Pop-Up Participatory Exhibitions: Combining Ideation, User Research, and Outreach in an Interactive Format

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Abstract

We present an exploratory reflection on the role of pop-up participatory exhibitions in the design process of an upstream technology. To involve the public in the design of novel projected user interfaces for tabletops, we combined ideas from design fiction, participatory design, and user-centered design with a pop-up science shop concept. The resulting approach aims to engage a broad audience in ideation, user research, and outreach via an exhibition of functional prototypes in a highly-frequented location. In four one-week exhibitions, over 400 visitors were guided through the exhibition in small groups and involved in small design and evaluation activities. Through ethnographic field research we gathered insights from different perspectives, ideas for new use cases and applications, and feedback on the presented prototypes. In this paper, we describe concept, methods, and properties of pop-up participatory exhibitions and their relation to other participatory approaches. We share our experiences, discuss design choices, and provide practical suggestions for implementing such exhibitions.

CCS Concepts

• **Human-centered computing** → **Field studies**; **Empirical studies in HCI**; *Interaction devices*; Mixed / augmented reality.

Keywords

participatory design, user-centered design, interactive tabletops, projected augmented reality, methods, pop-up science, exhibition

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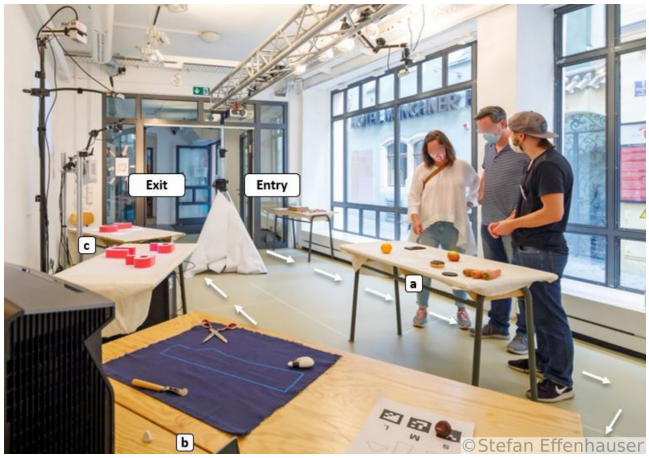

Figure 1: Pop-up exhibition space with three prototype setups illustrating different aspects of the envisioned system: a) object recognition and projected annotations (*Augmentation*), b) virtual tailor's workshop with projected cutting patterns (*Tool*), and c) remote connection between two tables via projected overlays (*Collaboration*). The large window front invites passers-by to enter the room. Participants are guided by a researcher along a predefined route.

1 Introduction

When developing novel interactive technologies and applications, it seems crucial to involve people who may be affected by them. This allows them to influence design decisions early on. The need for involving prospective users has been repeatedly pointed out in the long tradition of research on human-computer interaction (HCI) [27], user-centered design (UCD), and participatory design (PD) [22, 35]. Some scholars argue that participation in design processes is a democratic right [1, 38] . Frauenberger et al. argue that PD approaches that involve the general public are invaluable for disseminating and democratizing research, especially when it comes to challenging dominant patterns of technological futures [15].

Identifying and involving potential users is relatively straightforward when designing concrete solutions for well-understood contexts. It becomes much more difficult for abstract *upstream technologies* – emerging technologies with many application areas that have not yet reached mainstream adoption and thus have no clearly defined group of prospective users. But especially in these cases, it

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seems important to involve a broad sample of users and other stakeholders early in the design process to facilitate public discourse on the technology and critical reflection of its applications.
We faced this challenge in a research and engineering project that ran from 2019 to 2023. The project's technical goal was to develop a framework for interactive tabletops where tools and information are projected on the surfaces of ordinary tables and desks, turning Wellner's *DigitalDesk* concept [46] into an extensible ecosystem. The underlying vision was to design a generic digital tool which blends itself into everyday life and supports shared experiences instead of pulling people's attention into it.
Although we also conducted design workshops with selected participants, such as researchers, artists, designers, and technology enthusiasts, we wanted to incorporate ordinary users' perspectives and a broad sample of public attitudes into the development process and its discursive reflection. However, since such systems are currently neither in everyday use nor the topic of public discussion, there are no obvious current or prospective user groups that we could involve in the design process.
A similar problem exists in science communication: traditional museums only reach those who are already interested in the museums' offers, and not those who might learn the most from a visit [16, 23]. To address this problem, *pop-up science shops* have emerged as an additional means of science outreach in recent years: science exhibitions are temporarily set up in empty shops at highly-frequented places within cities in order to deliver science education to a wider audience [17, 28, 42].
In this paper we describe our experience with four one week-long pop-up science exhibitions which we used as platforms for a participatory and user-centered design process. In such *pop-up participatory exhibitions*, visitors learn about a specific topic while also actively and passively participating in the research and design process. Thus, pop-up participatory exhibitions inform the design and development process by creating a space for "collective 'reflection-in-action' " [37, p. 2] that supports the following goals:

- **ideation**: generating and discussing new application scenarios and use cases
- **user research**: learning more about users' attitudes and usability problems of our prototypes
- **outreach**: educating participants about technology and applications, enabling critical discussion of our concept, and building a network of participants and stakeholders for potential long-term involvement in the design process

The four exhibitions were set up in a gallery space in the old town of Regensburg (Germany) in Fall 2020, Fall 2021, Spring 2022 and Fall 2022. They comprised interactive prototypes (see Figure 2), a guided tour (see Figures 1 and 3) with semi-structured conversations, and a questionnaire. In these exhibitions, a total of over 400 visitors discussed applications, technical details, and social and ethical issues with us. To open up an exploratory space for reflection on and discussion of different layers of the project, we engaged with the visitors in small groups, covering a variety of topics, such as possible application scenarios, use cases and features, concerns of security and privacy as well as the motivations behind our research project and its broader social and ethical implications. At the same time, we observed and documented how visitors interacted with the prototypes. The data we gathered informed the further design of our system, but also our way of thinking about the technology. Conducting multiple exhibitions allowed us to evaluate and iterate both the exhibition and research concept, as well as the prototypes (e.g., to test different input methods).
In the following, we describe the general concept of pop-up participatory exhibitions and share our experiences with this format. This initial, exploratory work may help designers and researchers determine whether the approach is of use for their project and gives practical suggestions for designing similar events.
The paper is organized as follows: In Section 2, we give a quick overview of user-centered and participatory design, as well as pop-up science approaches. In Section 3, we suggest how these may be combined into pop-up participatory exhibitions. In Section 4, we describe the context of our exhibitions on interactive projected tabletops: the project context, the venue it took place in, the demonstrated prototypes of the four exhibition iterations, our presentation strategies, research methods, and participants.[1] Building on these descriptions, we present our observations on ideation, user research and outreach (Section 5) and our learnings on the exhibition format (Section 6). Finally, we discuss the strengths and limitations of our research and design approach (Section 7) and summarize our work (Section 8).

2 Related Work

In the following, we discuss previous research on upstream technologies, argue that existing participatory design and user-centered design approaches are not ideal for work on upstream technologies, and suggest that pop-up science formats may offer a useful environment for research on upstream technologies.

2.1 Upstream Technologies and Design Fiction

Upstream technologies are technologies that have not yet reached mainstream adoption but may become part of people's everyday lives sooner or later. Exploring upstream ideas before they become products or technologies allows designers to look into possible consequences before they happen [10]. Thus, it makes sense to facilitate public discourse on their applications and engage prospective users in their design.
However, most upstream technologies initially do not catch the public's attention because most people are not yet aware of their existence, arrival, or implications [24]. Broad public discussion of societal impacts often only occurs once the technology is already in use and causes controversy. Therefore, involving the public in the discussion and co-design of such upstream technologies requires externally triggered and organized processes [24].
Under the umbrella of *design fiction*, designers and researchers have explored potential futures involving upstream technologies. Design fiction, a term originally coined by Sterling [39] in 2005 and popularized by Bleecker [4] describes "the deliberate use of diegetic prototypes to suspend disbelief about change" [5]. These prototypes – be it videos, photos, physical objects, or environments – show or are artifacts of a fictional world. They allow people to better imagine that fictional world and discuss or explore how this

[1] Since the visitors of our exhibition became an integral part of the design process, we refer to them as participants instead of visitors in this paper.

world might look like. Economidou [12] gives a comprehensive overview of this space and describes a pop-up event for design fiction in human-building interaction.
In most cases, design fiction workshops are conducted with rather closed groups, such as domain experts [6, 21], local residents [33], or students [36].
Dunne & Raby suggest using design exhibitions as a vehicle for critical reflection about the underlying technology and its implications for individuals and society [10]. Björgvinsson et al. [2] describe participatory design projects in *living labs*.
In all of these instances, the participants are either selected by organizers or implicitly selected for by the venue they take place in. While design fiction offers methods for speculating about upstream technologies, it does not inherently target a broad public and rarely influences development of upstream technologies.

2.2 Technology Probes

The research prototypes we demonstrated in the exhibition are very similar to technology probes [20]. Like technology probes, they are working prototypes of an envisioned solution and partially support the three original goals of technology probes: collecting usage information, field-testing the technology, and inspiring users and designers. However, unlike technology probes, the research prototypes are not intended as standalone artifacts but are supported by in-person explanations and demonstrations, and participants only engage with them for a short time in an exhibition context. Therefore, the research prototypes don't need to be as polished and robust as technology probes. While the exhibition context facilitates interviews and discussions, the artificial setting is not representative of everyday use. Thus, pop-up participatory exhibitions complement technology probes and may be especially useful if the usage context for a technology is not yet well-defined.

