible goods [8, 37]. During the pandemic, such initiatives flourished especially Free Little Art Galleries (FLAGs) [40, 42, 47, 65], which allowed individuals to 'curate' and exchange artworks. Recent studies identify opportunities for self-borrowing schemes [65], though FLAGs remain underexplored in HCI. Our work builds on 'Emergent' [20], a miniature art gallery developed during the pandemic, and similar small-scale embedded exhibitions [30, 31].

2.4 Mobile Museums and Museums on Wheels

Early mobile collections began as portable libraries for easy transport. One of the first mobile museum displays, a textile collection from 1866, was designed for compact packing [38]. Since then, museums have promoted "knowledge diffusion" by bringing mobile collections into communities through "extensions" or "outreach" [39, 123], inspired by 19th–20th century travelling expos [124]. In 1901, Chicago's Principal's Association created portable artifact boxes for schools, serving over 60 schools with 1,100 collections by 1903 [120]. The Field Museum later adopted this model through the N.W. Harris Public School Extension [93], still active today [89]. The Virginia Museum of Fine Art followed with boxed exhibitions and later Artmobiles—automotive trailers that provided mobile display spaces [62]. The format spread globally [14, 34, 78] but often ended due to costs, staffing, and artifact safety concerns [111]. Despite popularity, financial limits restricted scaling. Museums continue refining these outreach models [71, 111]. Building on this legacy, we introduce low-cost, sensor-embedded replicas in a museum-on-wheels format, enabling unsupervised, trackable interaction, addressing a current gap in the literature [111].

2.5 Public Interactive Displays

There is a substantial body of HCI research examining Public Interactive Displays (PIDs), with particular attention to the challenges of attracting and sustaining engagement in public spaces. A well-documented phenomenon in this area is display blindness, where passersby fail to notice or acknowledge a display, even when designed for interaction [50, 88]. In addition, social barriers (such as the fear of "looking silly" in front of others) can inhibit interaction [60, 95], although the presence of others engaging can counteract this through the 'honeypot' effect, encouraging groups to participate more readily than individuals [122]. Designers must also provide clear visual

cues and affordances to guide interaction [32, 72, 86], which remains a consistent design challenge across installations. Research has explored how proxemics, content layout, and spatial arrangement influence engagement [46, 50, 114], and how exhibit placement (whether central or peripheral) affects approachability and perceived ownership [4, 100]. While these insights apply broadly, few studies have explored PIDs specifically in museum contexts. Exceptions include Hinrichs and Carpendale's work displaying artist information on-site [53], and Hornecker's extensive research on interactive exhibits that support open-ended sense-making and social interaction [57, 59]. However, most museum-related literature focuses either on digital off-site interfaces or structured on-site exhibits [85, 117], rather than pervasive or mobile installations in everyday contexts. Researchers [112] also noted that people's movements, habits, and expectations shape their interactions with public displays. Our study responds to these gaps by examining how physical museum artifacts operate in unstructured public contexts and what lessons PIDs can learn from museum outreach models.

3 Design Decisions and Implementation

Inspired by the Little Free Libraries and Free Little Art Galleries movements, we aimed to create a low-stakes, community-oriented approach to museum engagement. We prototyped a simple box that displays tangible replicas of museum objects, allowing them to be borrowed like books for wider social interaction. While authentic artifacts could not be used due to conservation and security concerns, we leveraged our tools and expertise to fabricate cost-effective engaging replicas.

Designing an interactive standalone museum outside traditional contexts required attention to size, weight, and ergonomics to ensure easy safe transport and deployment without special equipment. The compact display should accommodate a few handheld replicas, fabricated from low-cost, accessible materials to support scalability and public use. The design needs to invite open barrier-free interaction and borrowing, while embedded self-monitoring circuitry can enable anonymous quantitative data collection on user engagement.

3.1 The Artifact Collection

We collaborated with the curator of the *Wearable Tech* exhibition at our national science and technology museum, which showcases body-worn technologies throughout history, broadening visitors' understanding beyond today's digital "smart" wearables. The collection includes medical supports, analogue communication devices, animal wearables, and personal protection or enhancement gear. Artifact selection for the MobileMuseum prioritized items that were easy to handle, quick to prototype, and fit the display's size constraints. Eyewear artifacts met these criteria and allowed visitors to try them on, offering a tactile and visual experience where digital fabrication reproduces both form and function. Replicating these objects made this collection truly "wearable" for visitors. After reviewing several examples, we selected three diverse eyewear artifacts varying in form, historical era, and intended use (see Figure 2).

3.1.1 Pilot Training Eyewear. The first artifact was manufactured circa 1980 and was designed for training pilots to fly at night or in inclement weather. The eyewear was designed to block the pilot's peripheral vision during daytime training flights, in order to focus their attention on the flying controls and prevent them from seeking visual cues through the surrounding windows, which would typically be obscured by darkness at night or in storms. Due to the 3-dimensional structure of the eyewear, we used 3D-printing (with black resin and true size) for a smooth, robust, and close-to-original look and feel.

3.1.2 Anti-pix Chicken Eyewear. The second artifact was manufactured circa 1939 and is unique in that it was intended to be worn by chickens. There is a phenomenon observed that when a chicken is seen to have blood on its body it becomes a target for other chickens in the flock, who will

Fig. 2. Photos of artifacts we selected for inclusion in this study: (a) Pilot training eyewear (artifact no. 1996.0728); (b) Anti-Pix chicken eyewear (artifact no. 2016.0166); (c) Stenopeic eyewear (artifact no. 1993.0269). Orange-highlight shows the artifacts as displayed at the national science and technology museum (*Wearable Tech* exhibition) after being measured for replication. Green-highlight shows our digitally-fabricated replicas.

aggressively peck it, often resulting in injury or death. To solve this problem, farmers experimented with attaching red-tinted flaps onto the chickens' beaks, which would prevent them from noticing blood on other chickens. The flaps are hinged, so that they swing open when a chicken bends its head to eat. That way they would remain "blood-blind" when their head was up, but would be able to see their food with true colours when bent down to eat. Instead of a chicken-beak-pinned design, we created an enlarged human-sized replica to allow users to try the eyewear on, with adjustable straps for accessibility. We laser-cut both clear and transparent red acrylic sheets (with joints for free movement in one direction) so that flaps open when looking down, revealing true colours.

3.1.3 Stenopeic Eyewear. The third artifact was manufactured circa 1910 and was designed for individuals who were farsighted, nearsighted, or had astigmatism. It is made of opaque metal with tiny holes spread out in a circular pattern across the viewing area. Sometimes referred to as "pinhole glasses," the goal of this eyewear was to sharpen vision by reducing excessive light entering the retina, thereby increasing the individual's depth of field. We created multiple replicas of these using laser-cutting on brushed-metal acrylic[1] with the true dimensions and feel of the original artifact.

3.2 The MobileMuseum Prototype

3.2.1 Box Body. To build the MobileMuseum prototype, we adapted a Little-Free-Library[2] with modifications to transform it into a more inviting mini-museum structure. We also purchased a stand[3] to raise it to eye-level height and added swivel wheels for easier movement. The stand had a shelf that we used to place a 'guestbook' open with a note "Leave us a comment" to incentivize individuals to write down any thoughts they had in mind while interacting with the box. Then we added 'artifact labels' (a common practice in museum collections), as removable smaller boxes that fit like jigsaw pieces atop the main box. The replicas were all organized inside the MobileMuseum, either hung on a stand (if 3D), or placed on a transparent 6-layer acrylic rack (if 2D). Thus, the MobileMuseum could be easily disassembled and reassembled, making it easy to transport in most cars (see Figure 4). The MobileMuseum can be typically stocked with 12 Anti-Pix Chicken eyewear, 12 Stenopeic eyewear, and 3 Pilot eyewear (due to their relatively larger size) with enough for people to take away or borrow from the collection.