2.3 User-Centered and Participatory Design

In human-computer interaction, there are two prevalent approaches for involving users in design processes: user-centered design (UCD) and participatory design (PD).
In UCD [32, 43] the primary role of the involved users is to provide designers or researchers with the knowledge these need so that they can develop good solutions or artifacts, e.g. systems, processes, or user interfaces. Users are involved in the design and evaluation of solutions at several points in the iterative process but rarely drive the process.
In contrast, the focus of PD is on co-designing solutions together with users, establishing bi-directional communication, fostering mutual learning, facilitating open discussion, and empowering participants [7, 30, 35, 37]. Current PD endeavors range from solving concrete problems or developing products to effecting social or political change [14]. PD encompasses a variety of methods such as co-design workshops, cooperative prototyping, focus groups, ethnographic methods, user studies, interviews, or living labs [30, 37, 47]. In principle, PD's toolbox seems particularly suited for investigating the societal impact of upstream technologies.
However, identifying the right group of participants for a PD process becomes more difficult the greater and more diverse the affected group of users is [37]. It is even more difficult to motivate people to participate in discussion and design of a rather abstract upstream technology as participants might not anticipate an immediate personal benefit from their participation.

2.4 Pop-up Science

The term pop-up science emerged in the 2010s to describe temporary science centers that are set up in empty shops [9, 40]. This allows science educators to bring their offerings into environments that are typically under-served, e.g. to low-income quarters of a city. As pop-up science centers are not physically tied to existing institutions, they offer a low barrier to entry. Researchers use different terms for these environments: "stores" [28] or "shops" [9, 40] or "centres" [17] or simply "encounters" [25]. One of the more prominent instances of such pop-up science centers are the *Knowledgerooms* in Vienna [17, 40]. These "temporarily offer science center activities in empty shops in underprivileged urban districts – anyone passing by could just walk in and start engaging" [40]. Streicher et al. report success in fostering social inclusion through pop-up science and suggest three important characteristics of successful pop-up science centers: they are easy to access, are regarded as trustworthy by the local communities, and are respectful of time and knowledge of visitors [40].
In the context of human-computer interaction, pop-up events have been sometimes used for outreach, design fiction formats, or in participatory design. However, in most cases, the events were one-off, single-purpose, and less than a day long. Economidou [12] gives a thorough overview and notes that it is surprising "how little the pop-up event format is used".

2.5 How does Pop-Up Science relate to UCD and PD?

Pop-up science shares a basic vision with UCD and PD: all three approaches try to empower people through engagement. However, they clearly differ in other aspects:
Participants. UCD and PD typically involve a well-defined group of participants [34] – e.g., a school class, workers in a factory, or prospective users of a product. In comparison, pop-up science caters to a dynamic, walk-up audience – typically individuals or small groups with heterogeneous backgrounds, knowledge, and goals.
Goals. UCD or PD processes traditionally aim for a concrete, shared outcome within a specific context – e.g., artifacts, solutions, or political change. Pop-up science has the more abstract goal of fostering interest in scientific concepts or methods in individuals. However, it may also aim to transfer specific scientific knowledge into a broad public or provide a platform for discussion [9, p. 9].
Motivation. In UCD and PD, participants are ideally affected by a concrete problem and intrinsically motivated to find a good solution. In pop-up science, participants usually are not directly affected by the generic scientific concepts conveyed. Pop-up science aims at reaching not only a highly-interested audience but also those with just a little bit of interest in the topics.
Roles. In UCD, professional researchers or designers drive the design process, only involving participants as knowledge sources and testers, not as designers. In contrast PD emphasizes collaborative design and learning whereby organizers and participants ideally work together as equal contributors. Knowledge transfer happens

continuously between all participants. In comparison, pop-up science typically focuses on uni-directional knowledge transfer. The organizers explain science to visitors and guide them in exploring new topics. Thus, there is a clear division of knowledge and roles between organizers and visitors of a pop-up science exhibition. [2]
In summary, the role of science educators in pop-up science shares some similarities with UCD (uni-directional knowledge transfer) and PD (empowering participants). Participant selection, their motivations, and the researchers' goals differ significantly between pop-up science, PD, and UCD.
These key differences don't make the approaches incompatible, however. Sometimes, the approaches overlap, e.g., when conducting participatory design in public spaces [45] or using pop-up science stores for fostering public discussion [9, p. 9].
We found that concepts from pop-up science, UCD, and PD can be combined into a coherent exhibition concept which supports research and reflection on upstream technologies for human-computer interaction.

3 Pop-up Participatory Exhibitions

As part of our research project, we set up *pop-up participatory exhibitions* - interactive short-term exhibitions of research prototypes. They combine ideas from UCD, PD, and pop-up science in order to engage a diverse public in science outreach, ideation, and user research.
Our approach has similarities to design fictions but uses the exhibition not only for reflecting on a vision but also for collaboratively and concretely improving this vision and concrete implementations. The concept can be characterized as follows:

- In order to reach a diverse group of participants, an exhibition of research prototypes is set up in an environment that is frequented by a sufficiently large and heterogeneous group of people. This could be e.g., a small store in a pedestrian area or a shopping mall.
- In order to make the abstract upstream technology sufficiently concrete, it is showcased via several demos with different degrees of abstraction that can be explored by participants.
- In order to involve participants in the design process, the organizers lead small groups through the exhibition and engage them in semi-structured conversations, giving them the opportunity to experience the technology and reflect on it. The guided tour offers a low barrier of entry and provides structure.
- By learning about a new technology, trying it out, and sharing their opinion about it, participants are engaged on an intellectual, physical, and personal level. Participating researchers need to reflect their design choices and explain their research in layman's terms.
- Participant's attitudes and interactions are documented and analyzed with qualitative and quantitative methods. This informs further research and outreach activities.

[2] Dowell mentions the possibility that organizers of a pop-up science store might learn from the participants (p. 67) and suggests in the book's conclusion that scientists could move from experiences 'for' audiences to making experiences 'with' audiences [9, p. 71].

This basic framework can be extended with further components, e.g. surveys, small usability studies, short ideation exercises, or recruitment for subsequent workshops.
In our experience, this format also fills a gap between laboratory studies and in-the-wild evaluations [18]. Compared to laboratory studies, the setting is more natural, an interaction is determined by participants' interests, offering better insights into real-life usability problems. Compared to in-the-wild evaluations, participants are already in a conversation with the researchers and thus can be asked about encountered problems, possible solutions as well as new ideas and opinions.
In the following sections we present our concrete, evolving implementations of the approach and the observations we made in the process.

4 Four Pop-Up Participatory Exhibitions on Interactive Projected Tabletops

4.1 Context

In the underlying research project, we wanted to find out how physical (inter-)actions at and around tables may be supported and enriched by projecting interactive content onto a tabletop. We developed a projected augmented reality (PAR) system for tabletops which integrates personal digital devices and multiple table surfaces. Building on this technical foundation, we aimed to develop interaction techniques as well as digital tools to support common activities on and around tables. To this end, we investigated how people use tables in everyday life. The primary research methods we initially employed were online questionnaires and design workshops. To complement these methods, we presented our prototypes in four public pop-up exhibitions in September 2020, September 2021, March 2022 and October 2022. In the following, we describe the venue, demonstrations (prototypes per exhibition iteration, selection and order) and presentation mode of the exhibitions.

4.2 Venue

Each exhibition took place over the course of one week in a cultural and creative center in the old town of Regensburg (Germany). The exhibition space (~40m²) has a large window front that faces towards a small alley connecting two large squares in the pedestrian area. This alley is frequented by residents, shoppers, and tourists strolling through the city. As Dowell mentions, semi-public spaces like this work especially well for science communication endeavors, since their "rules and conventions are intuitively understood [...]. We know that we are allowed to gaze at the window displays, walk through the door [...] and leave when our interest is spent" [9, p. 7]. People passing by the window front would stop for a moment, peek inside, read one of the posters advertising the exhibition, and come in if they were interested.
We opened our exhibitions on five to six days with opening hours from midday (12 pm / 2 pm) to evening (7 pm) on workdays and from morning (10 am) to evening (7 pm) on Saturdays. Sundays were reserved for tearing down the exhibition again. As expected, most participants came to the exhibitions on Saturdays (see Table 1). During the week the peak was usually at 4 pm. Overall, 435 people visited the four exhibitions.

Table 1: Participant numbers by day of the week for iteration 1 to 4. Due to low visitor numbers on Mondays, we opened our exhibition for iterations 3 and 4 on Tuesday.

Exhibition	Mon (Ø/h)	Tue (Ø/h)	Wed (Ø/h)	Thu (Ø/h)	Fri (Ø/h)	Sat (Ø/h)	overall
Iteration 1 (Fall 2020)	7 (2.33)	13 (1.86)	18 (2.57)	13 (1.86)	14 (2)	38 (4.2)	103
Iteration 2 (Fall 2021)	5 (1.6)	9 (2.25)	27 (5.4)	12 (2.4)	26 (3.7)	32 (4.5)	111
Iteration 3 (Spring 2022)	–	7 (1)	24 (3.4)	30 (4.3)	27 (3.9)	64 (7.1)	140
Iteration 4 (Fall 2022)	–	13 (1.85)	19 (2,71)	18 (2.57)	10 (1.43)	21 (2.33)	81

4.3 Demonstrations

In the exhibition, we showcased three to four hardware/software prototypes developed for demonstrating core aspects of the research project (Figure 2). The prototypes illustrated different application scenarios ranging from rather concrete use cases to more abstract representations of possibilities. We refined and exchanged the prototypes from one exhibition to the next, showing new snapshots of our research each time.

All prototypes used a similar setup consisting of a video projector (3840x2160 px or 1920x1080 px), a depth camera (Intel Realsense D435 or Microsoft Azure Kinect), and custom software developed within the research project. For the projected graphics and text, we opted for thick white lines. The simple design language focused discussion on concepts instead of graphical details and ensured good visibility in daylight conditions.

4.3.1 First Iteration (Fall 2020). The first prototype (***Augmentation***, Figure 2a) served as an introduction to the concept of augmented tabletops. Participants were led to an empty table and asked to put different food items lying on a nearby table onto the tabletop. For each item placed on the table, an outline and nutritional values were projected, similar to previous work by Echtler and Wimmer [11]. When participants placed a mobile phone on the table, a mock-up screen extension was projected next to the device, containing a digital clock, message notifications and a photo.

The goal here was to introduce the general concept and convey how the semi-public projection sphere of the tabletop could make information on personal devices available for social interaction and shared experiences. The level of interaction here was low, but participants were able to explore the scenarios on their own. Most of them quickly discovered the projector and camera mounted above the tabletop.

The second prototype (***Tool***, Figure 2b) introduced a concrete, practical use case: transferring a cutting pattern to a piece of fabric. A piece of fabric, some tailoring tools, a sheet of paper with optical markers, and multiple *tangibles* – wooden blocks with optical markers – were lying on the table. Participants could move, scale, and rotate a projected cutting pattern by manipulating the paper proxy. By placing a certain tangible on the table, the *rewind* feature was activated, and a timeline appeared on the surface. Moving the tangible along the projected timeline, participants could scroll through a video recording of the table's contents and replay the actions that had just been performed on the table. The goal here was to introduce participants to the concept of digital tools that may interactively align with the surface or objects on the surface, and thus may be used to facilitate and augment a variety of actions performed at tables.

The third prototype (***Collaboration***, Figure 2c) consisted of two separate tables that were virtually linked to each other so that the objects on one of them could be projected onto the other and vice versa. The depth camera allowed to segment objects on the table, removing the background, so that only these would be projected onto the other tabletop instead of the whole camera image. Both tables had big cardboard letters on them to play around with. This way, participants could visually and haptically experience the coexistence of physical and digitally augmented objects on the surface. The goal here was to illustrate possible remote collaboration scenarios. While the two tables could have been placed at opposite ends of the room, we intentionally positioned them right next to each other so that participants could immediately and directly experience the link between the tables. This setup was the most abstract, generic and playful.

4.3.2 Second Iteration (Fall 2021). Participants started again with the ***Augmentation/Interaction*** prototype (Figure 2e), an empty table onto which they could place various fruits. However, instead of nutritional values, the table now presented the names of the recognized food items in four different languages next to them. Another demonstration at the first table allowed participants to annotate a paper document using a laser pointer as a pen. These annotations were continuously integrated into a digital PDF version of the document shown on a nearby screen. Using the laser pointer, participants could also leave messages to other visitors by writing or drawing on the table.

The second prototype (***Guidance***, Figure 2d) was provided by a partner in the project and projected step-by-step building instructions onto a Lego brick house. Participants could navigate the instructions by touching projected arrows on the table. The goal here was to show how a table might support simple assembly tasks by step-by-step instructions and using touch input for interaction. The prototype also illustrated the enrichment of objects by projecting content onto these objects and contextual information next to them. For the third and final demonstration, we re-used the ***Tool*** prototype from the previous year, which had been improved slightly (Figure 2b).

4.3.3 Third Iteration (Spring 2022). As before, we started with an ***Augmentation*** prototype. Participantrs were presented an initially empty table and asked how they would intuitively start it. After hearing their ideas, we handed them various small objects (such as a plastic flower, car, dog, wood) which they could use to trigger simple actions. For example, an object could virtually catch fire, and a toy fire engine could be placed next to it to extinguish the fire. This prototype was provided by a project partner.

Figure 2: We presented three to four prototypes of interactive tabletops with projected augmentations in every exhibition. *a. Augmentation*: projecting additional information next to placed items (iteration 1), *b. Tool*: transferring a cutting pattern to a piece of fabric (iteration 4), *c. Collaboration*: projecting one table surface onto the other (iteration 4), *d. Guidance*: projecting step-by-step building instructions onto a Lego brick house (iteration 2), *e. Interaction* via laser pointer: annotating a paper document and the table surface (iteration 2), *f. Interaction* via IR pen: drawing on the table surface (iteration 4).

At the second prototype (***Sketchable Interaction***), participants could use a laser pointer to interact with virtual items on the table, draw something, annotate a physical document, take a screenshot, or remove objects. Our goal here was not to evaluate a user interface but to field-test a new framework for interactive surfaces.
The third prototype was an extension of the ***Collaboration*** prototype: three tables were connected via virtual overlays. Two of them were set up in the exhibition space and one remotely in a cafeteria at Aalborg University in Denmark. Physical objects were distributed on the tables and could be moved by participants. The objects on each table and the arms of participants were projected onto the tabletops of the other two tables. Our goal here was to hear what people thought about this type of remote telepresence.

4.3.4 Fourth Iteration (Fall 2022). In our final exhibition, we replaced the laser pointer used in the previous exhibitions with a pen that allowed participants to virtually draw onto the tabletop [29]. The pen's tip emitted infrared light and was tracked using two cameras. A very low end-to-end latency created the illusion that the virtual ink directly emanated from the pen tip.
Again, participants started their tour at an empty table. We handed them the pen and told them to "do what you normally do with a pen" (Figure 2f). The goal was to introduce participants to the concept of interactive tables and to explore the idea of a table as a truly interactive surface in a playful-creative, yet practical, way.
At the second prototype, participants were able to explore the ***Sketchable Interaction*** system using a pen. They could draw shapes with different functions (e.g. mail inbox, file preview, file tagging, conveyor belt) and drag documents onto these shapes to trigger actions. The goal here was to discuss what participants expected from user-definable desktop environments.

The third and fourth demonstrations were slightly improved versions of the ***Tool*** prototype (Figure 2b) and the ***Collaboration*** prototype (Figure 2c). The main goal here was to showcase the most interesting demonstrations of the previous three exhibitions.

4.3.5 Selection and Evolution of Prototypes for Demonstration. The selection of prototypes was mostly pragmatic and determined by developments within the research project. The *Tool* and *Collaboration* prototypes had been developed early in the project. They were adapted and refined several times in order to be showcased to the public and at the iterations of the exhibition. The idea for the *Tool* prototype was conceived in discussions with handcrafters early on in the project. The *Collaboration* prototype was motivated by an example scenario from the grant application for the research project. Both prototypes differed greatly in regard to their level of abstraction, with the interlinked tables of the *Collaboration* prototype depicting a rather abstract illustration of possibilities, whereas the *Tool* prototype showed a very concrete, practical use case and its technological feasibility.
With the *Augmentation* prototype, custom-developed for the first exhibition, we intended to fill a gap between the other prototypes and offer a playful first impression. It, too, depicted a more abstract and generic concept of interactive tables but, through the use of food items as artifacts for object recognition, still hinted at the scenario of food consumption, which represents a central domain of everyday life we could be sure all participants were familiar with in some way.
A different *Augmentation* prototype focusing on *Tangible Interaction* with plastic bricks was presented in the third iteration. This

prototype as well as the *Guidance* prototype (iteration 2) was contributed by our project partners. For this collaboration, the exhibitions served as binding milestones for all partners to bring their prototypes into a presentable state. The *Sketchable Interaction* prototype exhibited in the third and fourth iteration was created by merging our interactive table hardware and a software framework developed by another PhD student in our research group. This allowed them to get feedback on their user interface. The prototype also demonstrated how interactive tabletops could be used for office work – a context not explicitly touched by the other prototypes.
Technical shortcomings of developed solutions also shaped our ongoing research as we iteratively improved the presented prototypes. As we found touch (*Guidance*, iteration 2) and laser pointer input (*Annotation*, iteration 2 and *Sketchable Interaction*, iteration 3) to be inadequate for interaction on the tabletop, we developed an IR-light-emitting pen to allow more precise input and intuitive handling [29]. The resulting device was evaluated in the last exhibition.
For some prototypes, we were able to give different interactions a try or develop them further by exhibiting them several times (e.g. laser pointer vs. pen or sliding vs. rotating the tangible for the rewind feature). Overall, we used the exhibitions to evaluate various interaction practices within a framework of scenarios, which we developed further based on participant feedback.