3.2.2 Labels. We designed a total of 4 interactive labels as boxes with knobs (affords grabbing) and top flap-hinges (affords opening upwards and self-closure): three for each of the artifacts and one for

[1]https://cesco.ca/Supplies/index.php
[2]https://littlefreelibrary.myshopify.com/collections/little-free-libraries/products/double-door-cottage-unfinished-little-free-library
[3]https://a.co/d/0r1tP61

Fig. 3. Four interactive labels fitted above the museum box (a), The Imagine Label opened revealing sticky notes for drawing (b), and slipping a sticky note inside the label from the top (c).

Fig. 4. Showing the MobileMuseum disassembled to fit upright in an SUV car (a) or alternatively placed fully assembled (b) inside the car (c), with all its interactive components (d).

users to imagine their own glasses, which we denote as an "Imagine Label" (see Figure3). We used the question and answer format that is common in tangible exhibition design. The inside answers included the same artifact descriptions that museum visitors would have seen at the museum when viewing the original artifacts. The "Imagine Label" was different from the others with respect to the information it holds inside. Unlike the others, sticky notes and coloured markers were added inside the "Imagine Label" to facilitate user engagement, encouraging users to design their own glasses. Additionally, there is an opening at the top of that label to allow users to slide their sketches inside.

3.2.3 Sensors. To passively track people's interactions in a non-intrusive manner (i.e., with no camera or image detection), a total of 6 microcontrollers connected to the cloud were embedded in different parts of the MobileMuseum box (see Figure 5). Four Particle microcontrollers[4] were placed in the labels to track when and for how long each of the labels was opened (using photosensors flushed to the inner surface) and one was placed in the main door to track when and for how long the door was opened (using a magnetic[5] sensor latch). Finally, a sixth sensor circuit was embedded beneath the housing table, to detect which objects are in the box at any given time (using a Sparkfun Simultaneous RFID wireless module and antenna). All circuits, except the latter RFID antenna, were battery-powered using 10500mAh LiPo that lasts four days before needing recharge.

3.2.4 Interaction. The MobileMuseum was designed to afford multiple forms of interaction. The different interactions available included opening the 4 labels, and main display door, grabbing the tangible replicas inside, taking them out, wearing them, and/or borrowing them for a while (see Figure 8). The MobileMuseum was set up to allow users to not only hold, open, and try the different replicas in the box, but also to give us their feedback and ideas. This was incentivized in multiple ways, namely, by writing in the guestbook, sketching an idea on a sticky note, or filling in a questionnaire that can be accessed by scanning the QR code on the adjacent poster.

[4]https://docs.particle.io/argon/
[5]https://www.dfrobot.com/product-233.html

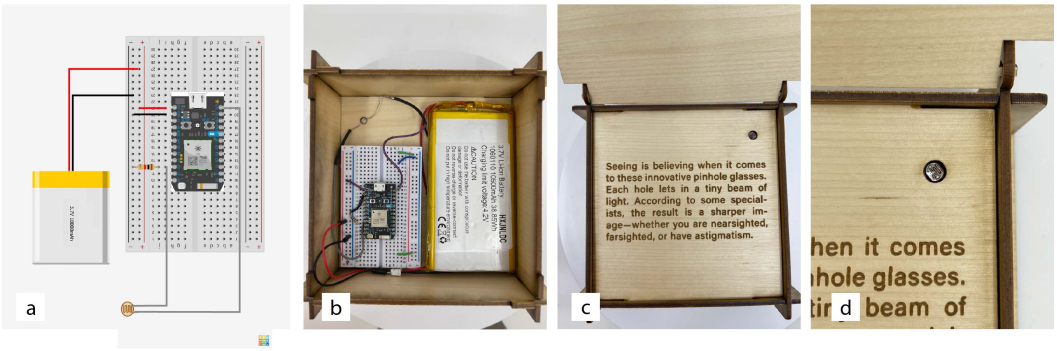

Fig. 5. Inside each label there is: a) an embedded circuit; b) hidden within a closed back compartment; c) where the front of the label has laser-cut engraved information and a flip-able cover. d) Shows a close-up of the photoresistor sensor that detects when the cover is opened.

4 Methodology

Our methods included prototyping the MobileMuseum (MM) as a portable tangible interactive system and evaluating user experience by collecting quantitative and qualitative data. After prototyping, we designed and conducted a 2-month deployment and evaluation (see Figure 6). The quantitative data was collected from the sensors embedded within the different elements of the MobileMuseum prototype, while the qualitative data was collected from field observation notes, user-generated content, guestbook, questionnaires, and user interviews. In this section, we discuss the situated study, describing the deployment process and its timeline, participant recruitment, data collected, and analysis methods.

4.1 Study Design

This study received institutional ethics approval before deployment. The MobileMuseum was installed at four downtown campus locations without special tools. Figure 8.a shows the setup with an instruction poster and QR code for a questionnaire. Four authors alternated observation shifts, recording notes in a shared template. Observers did not interact with participants but watched discreetly from 7∼10 m away, blending in to minimize bias and maintain natural behaviour.

4.1.1 Locations & Timeline. The two-month study placed the MobileMuseum for 14 days at each of four locations: two educational (L1, L2) and two recreational (L3, L4) (see Figure 7). L1, a university library, had high traffic, while L2, a departmental library, was quieter. L3, a community recreation centre, was busy throughout the day, housing a food court, a grocery store, a gym, a swimming pool, and a drugstore/pharmacy. L4, a performing arts centre, saw low traffic except during events in its auditorium and theatre hall. L4 also has a diverse set of audiences, ranging from children to seniors, which is a population not frequently seen in the other spaces. Locations were chosen for their varied traffic and function (see Table 1). Deployments occurred from November–December (L1, L2) and January–February (L3, L4), with traffic varying seasonally with student schedules.

4.1.2 Passers-by and Participants' Recruitment. All participants in this study organically approached the MM without prior knowledge of how it operated. We published one social media post (on Instagram) at the beginning of each deployment to advertise the launch at a new location among campus visitors. While a few participants mentioned seeing the post, most of them were casually visiting the location where the MM was deployed for other purposes and stopped by on their way.