4.3.6 Order of demonstrated Prototypes. The order in which we presented the prototypes was determined by multiple considerations and external factors. The first table's surface was always initially empty, and no information was projected on it. As most of our participants had no or only a partial understanding of what an interactive table could be, we gave them the chance to figure it out by themselves. This allowed the guide to introduce the exhibition without participants being distracted by objects or projections. By starting with a simple interaction and application, we intended to allow the participants to understand the technology and ask questions about it. This included in particular the fundamental aspects of the interactive enrichment of table surfaces and objects with digital information content, the recognition of objects and interaction with and through physical objects (tangibles). The second prototype (*Tool*, *Guidance*, or *Sketchable Interaction*) then featured a more concrete, complex and interactive application. Due to the more complex user interface, the guide first had to explain the usage. The final prototype (*Collaboration*) again offered a more abstract, open, playful experience that required little explanation. It allowed two or more participants to simultaneously interact with it and through it. Putting this prototype at the end of the guided tour created an open end where participants could choose how much longer they wanted to stay and how much they wanted to deepen the conversation with the guide.

4.4 Presentation

For our first exhibition in Fall 2020, COVID-19-related hygiene regulations restricted the maximum occupancy of the room to five persons at the same time, including our staff. Participants were required to write down their contact information, wear masks, and disinfect their hands before entering the space. This significantly affected how participants could experience the exhibition: Instead of just providing an open space where people could walk in and play around with the exhibits, we conducted guided tours and had semi-structured conversations with small groups of participants at a time (Figures 1 and 3). In order to minimize contact between groups of participants, we defined a one-way route through the exhibition space (Figure 1). To our surprise, this led to an exciting format for the exhibition and produced interesting results for our field research – so we kept many aspects of the presentation from the first iteration for the following ones.

Figure 3: A researcher (right) guides a participant to explore an interactive table prototype. Another researcher (left) takes field notes on the observed interaction.

In the course of the first exhibition, discussions with participants initially developed rather slowly. Therefore, we developed detailed presentation guidelines. We built on these guidelines in preparation for the following exhibitions, discussed them in the team, and required all researchers to familiarize themselves with the guidelines. The guided tour script was not intended as an attempt to convince participants of the idea of interactive tables, but rather to offer them space for their own reflection, criticism and engagement with the subject matter.
A sign at the entrance informed the participants that photos and videos might be taken in the exhibition. Participants were welcomed at the entrance and in case of first visit given a brief overview of "who we are" and the research project on interactive tables. Furthermore, the presentation guidelines contained information on each prototype with its initial state and the planned start of the interaction or the invitation to freely explore. Explanations of the functionality and technical background were provided, as well as key aspects of the interaction to highlight. The guidelines also contained impulses for questions or reflection. An outro concluded the tour with a final question about the concept of interactive tables, space to reflect the experience of the exhibition and a request for feedback. Over the course of the iterations of the exhibition, we continuously developed these guidelines further, including tips for conducting interviews and a list of frequently asked questions and answers. [3]

[3] See digital supplement for an example of the presentation guidelines (third iteration).

The tours took around 20-30 minutes on average but could take anywhere from ten minutes to over an hour, depending on the participants' interest, how much time they had available and whether the next participants were already waiting for their tour or not.
Beyond the mere presentation of the prototypes, we wanted to create a meeting space in which developers, ethnographers and participants could be on eye level. We wanted to enter into an active dialog with the participants and make the prototypes tangible. It was important to us that the participants were able to explore our prototypes and that the conversation could develop within the group. We implemented this by designing our presentation guidelines to be as open as possible and with plenty of opportunities for free interaction and feedback. Understanding the guidelines only as outline and reacting to the situational context as required was central to the implementation of the guided tours.

4.5 Research Methods

The exhibition served three main purposes: developing and discussing new application scenarios and use cases together with the participants (ideation), finding out more about public attitudes and requirements of prospective users (user research), and establishing a dialogue between researchers and public (outreach). To this end, we focused on gathering qualitative data and combined methods of varying openness: (participant) observation, semi-structured conversations, and a questionnaire. [4] With the (participant) observation of semi-structured conversations, we apply methods of ethnographic field research that are also used (but less common) in HCI [3, 27]. Through (participant) observation of a human group, a "rich description of activities, interactions, beliefs, roles, and goals" can be obtained [27, p. 263]. The semi-structured conversations helped us to steer the focus of the conversation and interaction, contextualize the observations and to create a similar starting point for all participants. In the questionnaire, participants were able to give us anonymous feedback on the exhibition and the prototypes, and demographic and contact details could be requested.
Our team consisted of four to five researchers who took turns throughout the week. Whenever more than one researcher was present, one took the role of guide and the other(s) quietly observed the ongoing interaction and documented their observations (Figure 3). If there was only one researcher present, they had to write down their experiences and participant observations from memory after the guided tour was over.
Via the **observation**, we unobtrusively gained data on how participants interacted with and perceived the prototypes and how conversations dynamics unfolded. The **semi-structured conversations** also took place during the guided tours, following the presentation guidelines. In these guidelines, we set out how participants were prompted to interact and ideate. Through the conversations, we gained data on ideas regarding possible application scenarios and use cases, opinions on presented scenarios and the project itself, as well as on the technical configuration and broader sociocultural and ethical context of the project. We documented the observations and conversations in structured field notes. Therefore, we created a template every team member could use – this template also reflects what aspects we focused on. As these aspects of interest were clearly defined while planning the exhibition, the observation notes were structured and systematic [3, p. 37]. The template was organized as a table in which the field notes were recorded per day for each guided tour. In the first iteration of the exhibition, there was a field for participant information (family/couple/..., profession) and fields for application ideas and positive and negative feedback for each prototype. For the second iteration, we revised the template and formalized the field notes more. We noted who led the tour, who took the notes, when the tour began and ended, how big the guided group was and the participants' professions. For each prototype, there were fields for ideas for use cases and scenarios, interaction aspects, reflections and problems. The observer was instructed not to see these aspects as necessarily distinct, and to understand the template as a guideline for taking notes. Because the aspects turned out to be less clear-cut, the template for the third and fourth iteration only contained fields for interaction and reflection for each prototype. The template also contained a field for general observations on the conversational situation during the tour and for other comments.
After the guided tour, participants were given the option to fill out a **questionnaire** (online or printed) with open-ended and closed-ended questions on demographic information (age and profession), feedback on the guided tour, the project and the prototypes and contact information for establishing a network for future collaborations. The questionnaire contained a declaration of consent; the participants were informed that their data would be stored anonymously and used in aggregated form for further research purposes. Contact information was stored separately from responses. We reflect on ethical considerations in the *Discussion* section.
Our choice of methods was mainly informed by three factors: they were suitable for participants with different backgrounds, they could be applied within the limited amount of time that participants were expected to spend in the exhibition, and team members had experience applying them to similar projects before. We also benefited greatly from the interdisciplinary composition of our team: the HCI researchers understood the technical background of the system and key aspects of human-technology interaction, whereas the ethnographers had experience in designing exhibitions and conducting field research.
For the qualitative data analysis after the event, we took an inductive approach. Thus, through detailed reading and iterative coding, categories for structuring the findings emerged. We gained data relevant for many different layers of our research, such as ideas for possible use cases, specific features, application scenarios, constraints as well as doubts, fears and things people are (not) ok with. These findings were incorporated into the further development of our exhibition and research concept (e.g. in the presentation guidelines and the field note template) as well as in our prototypes (e.g. various interaction modes from tangible objects and touch to laser pointer and pen).

4.6 Participants

Of the 435 participants, 190 filled out the short questionnaire at the end of their tour.

[4] See digital supplements for examples of the field note template for observations, the presentation guidelines for the semi-structured conversation and the questionnaire (third iteration).

We did not want to address a specific target audience with these exhibitions. Instead, our goal was to attract as many people with as different backgrounds as possible. Nevertheless, we anticipated that the choice of venue might influence the selection of participants. The venue serves as a cultural and creative center, so it primarily attracts a younger audience, consisting of creative professionals, artists, and students. The demographic data from the questionnaire shows that the majority of participants to all exhibitions were under the age of 35 (see Table 2).

Table 2: Age and gender of participants and their motivation for the visit (data based on questionnaire).

Participants	Iteration 1	Iteration 2	Iteration 3	Iteration 4
overall	50	47	70	23
u18	1	–	6	1
18-25	14	19	17	9
26-35	18	13	26	9
36-45	2	7	4	–
46-55	5	3	9	1
56-65	8	4	7	2
a65	2	–	1	1
Gender (f/m)	–	20/26	32/36	–
What motivated you to visit?				
Friends	12	17	23	2
Walk-in	33	19	28	4
Flyer/Poster	4	3	9	–
Social Media	2	–	4	1

We advertised the events on different channels, including our project website, social media, flyers, posters and invitations sent out to our existing network of previous workshop participants as well as other mailing lists. However, only 19% of questionnaire respondents came because of our advertising; most had heard about the event from friends or acquaintances, or were walk-in participants who spontaneously decided to enter the exhibition when passing by the window front (see Table 2). While participants worked in a variety of professions, such as engineering, media design, journalism or healthcare, many of the respondents were students (30% in the first exhibition, 43% in the second, 41% in the third) or worked in education (16%, 11%, 6%). Thus, academics were overrepresented among the participants compared to the general population.

While families with small children actually made up a significant proportion of all participants, they are underrepresented in the questionnaire responses because usually only one parent filled out the questionnaire, and oftentimes parents did not have time to fill out the questionnaire at all.