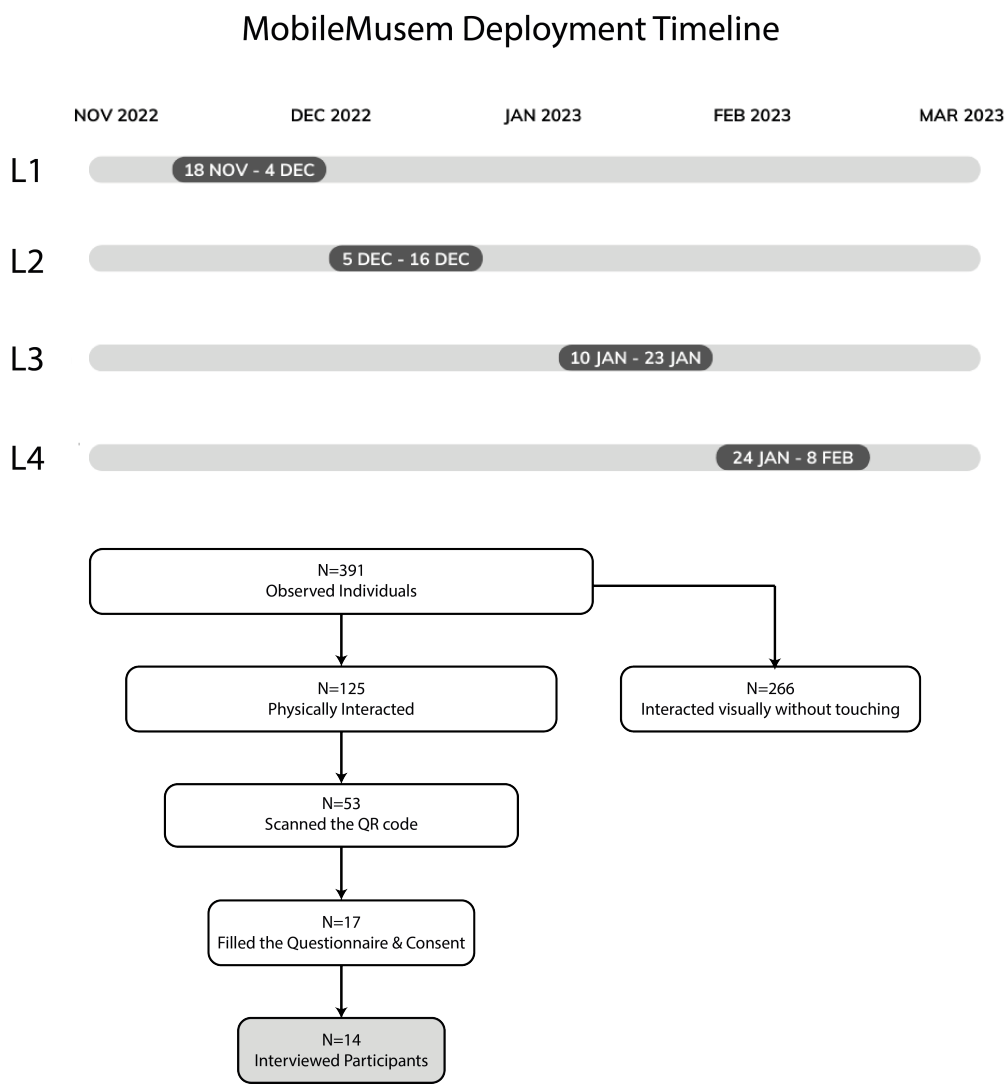

Fig. 6. Gantt chart showing MM's deployment timeline across all locations (top) and funnel diagram illustrating participant numbers at each engagement level (bottom).

Table 1. Description of the function and traffic of each location of deployment

Type	High Traffic	Low Traffic
Educational	L1 (University Library)	L2 (Department Library)
Recreational	L3 (Recreational Centre)	L4 (Art Centre)

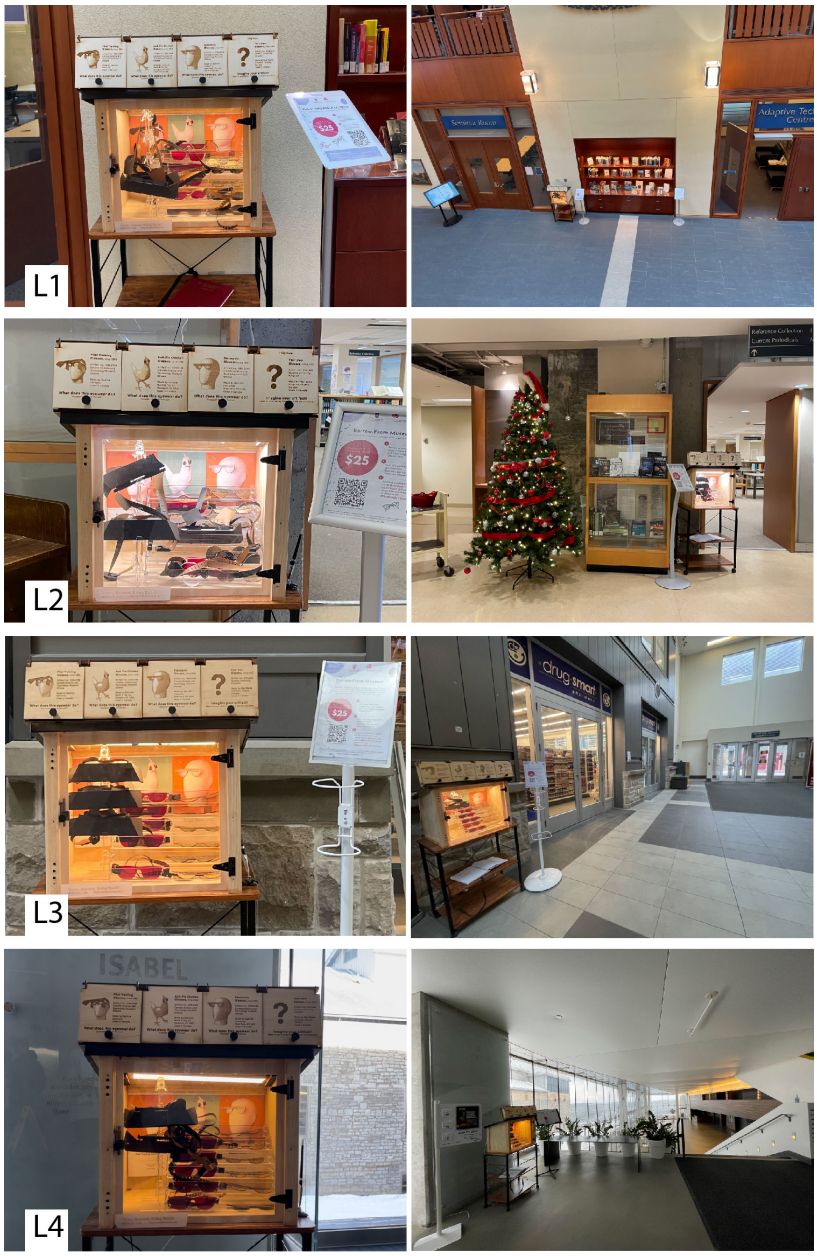

Fig. 7. L1) close to a reading room and a book display. L2) close to a Christmas tree, book display and a study room. L3) close to a drug store and the main entrance in front of the food court. L4) at the main entrance lobby near the ticket office and the stairway leading to the cafe and main theatre.

Table 2. Summary of deployment details. *This location was closed on weekends.

Location	Deployment	Observation Hrs	Num of Observed Individuals
L1	14 days	72	174
L2	14 days*	48	51
L3	14 days	66	103
L4	14 days	75	63

Data collected from system logs, field observations, the guestbook, and user-generated content were all through this initial interaction with the MobileMuseum. Some individuals came through word of mouth and snowballing, but none through direct recruitment from the research team. We refer to the users who encountered the installation but did not engage in the study as passers-by 'observed individuals', while those who completed the questionnaire, signed the consent form, and participated in the interview are referred to as *participants*.

4.1.3 Levels of Engagement. The level at which individuals engaged with our MobileMuseum varied from shallow (looking closely while passing by) to medium (opening the labels and reading them) and high (adding 'Imagine' sticky notes and leaving comments in the guestbook), see Figure 8. Scanning the QR code on the poster would yield another deeper level of participation with the project. When a user decides to scan a QR code, they are prompted to fill in a questionnaire. They are allowed to opt-out of this questionnaire if they wish. However, if they decide to complete the questionnaire, they can decide to follow-up with an interview or not as well, which would be a third level of participation. Hence, all individuals, whether they interacted with the box only, or filled in the questionnaire and conducted a user interview, entered the study through organic interactions that were not promoted by any member of the research team. People (N=291) who were observed during field work are referred to as [observed] individuals, while participants who conducted user interviews are denoted with "P1-P14".

4.2 Data Collection

The MobileMuseum relied on mixed methods for data collection including system logs, user-generated content, field observation notes, questionnaires, and semi-structured interviews. The sensors collected data about the duration and frequency of interaction with the labels and museum box, as well as the number of objects that were taken or borrowed. Written user contributions were also collected through the guestbook and user-generated content. These latter gave individuals room for creativity to contribute ideas, while the questionnaire and interview were designed to obtain deeper insight on user experience and behaviour.