We did not collect potentially sensitive information about ethnicity, education, or social status.

5 Observations

In the following we summarize and illustrate the findings from observations, semi-structured conversations and the questionnaire in regard to ideation, user research and outreach. In addition to more abstract findings, the results of the evaluation will be illustrated using the example of the *Augmentation/Annotation* prototype from the second iteration.

For the qualitative data analysis after the event, we took an inductive approach of iterative coding. We analyzed the data by prototype and developed categories for results on interaction aspects, ideas for application scenarios and the further development of features. Just as we formalized the field notes and our observation mode over the course of the iterations, we also optimized the qualitative data analysis. For example, we used tables to sort and code data for the evaluation of the first iteration and specific software[5] for a more structured and transparent qualitative data analysis from the second iteration onward.

5.1 Ideation

We identified participants' ideas by coding our field notes; this included responses to the question about ideas for further applications, as well as comments along the lines of "that would be cool" or "maybe we could use it for..." or questions such as "could you also use it like...?" Since the ideas unfolded as part of a conversational dynamic between researcher and participant/group, ideas could not always be attributed to individual participants and some ideas might have been lost or slightly misrepresented in our notes. The identified ideas represent a wide variety of possible new application scenarios and use cases in all four iterations of our exhibition. These consist of a mixture of concrete use cases ("enter the dimensions of furniture in your living space in order to move them around in a house planning environment") and scenarios ("support work of architects") as well as abstract possible features of an interactive table ("expand desktop screen" or "error tracking").

The ideas were highly influenced by the participants' personal backgrounds, everyday life experiences, and interests. For example, in the first iteration at the *Augmentation* prototype, a participant told us how tracking their inventory, such as wine bottles or dishes, could make checking the inventory much more efficient. A pensioner mentioned the possibility to enable and improve communication between deaf people and people not speaking sign languages. A dental technician suggested a scenario for her workplace where customers' files on the desk would be automatically recognized and projected onto the tabletop so that they could work with them and digitally sign them.

Comparing the ideas of the participants from the first and the second exhibition, it becomes clear that the design of the informative content had a strong influence on the ideas expressed. In both iterations the first demonstration required participants to place fruit on the table. In the first iteration the table then displayed nutritional information. Accordingly, the most frequently mentioned ideas related thematically to the context of food and food preparation. In the second iteration the table displayed the name of each fruit in different languages instead. Accordingly, the most frequently mentioned ideas were in the context of teaching and learning as well as presenting and sharing content/results.

In the process of iteratively coding the gathered data, categorizing the ideas for application scenarios and use cases of the *Augmentation/Annotation* prototype in the second iteration resulted in the

[5] Qualitative Data Analysis tool MAXQDA: https://www.maxqda.com/

following supercategories: Learning and teaching (22 mentions), presenting and sharing content/results (17), kitchen and cooking (8), support for building and crafting (7), displaying and editing texts (7), support for impairments (6), support in medicine (6), sketching, painting and drawing (5), gastronomy (5), collaborative document editing (4), games (4), product recognition (4), display information on products (4), scan function (3), digitizing notes (2), sports (2), use of interactive tables for exhibitions (2), displaying information on tools (2), recognition of people at the table (2).
We used the ideas gathered during the exhibition in further brainstorming sessions within the project and created a list of all gathered ideas within the project on the project homepage.[6]

5.2 User Research

The semi-structured conversations, questionnaire, and observations also enabled us to better understand participants' attitudes towards interactive tables, how our design choices affected their interaction with the prototypes, and how to improve the usability of our implementations. We also gained insights into ratings and requests for possible features of our prototypes.
For example, for the *Augmentation/Annotation* prototype in the second iteration, we gained insights into its particular suitability for children (5 mentions) and for playful learning (5); we learned of participants' desire for an undo feature (8) and a more precise input method than the laser pointer (3) and were made aware of a perceived lack of added value compared to displays and tablets (2). With regard to participant interaction, a key observation was documented in the field notes: participants often interacted playfully with the system while exploring the prototype and testing its behavior (14). In addition to using the tangibles, participants attempted touch input (4), wanted to have their own objects recognized (1), and had to learn how to use the laser pointer to interact (e.g. ideal distance to the tabletop, recognizing the drawing surface, lack of precision).
The problems encountered with user interaction in the second iteration with laser pointer (*Augmentation/Annotation*) and touch (*Guidance*) led us to deepen these insights in the third iteration (*Sketchable Interaction*, input via laser pointer) and to the development of the IR-light-emitting pen as a new interaction technology (presented in the fourth iteration).
In addition to observing the participants, we used the semi-structured conversations and questionnaires in the exhibitions to ask questions about specific aspects that had caught our attention in the previous iteration. For example, in the second iteration, we added questions on the evaluation of the exhibition concept, privacy concerns[7] and evaluated the field notes for feedback on the concept of interactive tables; in the third iteration, we paid particular attention to the aspect of launching the table and interaction device/mode (touch, tangibles, pen, gestures, combinations of it, etc.).

[6]List of use cases and application scenarios for interactive tables: https://hci.ur.de/projects/vigitia/use_cases
[7]In the first iteration's questionnaire, we asked a question about participants' concerns. 22 out of 50 respondents mentioned data security as one of their main concerns related to the use of interactive tables. However, they rarely explained what specific concerns they had in this context. We therefore asked about this in more detail in the second iteration's questionnaire.

5.3 Outreach

The third main goal we pursued with the exhibitions was showcasing our research to the public and establishing new communication channels with participants.
According to the questionnaire of the first/second/third/fourth iteration, 86% / 43% / 53% / 60% of respondents had not experienced interactive tabletops so far; in the first iteration for 58% this concept was entirely unknown. In the second/third/fourth iteration, 21% / 12% / 12% of the respondents already had personal contact with interactive tables and 21% / 30% / 26% had already heard of interactive tables. From this data it is clear that the majority of participants got in touch with the upstream technology for the first time in our exhibition. The questionnaire data also shows that some participants have visited several iterations of our exhibition and thus followed the development of our ideas and prototypes (2 persons in the second iteration; 4 in the third; 2 in the fourth).
83% of respondents who offered feedback on the first iteration were very positive ("very good", "very interesting", "very nice", "innovative!"); some suggested minor improvements. None of the responses contained negative feedback. One person suggested that we should set up our exhibition at their venue, too. To us, this suggests that the first exhibition at least reached the goal of getting people interested in our research and discussing the societal impacts of design decisions with them. The overall very positive feedback on all exhibitions strengthens our resolve to bring science to the public outside the university in this kind of exhibition format. We experienced that the participants came into contact with our prototypes and the research project in a playful way and almost everyone got involved with the topic and the exploration. As we had no way of following up with most of the participants, we do not know whether the visit of the exhibition had a lasting effect.

6 Learnings

As the four exhibitions were our first attempts to combine science communication with participatory design elements, we observed, documented and reflected on our experiences with the format. In the following, we discuss the most important meta-observations with focus on a) how participants interacted with the exhibition and b) how our design decisions and external factors influenced these interactions and our observations.

6.1 Participant (Self-)Selection

The primary reason for setting up a pop-up exhibition is to reach new, diverse audiences. Interviews and questionnaires allowed us to reflect on the question of who was there and why – and in turn, who were the non-participants and how did our decisions shape the audience?
The well-frequented location in the city center seems to have been a good choice, as the majority of participants found the exhibition by accident. However, it also defined who would visit the exhibition. On one hand, location and format allowed access to a variety of people who would probably not take part in more formal formats at a museum or university. For example, the interactive exhibition allowed us to initiate conversations with whole families, a group of users that is rarely present at typical design workshops or focus groups. On the other hand, format and location made it harder to

reach out to other groups of potential users. While, for example, we had participants from all age groups, only a few elderly people entered the exhibition. We can only make informed guesses about the underlying reasons. However, it seems clear that even an inviting walk-in pop-up shop selects for a certain group of participants, e.g. people who are curious about the exhibition's topic, have free time during the day, and frequent the location of the exhibition. Therefore, it is necessary to reflect about which groups of people one is willing to exclude and how to reach those who should be included.

6.2 Participatory-ness

Another goal for us was to not only showcase research but also to use this opportunity to initiate participatory design and evaluation processes. The semi-structured conversations gave participants the chance to explicitly shape the direction of the research project and the applications to be developed – within the scope of our time and staff resources. However, conversations lasted only a few dozen minutes at most. The distinct roles of guide and participant remained, as there was little time to blur these roles, e.g. to make participants active moderators of the conversation. Thus, we think that this format cannot replace deeper, more intimate methods. Instead it may give initial guidance, serve to initiate conversations and facilitate follow-up events that can be considered and further developed as part of a *learning network of social actors* [14]. Conversations and demonstrations established a relationship between participants and the research project, serving as a first step towards including them in future events and motivate some of them to visit the next exhibitions. For example, several participants actively suggested collaborations or asked to be involved in further design workshops. Furthermore, the short interactions with a diverse set of people gave us many chances to reflect on interaction dynamics, priorities, and our methodological approach. This allowed us to iteratively and rapidly improve how we approach these interactions and served as a foundation for further developing the general concept and research methodology over the various iterations.

6.3 Communicative engagement

In everyday academic work contexts we are rarely forced to explain the motivations and underlying assumptions of our research to people other than colleagues or students. Conversations with these are based on shared knowledge and a general understanding of research practices. Presenting an abstract concept to people without similar knowledge required us to refine how we think and talk about our research. Although we planned our first exhibition knowing which issues we wanted to explore and discuss with the participants, our first conversations with them were not as prolific as expected. In the beginning, we engaged in conversations rather spontaneously which led to them being quite short and stiff, not providing enough room to address the various issues we aimed to discuss. Therefore, we developed open and situationally adjustable presentation and communication guidelines for all involved researchers covering the following topics:

- Motivational and institutional context of our project
- Underlying intentions of the pop-up participatory exhibition
- A small and open introduction and conclusion for the presentation of each prototype
- Open questions to stimulate the participants to verbally express their opinions, attitudes, ideas, doubts, fears, etc.
- Explicit reflections on the sociocultural, ethical, political implications of digital technologies

Furthermore, this process gave rise to internal discussions about how to avoid influencing the semi-structured conversations too much with our questions and explanations. For example, if we explain excitedly why our technical solution is better than existing alternatives, we create narratives carrying discursive power, influencing participants' reactions and thus our data. Since this cannot be fully avoided, we opted to document the situational and argumentational context of the conversations in more detail. Thus, drawing from cultural anthropology, we aimed at a "thick reflexive inquiry" [31, p. 2] that allowed us to consider the researcher's partaking in the joint meaning-making process and situational dynamics of communicative engagement. This necessary reflection also fostered a mutual learning experience and interdisciplinary exchange about research methods as well as motives driving our research within the team of HCI researchers and ethnographers. We tried to make the reflection process active and iterative as part of our exhibition planning and let it guide us through all iterations.

6.4 Group Size

Due to COVID-19-related hygiene regulations, in the first exhibition, the maximum occupancy of the room was limited to five persons at the same time. For this reason, the guided tours were conducted with very small groups, almost always consisting only of people knowing each other comparably well, such as families, couples, or groups of friends.

While we initially worried about the lower throughput of participants, we found that this restriction supported our goals very well. This is why we continued to stay with small groups of people knowing each other in the follow-up iterations despite an easing of the regulations. The semi-structured conversations benefited greatly from the intimate and open atmosphere in those small groups. We experienced this as an advantage over other formats, such as focus groups or design workshops, where participants mostly do not have any previous knowledge of each other, or where power negotiations and conflicts between participants emerge. Moreover, it was much easier for us to adjust to the organic conversation style already established between the members of the small groups and to customize the topics discussed according to their interests. As the groups usually already had established communication protocols, they often carried the conversations themselves, allowing us to switch from narrator to observer and observe the internal communication dynamics. In the questionnaire, several participants explicitly mentioned the personal atmosphere within the individual guided tours as a very positive experience.

Given these positive experiences, we would not suggest modifying the format to increase participant throughput. Making the groups larger would make semi-structured conversations harder and less easily adaptable to the individual groups. Letting participants explore the exhibition on their own would lead to less engagement and less opportunities for ideation and user research. As became

clear in the course of the second iteration (without hygiene regulations), multiple tours in parallel requires significantly more staff and coordination. Further factors to be taken into account are, e.g., room size, number and size of prototypes, or ambient noise and noise generated by participants and prototypes.

6.5 Artifacts as mediators

How participants interacted with the individual prototypes was influenced by whether a prototype depicted a concrete use case or a more illustrative and abstract representation of possibilities.
The *Augmentation* prototype, for example, allowed the participants to freely experience the technological possibilities and implications of interactive tabletops. As the table itself was unmodified, initially empty, and the projection setup was mounted on the ceiling, participants oftentimes did not notice the setup at the beginning. When the guide then handed them fruit or a tangible and asked them to place them on the tabletop, the participants were made active drivers of the subsequent demonstration instead of just onlookers. In contrast, with its more concrete, complex and interactive application, the *Tool* prototype had to be explained by the guide first, before participants explored it themselves. Thus, they seemed to feel more inclined to follow the guide's explanation like an instruction instead of playfully trying it out themselves. This resulted in more detailed and focused feedback on possible use cases similar to the presented one. However, when participants were shown a second application featured by the *Tool* prototype – scrolling through a video replay of their previous interactions on the table via a tangible – they not only experienced a second tool. Seeing a video of themselves interacting with the prototype allowed for a shared reflection of the interaction they had just been a part of. This, again, resulted in more abstract feedback. Placing this prototype at the beginning of the tour would have changed both the focus of the following conversations and the way participants tested the prototypes. The *Collaboration* prototype, on the other hand, represented the most abstract illustration of the technology, affording an open and playful experience. We could, for example, observe people playfully arranging the big cardboard letters on the tables, forming words with them or putting them on top of each other using them like building blocks. This worked especially well for groups that could split up between the two interlinked tables and virtually interact with each other. All in all, we found that this sparked the imagination of the participants very well and also marked an open end of the tour which then sometimes resulted in further conversations shifting from ideation to more general reflections on topics, such as the role of digital technologies and infrastructures in society, or how to involve the public in scientific research endeavors.
The *Guidance* prototype shown in the second exhibition only offered step-by-step building instructions and left little room for exploration. Nevertheless, many participants felt obligated to finish the simple Lego model before advancing to the next demonstration. We would not suggest including such demonstrations unless necessary.
In general, it seemed sensible to start with a rather generic use case that gently introduces core concepts of the presented systems and shows participants how they can interact with the prototypes. Afterwards, more concrete use cases can be demonstrated. The final demonstration should allow open-ended exploration and ideally facilitate reflection about further use cases and technological possibilities. The selection and arrangement of tangible artifacts also affected interactions and conversations, and therefore also the overall insights we gained from the exhibition. In our case, in addition to the overall technological setup itself, the presence of e.g. food items on the first table caused many conversations to initially focus on food preparation. For this reason we sometimes had to highlight that the depicted scenario was only one of many possible application scenarios.

6.6 Generating Ideas

Through the conversations we also wanted to learn more about novel use cases for interactive tables as well as to identify issues that are important for a subset of users. For this purpose, the presented example applications and interaction techniques were used as conversation starters, encouraging participants to reflect on how the technology could fit into their everyday lives or what possible problems or negative impacts they identified. The discussions revealed many new ideas and new possibilities that had not occurred to us before. We were particularly able to benefit from the diverse previous private and professional experiences of the participants, who thought about how and what the concept of an interactive table could be transferred into their own everyday lives.
In addition, we were able to identify moments of friction in our research that gave rise to further reflection: For example, when discussing the *Tool* prototype, some participants talked about how its application could help increase efficiency in workflows, help reduce human errors and avoid fabric to be wasted. However, what is expressed as a potential benefit of the technology here by the participants, can also be questioned and considered as overemphasizing efficiency and the negative connotation of making errors. Thus, such exhibitions might as well function as a space for constructive conflict, as Frauenberger et al. suggest [14].
Overall, pop-up participatory exhibitions seem able to document a larger number of diverse experiences than PD endeavors with carefully selected participants. However, in order to make the heterogeneous ideas gathered through the exhibition usable within the design process, researchers need to invest significant effort to filter, structure, and reflect on the outcomes.

6.7 Interest in the technology itself

Lawson et al. report that participants in a case study about ethically questionable, speculative animal-computer interaction technologies "displayed little or no concern for how they worked" or for ethical implications [26]. We had the opposite experience. A noticeably large number of participants[8] showed interest in our technical setups. For example, we were asked how object recognition works, what neural networks are, how the tip of the IR-pen was recognized by the camera, or how the camera-projector system will be able to recognize personal objects it was not trained to recognize. A large number of participants was also interested in ethical questions of our research – even though they only visited the exhibition for a short time. This could be due to a different participant sample, a different topic, or differences in presentation. The guides being part

[8]No quantitative data collected.

of the research project as well as a explanation of the technology setup being part of the presentation guidelines may underpin the observation.