4.2.1 System Logs (Sensor Data). All observed individuals had access to every interactive element on the box, defined by two independent variables: the *interactive element* (Pilot Label, Anti-Pix Chicken Label, Pinhole Label, Imagine Label, and Museum Box Door) and the *location* (L1, L2, L3, and L4). The dependent variables included the timestamp of each interaction, its duration, and the number of times each element was used. We also recorded which objects were taken and from where. We expected that neither location nor label type would significantly affect engagement duration. However, as participants moved between sites organically, the study was not a controlled within-participant design. Over 350 data points were collected per sensor, totaling more than 2,000 across four label microcontrollers and one for the door. The data was analyzed in Python to clean and segment sensor time-series data and extract interaction frequencies for each element.

Fig. 8. Visual affordances cued interaction with the MobileMuseum by: a) flipping instruction labels using knobs; b) opening the glass door using handle; c) interacting with tangible replicas; d) trying or wearing eyewear artifacts; e) sketching ideas on sticky notes via the "Imagine Your Own" label; f) inserting them in the "Slip here" slot; and g-h) writing or drawing in the guestbook.

4.2.2 Field Observation. During weekdays, we performed field observations totaling 261 hours in all 4 locations, observing a total of 391 individuals. Table 2 shows a breakdown of the total number of deployment hours per location. We sat away from the box without intervening at any point in time. Information about the users' interactions were recorded along with the timestamp, duration, and behavioural notes. We collected information about which labels were opened, whether the main box's door was opened and a replica was taken, and if the poster was seen/interacted with. We also added descriptive notes of each participant describing in detail their behaviour while interacting with the MobileMuseum. Some of the field notes were analysed in conjunction with the interviews to support the inductive analysis. Observed individuals went through different levels of engagement, from bystander to tangible interaction. Among observed individuals, a large portion (n=266) looked at the MobileMuseum without touching anything, and 31% (n=125) interacted with it physically. From those who did, 42% (n=53) scanned the QR code, while 17 filled out the questionnaire and signed up for the follow-up interview, but only 14 (P1~P14) conducted it. Figure 6 shows a funnel diagram with a summary of the number of individuals at each level of engagement.

4.2.3 User-generated Content. We collected user-generated content daily from each location, totaling 22 items across L1–L3, with most at L1 and none at L4 (see Figure 9). Furthermore, the guestbook on the lower shelf of the MobileMuseum encouraged open expression, while sticky notes (hidden inside a label prompting users to suggest eyewear ideas) elicited more directed input. Despite these contributions, the data yielded limited insights. Notably, some individuals left other things inside the MobileMuseum such as some miniature figurines (see Figure 9.c). Others placed their eyeglasses inside the museum box while wearing the displayed artifacts (see Figure 9.d).

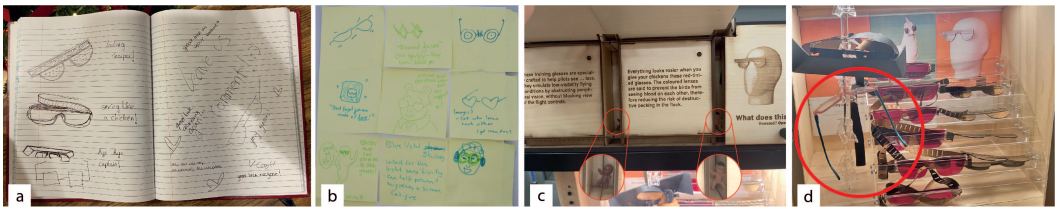

Fig. 9. Images of the user-generated content left by passers-by individuals during deployment: a) in the guestbook; b) 'imagine' label sticky notes; c) miniature figurines inside labels; and d) personal eyeglasses hanged while wearing artifacts.

Table 3. Participants' demographics (6M, 8F) who signed up for post-interaction follow-up interviews

ID	Age	Background	Gender	Location
P1	22	CS Student	M	L3
P2	27	CS Student	M	L1
P3	22	Education Student	F	L3
P4	21	Student	M	L1
P5	21	CS Student	M	L3
P6	19	Student	F	L3
P7	20	Student	F	L3
P8	20	Health Sci Student	F	L3
P9	19	CS Student	M	L3
P10	20	Student	F	L3
P11	20	Education Student	F	L3
P12	26	Staff	F	L1
P13	28	CS Student	F	L3
P14	22	CS Student	M	L3

4.2.4 Questionnaire. We added a questionnaire to collect qualitative insights from a broader audience beyond interviews. Users accessed it by scanning a QR code on the poster, which linked to a Qualtrics form with consent and five questions: two mandatory closed-ended and three optional open-ended. Afterward, participants could opt into a follow-up interview. Seventeen individuals completed the questionnaire, and fourteen booked interviews.

4.2.5 User Interviews. The questionnaire gathered short responses from many participants, while interviews provided deeper insights from a smaller group. Interviews were conducted in person or via Zoom, with audio recordings for transcription. Participants could optionally share images of replicas or items mentioned. The interview covered five sections: demographics, interactions with the box, interactions with the objects, museum habits, and remote museum experiences. Fourteen participants (6M, 8F) were interviewed—three from L1 and eleven from L3 (see Table 3). Interviews were transcribed verbatim from Zoom's automatic transcription [33] and manually verified. We performed thematic analysis following Braun et al. [17–19], emphasizing iterative researcher-driven coding [19]. The first two authors coded the first transcript together, then divided the remainder. Codes were iteratively grouped into organizing concepts and narrative themes, supported by participant quotes.

5 Qualitative Findings

5.1 Familiar and Self-monitored Environments Encourage Interaction

Several participants (n=9) noted how certain aspects of their environment encouraged interaction. Herein, we discuss how familiarity, self-monitored interactions and recreational spaces all invited creative misuse and leisurely learning.

5.1.1 The Role of Familiarity and Prior Knowledge on Interaction. Participants mentioned that they approached the MobileMuseum because it either reminded them of something they had prior knowledge of or they were familiar with the format. A few participants (n=3) related the MobileMuseum to Free Little Libraries and the practice of borrowing and exchanging books: *"I like the idea that you can take it and try it, and then return it. Kind of like those free libraries where you exchange it" (P3).* One of the participants had prior knowledge of the pinhole glasses stating that *"the thing that initially intrigued me was my prior background, knowing about ophthalmological solutions" (P6).* This sense of awareness with specific items or concepts makes people *"really excited to interact with it versus if I've never seen anything before" (P6).* Prior knowledge could also come from social sharing, either from social media *"when I saw it on Instagram it was interesting. And so when I went back the next time I walked, I looked at it" (P3)* or from word of mouth *"Honestly, my friend had told me about the box" (P14).*

Furthermore, familiarity with either the space or the project played a significant role in people's likeliness to interact with the MobileMuseum. Just seeing the MobileMuseum frequently made participants less intimidated to approach it *"That's why the first few times, I just passed by. I don't know what it is, so I'd rather not go try to find out. I feel once you get used to it, it's cool." (P5).* The space the MobileMuseum was placed in also played an important role as, if it were in a place a person is unfamiliar with, their *"focus would have been on other things, maybe [I would've] interacted with it for a shorter period of time because I didn't feel as comfortable in the place I was because it was so unfamiliar" (P10).*

5.1.2 Encouraging Creative Engagement/Contributions through Self-monitored Interaction. The MobileMuseum was placed in 4 different locations, all of which were not perceived to be monitored by anyone in close proximity to it. It was a standalone interactive station that seemed to be self-maintained and had no owner. Participants mentioned that they were encouraged to engage with the MobileMuseum because there was no one monitoring it. L3 specifically was quite unique as there are usually people *"setting up booths and telling people about new interesting things being around there." (P9).* However, the MobileMuseum was a different experience as there were no people around it, *"I didn't see anyone around it. So I thought, why not give it a look" (P8).* This unmonitored experience did not only invite interaction but also freedom and creativity in the way participants could interact *"There was no one to direct you on what's right or wrong. It was there for you to interact with it" (P10).* Of those that contributed, most did so by leaving textual messages in the guestbook and drawings on the log notes imagining glasses with superpowers, others creatively misused the MobileMuseum by contributing to it miniature toy figures between the instruction labels.