7 Discussion

As reported in the previous sections, our combination of demonstrations, observations, conversations, and questionnaires was intended to facilitate ideation, user research, and outreach at the same time. Pursuing all three goals requires good planning and necessarily reduces the amount of time spent on each of the goals. In the following, we reflect on the benefits and strengths, as well as the challenges and limitations of our attempt at a combined approach.
Any ideation process requires introducing new participants to the overall topic, and participants can be easily observed while they explore the exhibition. Therefore, we believe that combining the three processes into one exhibition is less effective but more efficient than pursuing each goal in independent events. Nevertheless, the three parallel processes inevitably affect each other. For example, the way a prototype is presented might influence the ideation process.
Instead of providing clearly structured answers, the exhibition format especially helps to raise questions and bring forth ideas that would otherwise not have been asked or found. As interactions with participants are short and repetitive, they allow for iteratively improving communication strategies and observational methods. Planning and conducting an exhibition requires that programmers and ethnographers make their understanding of the topic of research explicit. Furthermore, frequent and diverse shared observations during the tours allow team members to gain and ensure a shared interpretation of phenomena. Especially in the early stages of a research project, an exhibition might serve as a catalyst for internal reflections and discourse on the motives driving joint research endeavors.
Another strength of the participatory exhibition format is that participants become potential users and are also observed as such. That way we did not only discover new ideas together but also usability problems. The problems were documented during the observations, and approaches or ideas for solutions could be developed and discussed directly with the participants. In order to obtain more focused results, it proved useful for us to concentrate on certain aspects of interaction (e.g. input methods or application launch). The implementation of an exhibition series also allowed us to implement improvements for problems and evaluate them in the following iterations of the exhibition.
Compared to traditional PD formats, such as design workshops, pop-up participatory exhibitions offer a typically larger and more diverse audience that could be recruited for further activities. However, the exhibitions require significantly more planning, standardization, and preparation. They also require more communication both between researchers and with participants. This additional effort is rewarded with opportunities for science communication and community-building.
Three additional benefits have transpired for our research project, which might also apply to other projects: (a) Having to present prototypes to participants with wildly varying backgrounds and knowledge forced us to make the demonstrations more concrete than if we were presenting them to selected groups; (b) the exhibition was not only a chance to engage with the public but also to invite collaborators, stakeholders, and colleagues to discuss the project as well as possible further collaborations with them; (c) planning and setting up an exhibition together proved to be a valuable team building exercise that helped with integrating new team members and the process of conducting an exhibition and reflecting on the process contributed to the mutual understanding of scholars coming from different disciplines. From our experience with this format, we would argue that the primary and secondary benefits and the opportunity for science communication and community-building clearly outweigh the additional effort required to set up the exhibition.
Despite its strengths, we also see clear limitations and challenges of our approach. The concept might be less suited for technologies and topics that generate very little public interest or require domain-specific knowledge that cannot be conveyed within a short conversation. Therefore, ideal topics for such exhibitions might be ones that are easy to explain (and explore) and of interest to the general public.
Furthermore, the exhibition attracts passers-by and invites them to immerse themselves into a design process for a short amount of time. Thus, participant engagement is of rather short and fleeting quality and very much focuses on the here-and-now. This has also been critically addressed in previous works [8]. It remains unclear how successful we have been with our outreach efforts, or how sustainable and long-term they are. Recruiting the participants for further activities probably requires additional incentives.
Participants are self-selected as well as selected by the location of the venue and thus not necessarily representative of the general population. As noted by Walsh [44], financially privileged groups may have more opportunities to participate in public co-design sessions. To make such offerings more accessible, he suggests to conduct short sessions in locations that are easily accessible for the target group. Given the heterogeneous mix of people in pedestrian areas, we feel that setting up a walk-in exhibition there or in a shopping mall is a good choice in general. Depending on goals and intended participant group, setting up the exhibition at multiple locations may be necessary.
According to the current guidance from the University of Regensburg's ethics commission[9], no IRB approval was required for our research (no AV recording, no intervention, no vulnerable groups, no personally identifiable information, no harm expected). Following long-standing practice in ethnography, we did not actively inform the participants about our field research or ask for explicit consent in order to preserve their natural way of interacting with each other and the prototypes [13, 19, 41]. We reflected this decision for each exhibition [3, p. 36f.]. From the second exhibition on, we informed participants up front that we wanted to use their feedback to inform our further research. As the participants did not know that they were being observed , the more closely we documented conversations and interactions, the more intrusive it started to feel. Furthermore, while the observations initially just were an added-on part of the exhibitions, they became an integral

[9] https://www.uni-regensburg.de/assets/ethikkommission/ek-ur/Brauche_ich_ein_Ethikvotum_.pdf

part later on. Multiple researchers switched between being a guide and an observer, blurring the line between passive observation and active intervention. Eventually, we found this approach justifiable because the exhibition forms a closed space that is consciously entered and we informed the participants directly that the exhibition was taking place as part of a university research project. Depending on the level of interaction and the intrusiveness of the research, we would suggest getting informed consent in an appropriate way at the end of the guided tour.

We found that the use cases presented in the exhibition have a significant influence on the type of ideas participants came up with. As these exhibitions were the first public showcases of our research, we did not want to include explicitly dystopian use cases – e.g. ones concerning surveillance or information overload. However, we asked participants about their opinion on such topics and think that presenting scenarios that highlight potential problems and dangers of a upstream technology is a sensible next step. Such scenarios should probably be presented towards the end of the tour as they offer much potential for deeper discussions and design fiction activities.

8 Conclusion

In this paper we presented an approach to pop-up participatory exhibitions and shared our observations about research process and outcomes. Implementing the pop-up participatory exhibitions with the goal of ideation, user research, and outreach, we gathered data via semi-structured conversations, questionnaires, and participant observation during guided tours. While we can only report on four instances of the exhibition, the many guided tours we conducted allowed us to reflect on our approach and it's iterative improvement, and generalize some insights.

By leading participants through the exhibition in small groups, we were able to conduct deeper and more personal conversations with them. Demonstrating three to four prototypes which showcased different aspects of our development goals at different levels of interactiveness and abstractness, allowed us to gain useful feedback and reflect on both concrete and abstract ideas as well as specific interaction technologies. Through our structured field research, we were able to evaluate and iterate both the concept for the exhibitions and various aspects of the prototypes presented. Providing an easily-accessible and interactive showcase of our work attracted a wide variety of interested participants.

Further research is required to better understand how useful these kinds of exhibitions are for upstream technologies in general or entirely different topics. It might also make sense to systematically compare the outcomes of such an exhibition to those of workshops that focus purely on ideation, user research, or outreach. Another open question is: how can we better identify and involve underrepresented user groups?

While pop-up participatory exhibitions can certainly not replace deeper and longer PD or UCD formats, we find them useful as an early step in a larger research or design process. They allow for collecting a wide range of ideas from a large group of potential users and foster internal reflection within an interdisciplinary research group.

References

[1] Liam Bannon, Jeffrey Bardzell, and Susanne Bødker. 2018. Reimagining participatory design. *Interactions* 26, 1 (2018), 26–32. https://doi.org/10.1145/3292015

[2] Erling Björgvinsson, Pelle Ehn, and Per-Anders Hillgren. 2010. Participatory design and "democratizing innovation". In *Proceedings of the 11th Biennial Participatory Design Conference (PDC '10)*. Association for Computing Machinery, New York, NY, USA, 41–50. https://doi.org/10.1145/1900441.1900448

[3] Ann Blandford, Dominic Furniss, and Stephann Makri. 2016. *Qualitative HCI Research: Going Behind the Scenes*. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-031-02217-3

[4] Julian Bleecker. 2009. *Design Fiction: A Short Essay on Design, Science, Fact, and Fiction*. Technical Report. Near Future Laboratory. https://systemsorienteddesign.net/wp-content/uploads/2011/01/DesignFiction_WebEdition.pdf

[5] Torie Bosch. 2012. Sci-Fi Writer Bruce Sterling Explains the Intriguing New Concept of Design Fiction. *Slate* (March 2012). https://slate.com/technology/2012/03/bruce-sterling-on-design-fictions.html

[6] Tone Bratteteig and Ina Wagner. 2010. Spaces for participatory creativity. In *Proceedings of the 11th Biennial Participatory Design Conference*. ACM, Sydney Australia, 51–60. https://doi.org/10.1145/1900441.1900449

[7] Tone Bratteteig and Ina Wagner. 2016. Unpacking the notion of participation in participatory design. *Computer Supported Cooperative Work (CSCW)* 25, 6 (2016), 425–475.

[8] Susanne Bødker and Morten Kyng. 2018. Participatory Design that Matters - Facing the Big Issues. *ACM Transactions on Computer-Human Interaction* 25, 1 (Feb. 2018), 4:1–4:31. https://doi.org/10.1145/3152421

[9] Ellen Dowell. 2017. *Pop up science*. Imperial College London, London. http://www.imperial.ac.uk/nhli/pop-up-science

[10] Anthony Dunne and Fiona Raby. 2013. *Speculative Everything: Design, Fiction, and Social Dreaming*. MIT Press, Cambridge / London.

[11] Florian Echtler and Raphael Wimmer. 2014. The Interactive Dining Table, or Pass the Weather Widget, Please. In *Proceedings of the Ninth ACM International Conference on Interactive Tabletops and Surfaces*. ACM, New York, NY, USA, 419–422. https://doi.org/10.1145/2669485.2669525

[12] Eleni Economidou. 2023. Engaging the General Public in Speculation on Human-Building Interaction Futures at a Pop-up Event: A Design Fiction Approach. In *Proceedings of the 26th International Academic Mindtrek Conference (Mindtrek '23)*. Association for Computing Machinery, New York, NY, USA, 154–168. https://doi.org/10.1145/3616961.3616966

[13] Carolyn Fluehr-Lobban. 1994. Informed Consent in Anthropological Research: We Are Not Exempt. *Human Organization* 53, 1 (1994), 1–10. https://www.jstor.org/stable/44126554

[14] Christopher Frauenberger, Marcus Foth, and Geraldine Fitzpatrick. 2018. On scale, dialectics, and affect: pathways for proliferating participatory design. In *Proceedings of the 15th Participatory Design Conference: Full Papers - Volume 1 (PDC '18)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3210586.3210591

[15] Christopher Frauenberger, Judith Good, and Wendy Keay-Bright. 2010. Phenomenology, a framework for participatory design. In *Proceedings of the 11th Biennial Participatory Design Conference (PDC '10)*. Association for Computing Machinery, New York, NY, USA, 187–190. https://doi.org/10.1145/1900441.1900474

[16] Christian Haag and Inga Specht. 2022. Reducing the gap in nonvisitor studies: Evidence on museum attendance from the German National Educational Panel Study. *Poetics* 95 (Dec. 2022). https://doi.org/10.1016/j.poetic.2022.101730

[17] Hessam Habibi Doroh and Barbara Streicher. 2021. Knowledge∘Room exploring social justice by going beyond 'traditional' spaces and activities of science centres. *Journal of Science Communication* 20, 01 (Feb. 2021), C03. https://doi.org/10.22323/2.20010303

[18] Eva Hornecker and Emma Nicol. 2012. What do lab-based user studies tell us about in-the-wild behavior? insights from a study of museum interactives. In *Proceedings of the Designing Interactive Systems Conference (DIS '12)*. Association for Computing Machinery, New York, NY, USA, 358–367. https://doi.org/10.1145/2317956.2318010

[19] Elisabeth Huber and Sabine Imeri. 2021. Informed consent in ethnographic research: A common practice facing new challenges. https://doi.org/10.26092/ELIB/1070

[20] Hilary Hutchinson, Wendy Mackay, Bo Westerlund, Benjamin B. Bederson, Allison Druin, Catherine Plaisant, Michel Beaudouin-Lafon, Stéphane Conversy, Helen Evans, Heiko Hansen, Nicolas Roussel, and Björn Eiderbäck. 2003. Technology probes: inspiring design for and with families. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '03)*. Association for Computing Machinery, New York, NY, USA, 17–24. https://doi.org/10.1145/642611.642616

[21] Maria Huusko, Yiying Wu, and Virpi Roto. 2018. Structuring and engaging: the roles of design fictions in a co-design workshop. In *Proceedings of the 30th Australian Conference on Computer-Human Interaction (OzCHI '18)*. Association for Computing Machinery, New York, NY, USA, 234–241. https://doi.org/10.1145/3292147.3292165

[22] Finn Kensing and Jeanette Blomberg. 1998. Participatory Design: Issues and Concerns. *Computer Supported Cooperative Work (CSCW)* 7, 3-4 (Sept. 1998), 167–185. https://doi.org/10.1023/A:1008689307411 Number: 3-4.

[23] Volker Kirchberg. 1996. Museum visitors and non-visitors in Germany: A representative survey. *Poetics* 24, 2 (Nov. 1996), 239–258. https://doi.org/10.1016/S0304-422X(96)00007-1

[24] Anna Krzywoszynska, Watson Matt, Alastair Buckley, Prue Chiles, Nicky Gregson, Helen Holmes, and Jose Mawyin. 2018. Opening Up the Participation Laboratory: The Cocreation of Publics and Futures in Upstream Participation. *Science, Technology, & Human Values* 43, 5 (Sept. 2018), 785–809. https://doi.org/10.1177/0162243917752865 Publisher: SAGE Publications Inc.

[25] K. Kurtz, S. K. Cooper, T. Bishop, and K. Thomson. 2018. Bringing Earth and Ocean Science to Underserved Audiences: An Overview of a NSF-funded Traveling Pop-up Exhibit. 2018 (Dec. 2018), ED53B–03. https://ui.adsabs.harvard.edu/abs/2018AGUFMED53B..03K

[26] Shaun Lawson, Ben Kirman, Conor Linehan, Tom Feltwell, and Lisa Hopkins. 2015. Problematising Upstream Technology through Speculative Design: The Case of Quantified Cats and Dogs. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 2663–2672. https://doi.org/10.1145/2702123.2702260

[27] Jonathan Lazar. 2017. *Research methods in human-computer interaction* (second edition ed.). Morgan Kaufmann, Cambridge, MA.

[28] Kirsti Lehmusto, Tanja Paananen, Antti Asumaa, and Jarmo Suominen. 2018. Think Corner: A platform for engaging the public in research and learning. *Journal of Education Advancement & Marketing* 2, 4 (March 2018), 371. https://doi.org/10.69554/CPRZ2994

[29] Vitus Maierhöfer, Andreas Schmid, and Raphael Wimmer. 2024. TipTrack: Precise, Low-Latency, Robust Optical Pen Tracking on Arbitrary Surfaces Using an IR-Emitting Pen Tip. In *Proceedings of the Eighteenth International Conference on Tangible, Embedded, and Embodied Interaction*. ACM, Cork Ireland, 1–13. https://doi.org/10.1145/3623509.3633366

[30] Michael J. Muller and Sarah Kuhn. 1993. Participatory design. *Commun. ACM* 36, 6 (June 1993), 24–28. https://doi.org/10.1145/153571.255960

[31] Jörg Niewöhner. 2016. Co-laborative anthropology: Crafting reflexivities experimentally. In *Etnologinen tulkinta ja analyysi: Kohti avoimempaa tutkimusprosessia [Ethnological interpretation and analysis: Towardsa transparent research process]*, Jukka Jouhki and Tytti Steel (Eds.). Ethnos, Helsinki, 81–125. https://edoc.hu-berlin.de/bitstream/handle/18452/19241/Niewoehner2016-Co-laborative-anthropology.pdf

[32] Donald A Norman. 1986. *User centered system design: New perspectives on human-computer interaction*. CRC Press, Hillsdale, NJ.

[33] Sebastian Prost, Elke Mattheiss, and Manfred Tscheligi. 2015. From Awareness to Empowerment: Using Design Fiction to Explore Paths towards a Sustainable Energy Future. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing (CSCW '15)*. Association for Computing Machinery, New York, NY, USA, 1649–1658. https://doi.org/10.1145/2675133.2675281

[34] Toni Robertson and Ina Wagner. 2013. Ethics: engagement, representation and politics-in-action. In *Routledge International Handbook of Participatory Design*. Routledge, London / New York.

[35] Douglas Schuler and Aki Namioka. 1993. *Participatory Design: Principles and Practices*. CRC Press, Hillsdale, NJ.

[36] Sumita Sharma, Heidi Hartikainen, Leena Ventä-Olkkonen, Netta Iivari, Grace Eden, Essi Kinnunen, Jenni Holappa, Marianne Kinnula, Tonja Molin-Juustila, Jussi Okkonen, Sirkku Kotilainen, Ole Sejer Iversen, and Rocío Fatás Arana. 2021. In Pursuit of Inclusive and Diverse Digital Futures: Exploring the Potential of Design Fiction in Education of Children. *Interaction Design and Architecture(s)* 51 (Dec. 2021), 219–248. https://doi.org/10.55612/s-5002-051-010

[37] Jesper Simonsen and Toni Robertson (Eds.). 2013. *Routledge International Handbook of Participatory Design*. Routledge, London / New York. https://www.routledge.com/Routledge-International-Handbook-of-Participatory-Design/Simonsen-Robertson/p/book/9780415720212

[38] Rachel Charlotte Smith and Mette Gislev Kjærsgaard. 2014. Design anthropology in participatory design from ethnography to anthropological critique?. In *Proceedings of the 13th Participatory Design Conference: Short Papers, Industry Cases, Workshop Descriptions, Doctoral Consortium papers, and Keynote abstracts - Volume 2 (PDC '14)*. Association for Computing Machinery, New York, NY, USA, 217–218. https://doi.org/10.1145/2662155.2662209

[39] Bruce Sterling. 2005. *Shaping Things*. MIT Press.

[40] Barbara Streicher, Kathrin Unterleitner, and Heidrun Schulze. 2014. Knowledge⊙rooms — science communication in local, welcoming spaces to foster social inclusion. *Journal of Science Communication* 13, 2 (2014), 5.

[41] Barrie Thorne. 1980. "You Still Takin' Notes?" Fieldwork and Problems of Informed Consent. *Social Problems* 27, 3 (1980), 284–297. https://doi.org/10.2307/800247

[42] Jonathan M. Tyrrell, Christie S. Conlon, Ali F. Aboklaish, Sarah Hatch, Carl Smith, Jordan Mathias, Kathryn Thomson, and Matthias Eberl. 2022. 'Superbugs': raising public awareness of antimicrobial resistance through a pop-up science shop. *Research for All* 6, 1 (Feb. 2022), 1–21. https://doi.org/10.14324/RFA.06.1.06

[43] Karel Vredenberg, Scott Isensee, and Carol Righi. 2002. *User-Centered Design: An Integrated Approach*. Upper Saddle River, NJ.

[44] Greg Walsh. 2018. Towards equity and equality in American co-design: a case study. In *Proceedings of the 17th ACM Conference on Interaction Design and Children (IDC '18)*. Association for Computing Machinery, New York, NY, USA, 434–440. https://doi.org/10.1145/3202185.3202768

[45] Astrid Weiss, Daniela Wurhofer, Regina Bernhaupt, Elke Beck, and Manfred Tscheligi. 2008. "This is a flying shopping trolley": a case study of participatory design with children in a shopping context. In *Proceedings of the Tenth Anniversary Conference on Participatory Design 2008 (PDC '08)*. Indiana University, USA, 254–257.

[46] Pierre Wellner. 1993. Interacting with Paper on the DigitalDesk. *Commun. ACM* 36, 7 (July 1993), 87–96. https://doi.org/10.1145/159544.159630

[47] Jon Whittle. 2014. How much participation is enough? a comparison of six participatory design projects in terms of outcomes. In *Proceedings of the 13th Participatory Design Conference: Research Papers - Volume 1 (PDC '14)*. Association for Computing Machinery, New York, NY, USA, 121–130. https://doi.org/10.1145/2661435.2661445