5.1.3 Environment Inviting Leisurely Learning. Some individuals can feel intimidated with loads of information *"in large museums as a whole, it's just too overwhelming" (P5).* While museums can be huge crowded content-rich environments, our display was placed in locations where people pass by frequently with no need to actively manage their spent time or mental energy. This allowed them to be playful with artifacts, and have the opportunity to learn more if they wanted by flipping the instruction labels open. Furthermore, it was set up in a familiar space without any person nearby to monitor it. Participants enjoyed the freedom this has brought as they could learn without being pressured or expected to. *"There is less pressure to be insightful.. You could come to things at your own*

time and learn at your own speed" (P10). The information provided by the MobileMuseum was brief enough for individuals to not lose interest yet learn. This was received positively by participants as they liked *"how it was a little piece of information. It wasn't overwhelming" (P8).*

5.2 Borrowing Raises Issues of Responsibility and Shareability

The MobileMuseum encouraged creative engagement with the objects but was limited by participants' feelings of accountability, sanitation concerns, and uncertainty about the new borrowing dynamics it introduced to the museum experience.

5.2.1 Wearables are Perceived as Less Shareable. Because our artifacts were facial wearables (specifically eyewear) and the study took place shortly after pandemic lockdowns in the city, participants expressed uncertainty around whether such items could be safely shared. This prompted participants to raise concerns regarding hygiene and made them hesitant towards interactions of wearing the items *"my friend was concerned about hygiene. She's like, who knows how many people have used this? Who knows if they cleaned it?" (P8).* Not only did sharing wearables raise concerns over sanitation, so did the idea of touching surfaces that have been touched before (n=9). *"If you don't like touching other things, or like touching things from other people, you might not be as inclined to explore it" (P3).* Furthermore, the general cleanliness and organization of the whole setup were contributors to individuals' inclination to interact with it. *"When I saw the box, it was fairly organized, so I felt more comfortable with it" (P3).* During the deployments, we organizes and cleaned the MobileMuseum every morning between 8 AM - 9 AM before the rush of foot traffic. This ensured that the MobileMuseum would always be well-stocked, clean, and organized. Participants noted how this was essential, as the MobileMuseum became unusable if left unattended for more than a day, reflecting local expectations and community norms around shared public surfaces.

5.2.2 Restrictive Nature of Borrowing. Although some individuals took away replicas *"because they would fit in my pocket, and they had a backstrap" (P9)*, our participants expressed feelings of hesitancy towards the idea of borrowing artifact-like objects, despite the poster's invitation. This was discussed by n=8 participants. There were different reasons why participants decided not to borrow an item. They questioned the impact borrowing an item would have if they had to return it. They were *"not sure how much that would add value to it" (P4).* They also felt that the concept of having to return an item would not be feasible for some as *"if you're a tourist coming in through.. then you have to bring it back. It'd be kind of difficult" (P14).* Additionally, participants felt less comfortable taking an item as the MobileMuseum was inviting 'borrowing' items only which added a sense of responsibility that they did not want to take.

5.2.3 Feeling Accountable When Borrowing. The MobileMuseum invited individuals to borrow replicas without any further instructions about the borrowing process. This led to confusion from participants as they *"started to overthink about what if, if I want to borrow it, should I report it to someone else? And just I stood there looking at the first instruction without doing anything" (P12).* They found it difficult to comprehend as they associated it to the check out processes in libraries where *"in a library, you write your name.. but in the borrowable glasses there was no way for me to say, okay, this my name.. I'm going to return it by this day" (P8).* Despite lacking instructions on how to borrow and not enforcing any rules to make people accountable for returning items, participants felt responsible for returning the items and *"didn't wanna take something, and then also have to bring it back.. in case I lost it" (P7).* This high sense of responsibility might differ from one community or culture to another depending on their norms and values. Statements like *"[I] would have felt bad" (P11)* and *"I didn't trust myself with it" (P10)* were the drivers for not taking up the MobileMuseum's invitation to borrow novelty items.

5.2.4 Financially-accessible Tangible Memorabilia. Some participants (n=5) discussed the finances of museums, and how the MobileMuseum introduced a more financially accessible alternative since it doesn't impose any monetary exchange: *"I liked that it was free" (P4).* Apart from admission fees, other costs during museum visits include special exhibitions, parking spots, and gift shops. Gift shops usually feature memorabilia for people to remember their experience: *"I usually get [a] small piece, to just remember the exhibition with it" (P12)*, or share it with others. While purchasable gift shop items might be the only memorabilia for people's visits, our participants usually *"avoid going to museum gift shops. They're too overpriced" (P5).* This financial burden usually leaves visitors with no tangible memorabilia of the place/experience. The MobileMuseum experience, on the other hand, is free which can be more accessible. Moreover, the MobileMuseum allows individuals to borrow, exchange, or take away artifacts which invites sharing *"I told one of the people I was walking with outside that they should try out looking at them" (P9)*, and remembering the experience without being tied by financial constraints. Participants' friends were also curious to know more about the MobileMuseum *"They asked me where I got it from. I was like, yeah, this little box in the [L3] where they have a bunch of them to try it on" (P5).* This shows how tangible artifacts can act as physical memorabilia that promote an experience and encourage sharing between individuals.

5.3 Participants are Less Comfortable Engaging in Novel Interactions When Watched

A key theme in this study was participants' hesitation to touch the MobileMuseum. We discuss how design ambiguity, lively surroundings, and purposeful settings each influence user behaviour.

5.3.1 Hesitancy to Touch Ambiguous Designs. While the MobileMuseum's novelty piqued the interest of passersby, it was also one of its main downfalls. Most participants (n=13) expressed that they were not sure if they could touch the MobileMuseum or not, while others expressed confusion towards the concept as a whole and its purpose. Passersby were *"more likely to just skip over it because you don't want to deal with something new" (P5).* People were cautious when interacting with no prior experience: *"It's such a unique concept, and I haven't seen anything like it that I didn't know how to [interact] with it" (P8).* The MobileMuseum was designed to have minimal amounts of text to invite individuals to be creative with their interactions, which in turn led to further hesitancy and skepticism towards touching it. Participants expressed that *"it was definitely a little confusing" (P6).* Most individuals used the poster to guide their experience *"I looked for the instructions because I was afraid to break anything or touch anything" (P12).* This is supported by field observation as observed participants typically examine the MobileMuseum from afar without touching it, eyeing every part of it from a distance. Other observed individuals look at the poster and then slowly reach out to the different handles that afford interaction. This was emphasized in the answers received from the questionnaire since respondents found that it: *"hard to understand what it is at first, but it's very cool when you read more and try things" (P5).* Some participants also noted that linking the instructions to their associated element was unintuitive (n=4) suggesting to *"connect the glasses to the [labels] in a different way" (P12).*

5.3.2 Consciousness of People's Perception. Given the nature of interaction that the MobileMuseum affords, participants raised concerns about how this interaction could seem odd to passersby. Some participants (n=6) were hesitant to borrow from the MobileMuseum because they were worried about having individuals *"looking at me thinking that I'm stealing" (P12).* Not only borrowing but also their decision on whether to touch the MobileMuseum or not was dictated by how they thought people thought of them *"I noticed that people (were) watching me so, at this point, I wasn't even sure that I'm allowed to, you know, use the box" (P2)* While some participants were wary of how they *might* look, others felt they *"got some funny looks from people walking by" (P1).* Many participants advocated for larger disclaimers or banners to implicitly set a public understanding

that this interaction is welcomed *"because from a bystander's perspective, I'm going up to this box, I'm taking something from it, and then I'm moving with [it]." (P1)*. The placement of the MobileMuseum also contributed to how comfortable people were towards interacting. At L1, it was placed at the entrance which was noted as a place that is not meant for loitering. *"I felt I can't stand for too long. Otherwise, people will notice me, and then look silly standing there doing nothing" (P12)*.

5.3.3 Purposeful Environments Raise Tension. Another significant factor that affected people's perception was whether the MobileMuseum was located in a well-suited space for its purpose which was discussed by many participants (n=8). Despite describing L3 as ill-suited due to the rushing nature, sensor data and field observation showed that observed individuals were more likely to engage more frequently and for longer there. While participants had different opinions about the specific locations the MobileMuseum was placed in, they all mentioned that MobileMuseum should be placed where people are not in a purposeful state, whether going to the library with the purpose of studying or going to the gym to work out. For the MobileMuseum to be seen and interacted with, it should be in a place where people are not in a rush and feel comfortable loitering. *"They [i.e. students] come to the library to study. So they kind of ignore other things" (P8)*. While there were external factors that affected people's decision on whether to interact, their personal availability also played a role in whether they would interact. People who stopped to interact were usually waiting for a social encounter *"I probably wouldn't have actually approached the MobileMuseum if I wasn't waiting for my friend" (P8)*, waiting for a scheduled activity *"people sometimes don't go home between classes, so they have time to spare" (P11)*. Participants also suggested placing the MobileMuseum in locations where there are long wait times like bus stops *"They have 5 min to stay, or they're waiting for the bus, having it nearby. It's just like they can check it out when they have time" (P3)*, or hospitals where patients and visitors *"have to be [there] for a long time" (P2)*.

5.4 Tangible Encounters Supports Social Engagement

Participants (n=8) viewed the MobileMuseum as a hub for social engagement and conversation. Take-away replicas further extended interaction, prompting people to share and discuss their experiences both online and offline.

5.4.1 Experiencing the MobileMuseum as a Group Activity. Sharing was not only in the context of sharing stories or replicas with friends, but also of sharing the experience together in real-time. Participants were inclined to tell their friends about what they saw and invite them to visit the installation together as well. *"I did it myself, and then I brought my friends to look at it as well" (P8)*. Participants were not only sharing to let their friends know about what they saw but also to learn more *"I went back with friends because I was intrigued to learn more" (P6)*. Participants thought that the MobileMuseum is more engaging and fun with friends compared to visiting it alone *"I thought it was more fun to do with friends, because we were talking together about what we were seeing and about the box, and what to do with them" (P11)*. It also allowed them to confidently engage and *"experience it together, laugh at it, talk about it. [We] tried to discover what this was together, and also feel more confident in the sense that I am not alone doing this" (P9)*. This was highly supported by field observation where, across all locations, observed individuals were more likely to stop and engage if they were in groups of two or more individuals.

5.4.2 Engaging Remotely Through Online Sharing. Participants did not only share their experiences during in-person social events and occasions, but also online by taking selfies and photos to share with their friends online. There were participants who were alone during their interaction with the MobileMuseum *"I took a picture of myself, and I showed it to them [referring to friends]" (P9)*, while others were with friends *"It was fun to do it with someone else .. They put it on, and then I just took a*

Fig. 10. Staged photographs depict fieldwork moments: a) a participant photographing a friend wearing the Pilot glasses at L1; b) a participant joining others to observe at L3; c) individuals trying the glasses by holding them rather than wearing them.

picture, and I was like, oh, you look so silly" (P8). Participants expressed that they liked to share it online to hear people's opinions and thoughts *"Whenever I have something interesting I try it on and send it to whoever, (see) if they say anything about it or not" (P3).* This was well-supported by field observation as well as several observed individuals were seen either taking selfies, videos, or taking photos with their friends. Some observed individuals also asked their friends to take photos of them while wearing the artifacts (see Figure 10.a).

5.4.3 Repurposing Historical Function into Contemporary Social Expression. Participants discussed taking the replicas with them to the streets: *"There was snow outside. So I wore it for a bit outside over my glasses (P5)"*, to lunch, and to their homes. Once participants took replicas away, they found new creative ways to use them playfully outside their expected function. They *"put them on in random situations, and that was very fun (P9)"*. Some wore them while playing video games with their friends *"I wore them for a bit. when we were playing video games one night, and just out of curiosity (P14)"*, while others wore while dancing *"I wear them when I dance often, just to, add some more fun to it (P10)"*. One of the participants related the Anti-Pix chicken glasses to their own red glasses which they wear for clubbing.

5.4.4 Conversation Starter and Material with Others. Participants enjoyed using the MobileMuseum in different contexts, including using it as a conversation material. *"That was also a fun way to spice conversation up anytime there is a silence" (P9).* Not only did the MobileMuseum serve as a conversation starter for friends, but also for strangers. Several participants were asked while playing with the replicas about what they were doing. Some strangers even engaged with them *"Another two people walked up to us, and they asked, what is this? And we said, oh, we're just trying to figure it out. And they also tried on some glasses" (P9).* This was well supported by field observation, as passersby were seen to gain interest in the MobileMuseum when there is someone already there playing with the replicas. Figure 10.b shows a stranger (on the right) talking with 2 individuals (on the left). The stranger seemed intrigued by the individuals' interactions and decided to engage with them. After a while of trying out different glasses, both parties walked in separate paths.

6 Quantitative Sensor Data

During deployment, five different sensors were embedded in various elements of the MobileMuseum to collect data about people's interactions in addition to a sixth RFID sensor. We analyzed the data collected using two-way ANOVA analysis and compare field observation data as well. Below, we discuss the impact of changing locations on duration of engagement and how visiting the MobileMuseum in groups increases the likelihood of user interaction.

Table 4. Summary of the duration of interaction and number of interactions for each element at each location.

Location	Pilot Label	Chicken Label	Pinhole Label	Imagine Label	Museum Box
	Average Duration in Seconds				
L1	6.1	7.1	5.7	4.6	52
L2	6.5	7.0	5.4	5.0	48
L3	5.7	7.4	6.7	5.3	46
L4	5.5	6.6	6.5	6.1	54
Average	**5.85**	**7.08**	**6.22**	**5.12**	**50**
	Total Count of Interaction				
L1	160	161	137	149	93
L2	49	54	50	60	47
L3	169	167	159	141	129
L4	117	95	89	75	68
Total	**495**	**477**	**435**	**425**	**337**

Table 5. Summary of the transactions made on all the artifacts that were in the MobileMuseum box.

Eyewear	Created	Taken Away	Borrowed	Broken
Pilot	11	2	0	4
Chicken	20	7	2	0
Stenopeic	25	15	1	0

6.1 The 'Order Effect' on Interaction

The number of interactions with labels was measured using the embedded sensors with labels placed in a *fixed* left-to-right order atop of the museum box. While engagement might be expected to vary randomly with interest and intrigue, both field observations and sensor data revealed a consistent 'order effect': interactions were most frequent on the left, decreasing gradually rightward, see Table 4. Label content influenced the average duration of engagement (i.e. Chicken label #2 has longest engagement average time, likely due to its bizarre concept) but the arrangement defined the number of times each was opened. This pattern persisted across all four deployment sites and appears primarily driven by left-to-right placement (Figure 11).Though it's possible that left-positioned labels (Pilot #1, Chicken #2) were inherently more intriguing, the more plausible explanation is a systematic, left-to-right approach. Field notes confirmed this behaviour where observed individuals opened labels one by one from the left and stopped once curiosity has saturated at 2nd to 4th label) then often returned back to the Chicken label. Since the study was carried out in an English-speaking context, it's reasonable to conclude that individuals carried over their behaviour from one context to another: left-to-right reading direction (as opposed to right-to-left or top-to-bottom). Their cognitive attention (demonstrated by their physical interaction) operated along the horizontal meridian was biased towards the left visual field. It is important to note such findings for future studies, so that researchers are aware of how certain interactive elements might be expected to follow certain patterns or receive the highest engagement, not necessarily due to their own merit (as being the "most" interesting or engaging), but in accordance with local/prevalent cultural contexts and previously learned behaviours.

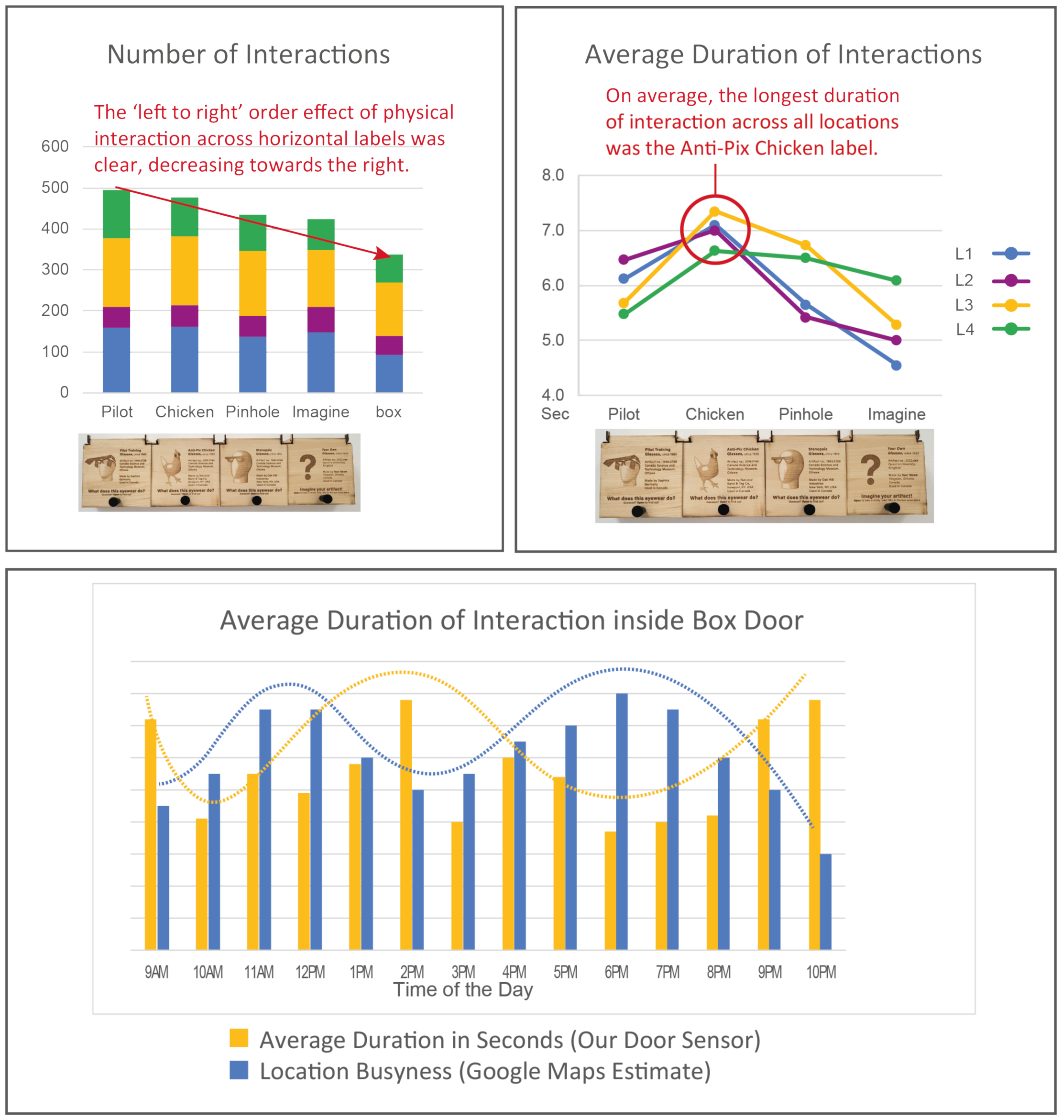

Fig. 11. Graphs showing: (left) the total number of interactions recorded by the sensors of each interactive element, (right) the average duration of interactions per deployment location, and (bottom) interaction durations versus the space busyness per hour.

6.2 Eyewear with the Highest Transactions

The MobileMuseum had three different artifact replicas of varying sizes and functions. When analyzing the activities carried out, whether taking or returning replicas across all locations, we found that 15 out of 24 replicas that were taken away were all Stenopeic eyewear (the smallest in size and weight), while only 2 were of the Pilot glasses (the largest and heaviest), see Table 5. One of the two observed individuals who took away the Pilot glasses was observed during this transaction: That participant was trying out different eyewear, and when they held the Pilot glasses, it fell on the

ground and broke, so they took the broken parts and left quickly. Several Pilot glasses were taken by the researchers because they were found broken inside the MobileMuseum. However, for the Stenopeic eyewear and the Anti-Pix Chicken ones, they were restocked approximately every week. There was a significant difference in the number of replicas that were taken across the different types. This indicates that portability could be a defining factor in whether people would take away replicas or not. This was further supported by the qualitative results as participants mentioned taking artifacts *"because they would fit in my pocket" (P9).*

6.3 Parameters Affecting Interaction Duration

We summarized the average interaction duration and record count for each interactive element and location in Table 4. Based on these results, we sampled 45 records per element per location (below our lowest recorded sample) for statistical analysis. We tested whether deployment location affected engagement and found no significant effect across any interactive element (p=0.311). Similarly, the different labels showed no significant effect on engagement duration (p=0.1).

Time of day influenced how long people interacted with the MobileMuseum. Door sensor data revealed engagement patterns reflecting user comfort levels: as traffic increased, interaction duration decreased, while quieter periods encouraged longer engagement (Figure 11). This quantitative pattern was reinforced by interview themes indicating that individuals felt less comfortable interacting when they perceived they were being watched.

6.4 The Impact of Togetherness on Engagement

We quantitatively analyzed the observational notes and quantified the number of individuals who visited the MobileMuseum alone and those who visited in a group of two individuals or more. We then compared the percentage of those who observed the MobileMuseum only from afar without touching it, with the percentage of those who did. We found that 77% of those who arrived in a group interacted with the MobileMuseum, while only 44% of those who arrived alone did. This shows that people who were together were more likely to interact with artifacts (perhaps more socially safe or empowered) than those alone.

7 Discussing Opportunities for HCI

In this section, we reflect on our research questions and discuss what we learned from this study in the form of key takeaways for the HCI community.

7.1 Patterns of Interaction

To address the first research question (RQ1), we reflect in the following on the patterns of interaction that emerge when people explore an off-site tangible museum experience.

7.1.1 Accounting for the 'Order Effect'. Across all deployment sites, we observed a consistent order effect in how participants engaged with the MobileMuseum labels: interaction frequency was highest for labels on the left and declined progressively toward the right. This pattern held despite variations in content, suggesting that spatial arrangement (not intrinsic interest) was the primary factor influencing which labels were opened first. Field notes confirmed that many participants opened labels sequentially from left to right, stopping after the third or fourth, and occasionally returning to a particularly intriguing one. We interpret this as a carryover from learned reading patterns in left-to-right cultures, where attention is biased along the horizontal meridian toward the left visual field. For HCI researchers designing tangible public interfaces, this highlights the importance of layout choices: the positioning of interactive elements can strongly shape engagement

patterns, regardless of content salience. Designers should account for culturally ingrained spatial habits when arranging physical elements to ensure balanced visibility and interaction.

7.1.2 Expecting Users' 'Leftovers'. Observed behaviors included users leaving toys and figurines behind, writing irrelevant or humorous guestbook notes, and even exchanging borrowed items (e.g., one user hung their personal prescription glasses in place of the borrowed replica). Designers should anticipate and design for such unpredictable contributions, which may seem whimsical or irrelevant but speak to user meaning-making.

7.1.3 Considering Limitations of Wearables. Besides functioning as a PID, the MobileMuseum is meant to be shareable and exchangeable. We modeled the MobileMuseum's shareability after FLAGs [65], where exchange and circulation drive collective value. Yet wearables proved problematic in our study where they introduced hygiene concerns and post-pandemic hesitation. While books and tools may pass freely between individuals [64], eyewear objects were perceived differently in our local community. This echoes challenges in designing for open-ended participation in public spaces [122] yet adds a layer of crowd behaviour. We acknowledge the limitation of focusing exclusively on wearable artifacts, which imposed unforseen constraints on shareability. Our study took place shortly after the COVID-19 pandemic, a period during which individuals remained particularly cautious about wearing items on their faces. This heightened awareness likely influenced willingness to touch or share artifacts, and should be considered when interpreting our findings. Alternative tangible forms (such as handheld or tabletop objects) may have supported different patterns of interaction and circulation.

7.1.4 Enabling Open-ended Interactions. Prior work that embedded tangible interaction did so within guided or supervised contexts [68, 73, 83], limiting users' freedom with a prototype and hence any unexpected findings. A previous study allowed participants to creatively engage with the prototype after their study concluded, referring to it as 'free play' [43], which brought in further insights that the controlled experiment limited. Building on that, we enabled open-ended use of the MobileMuseum from the start, supporting unsupervised 'free play' revealing insights that structured experiments could not. Our findings reinforce the importance of designing interactions that support improvisation and agency, extending the space of public tangible interfaces. This aligns with prior work [4] promoting how successful interactive installations should give users a 'license to play'. Unrestricted creative use of prototypes is thus worth encouraging and exploring within the HCI community to unravel insights that would otherwise be missed.

7.1.5 Designing for Borrowability. Prior work on memorabilia focuses on digital artifacts [70] or post-visit souvenirs [102] for visitors to remember their journey during a visit. However, these souvenirs were usually in the form of a representation of the museum experience, but are not tangible replicas of the museum artifacts they have seen there. Interestingly, while we aimed to enable individuals to borrow items and take them out of the box (which some people did), the opposite also happened (where they placed new items and visitors). This reflects a form of participatory dissemination, distinct from the more passive retention described in earlier souvenir studies. This behavioral pattern extends the "honeypot effect" [122] (where social influence drives re-engagement). Portability also influenced which items were borrowed i.e. slimmer, pocketable items were preferred over bulky fragile ones. Finally, we prioritized low-cost, easy-to-fabricate designs to reduce risks of loss or vandalism; a key consideration for unsupervised public deployments.

7.2 Social & Spatial Engagement Factors

To address RQ2, we present below some generalizable social and spatial factors that we found affecting whether passersby engage with a mobile public exhibit.

7.2.1 Creating Self-monitored Interfaces. The design of instruction labels for museums has been widely researched. The most commonly designed form is a label that prompts users with a question to pique their curiosity [55, 110]. We adopted this form but incorporated circuitry to monitor interactions, transmitting data to the cloud. This added functionality can support HCI researchers in remotely monitoring tangible prototypes and supplementing field notes (with sensor data) during the deployments. This embedded sensing approach reduces reliance on explicit input (e.g., pushing buttons [22] or clicking visuals [72]) and enables remote passive monitoring; an opportunity for curators and HCI researchers alike. Embedding such seamless sensing supports richer analysis of unstructured public interaction, a direction proposed by Hosio et al. [60] for creating sustained valuable engagements with pervasive displays.

7.2.2 Navigating the Impact of Foot Traffic. While PID guidelines [97] recommend locating interactions in high-traffic entry-points, our findings diverge. After testing the entrance of 4 different locations at places with high and low traffic, our findings reveal that such placement can unintentionally induce 'display blindness' [61] and 'interaction blindness' [50]. This happens when individuals overlook or consciously avoid interactive displays due to habituation or perceived social pressure. High visibility led to discomfort and reduced engagement. In contrast, low-traffic settings supported relaxed and extended interactions, aligning with prior work [4, 50] that emphasized how social context and proxemics influence engagement more than visual salience alone.

7.2.3 Supporting Confidence and Intuitiveness. While 'designing for ambiguity' can be considered a 'value for design' [36, 48], it may discourage engagement, particularly with unfamiliar public interfaces. Although we designed the display front as a wide clear glass door with a knob, participants hesitated to interact with the MobileMuseum due to unclear cues. Our engraved instruction label on the glass door was not prominent; adding a coloured background did little to improve visibility. Designers should ensure affordances are legible and permissions to interact are explicit (e.g., a clear label stating "It's OK to Touch and Borrow").

7.2.4 Understanding Community Behaviours. Designing tangibles for public use is not a one-size-fits-all task. People's willingness to interact with shared artifacts can vary significantly across cultures, communities, and geographies. We acknowledge that our study was conducted in a country with an above-average heightened awareness around public health, where community-adopted lockdown practices persisted well beyond global averages. As a result, participants expressed more caution towards face-worn objects and shared surfaces. Such behaviours may not generalize to regions with different experiences but should be acknowledged as one of the social barriers to public display Use [95]. Researchers and designers should therefore engage in contextual inquiry to better understand the social norms [122], event practices [4], specific values, and concerns of their target communities. Accounting for local values and expectations is essential to ensure that tangible interfaces in public spaces are both culturally appropriate and socially acceptable.

7.2.5 Leveraging Social Circulation (The Honeybee Effect). Designers should anticipate that users in-the-wild will share their experiences by taking photos, posting online, returning with friends (talking with them about it), or initiating conversations with strangers (talking with strangers through it). Wearables worn in public may enable novel uses and social interactions in varied settings (e.g., different weather or social activities). Such patterns offer opportunities for designing for togetherness, cross-generational use, and extended community engagement. We call this the "Honeybee Effect" referring to when users guide others to an interactive element in space (similar to how bees guiding to nectar). This complements the "Honeypot Effect" [122] which describes attraction through visibility and social proof at the site itself. In contrast, the "Honeybee Effect" highlights peer-to-peer, off-site, or social media routing to points of interest. HCI can utilize

these opportunities (not only to recruit participants, but also) for crowd mobilizing, to unpack post-encounter stories, or generate insights from collective memory.

8 Conclusion

In this paper, we explored tangible museum experiences beyond digital media for off-site communities. Through the MobileMuseum, a portable interactive display, we conducted a replicable, independently monitored user study outside the lab. Our work extended prior research by enabling remote, screenless museum experiences that operate independently across locations, using self-monitored sensors to collect anonymous interaction data. Findings indicate that designing public tangible exhibits outside of museum walls must account for interaction patterns shaped by spatial arrangement, social context, and the type of tangibles' formfactor. From the *order effect* in linear interaction to the 'community behaviour' and concerns on wearables, our study reveals how deeply local public behaviors shape tangible engagement. Design opportunities emerging from this work include supporting open-ended interaction through unsupervised 'free play', leveraging peer-to-peer social circulation (the 'Honeybee Effect') to extend engagement beyond the site, and embedding passive sensing to capture nuanced in-the-wild usage. For HCI researchers, these insights offer guidance in crafting mobile tangible experiences that are not only engaging and intuitive, but also socially generative and culturally situated. This paper contributes a 2-months study with insights to expand access beyond traditional brick-and-mortar institutions, and their regular visitors, providing opportunities for engagement of potentially underserved communities.

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