Pre-print
Pop-Up Participatory Design Combines Ideation, User Research, and Outreach

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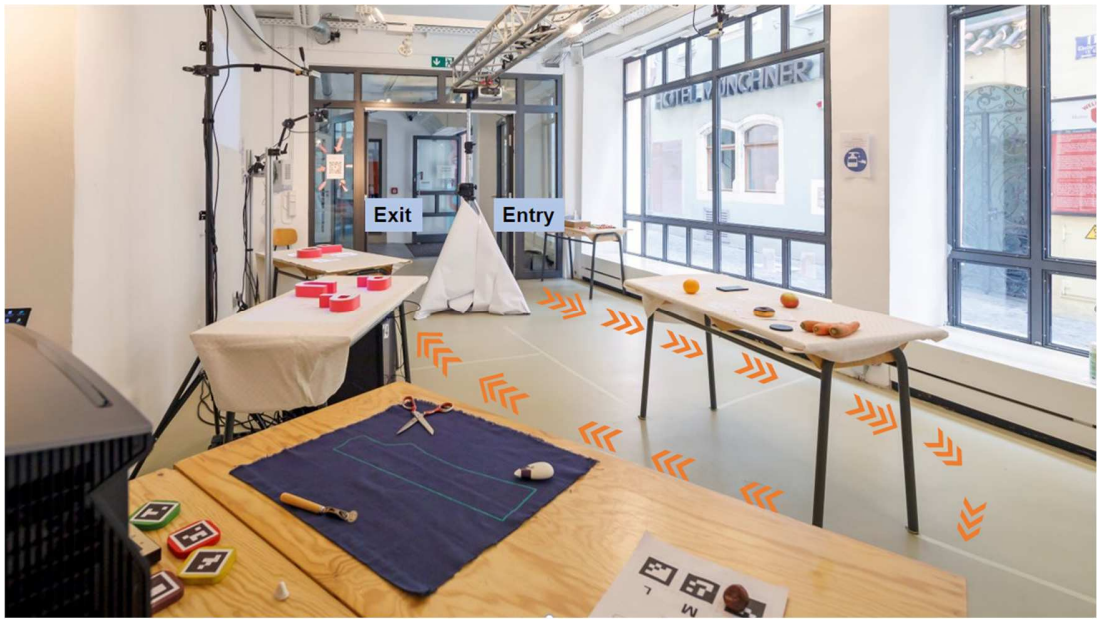
Abstract

Upstream technologies are technologies which are not yet in widespread use but may become part of people's everyday lives sooner or later. Thus, it makes sense to facilitate public discourse on their applications and engage prospective users in their design - if one can find them. To involve the public in the design of novel projected user interfaces for tabletops, we combined participatory design with pop-up science shops. Our pop-up participatory design approach engages a broad audience in ideation, user research, and outreach via an exhibition of functional prototypes in a highly-frequented location. Visitors are guided through the exhibition in small groups and involved in small-scale participatory design activities. In two one-week exhibitions, over 200 visitors discussed applications, technical details, and social and ethical issues with us. We gathered diverse viewpoints and a list of more than 60 use cases, of which only few had been mentioned previously. We describe design choices, results, and limitations.

Introduction

When developing new interactive systems, it is considered good practice to identify and involve potential users and other stakeholders who might be affected, so that they can influence design decisions [@Schuler_Namioka_1993]. This is straightforward for applications that address a clearly-defined or existing target group. For example, a company-internal tool might only be used by a few well-known users. Identifying prospective users is more difficult for interactive systems that can be used in many different environments and contexts. In these cases, it is sensible to involve a broad sample of users in the design process. If there is already a large, diverse, group of existing users, one might involve a random sample from it. However, finding users and motivating them to participate in a design process is particularly difficult for abstract *upstream technologies* that are not yet in current use and have no clearly defined group of prospective users.



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

We faced this problem in an ongoing research and engineering project. The project's goal is to design and 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 [@Wellner_1993] into an extensible ecosystem. In addition to design workshops which we conducted with researchers, artists, designers, and technology enthusiasts, we also wanted to consider everyday life perspectives and expectations of "typical" users to be represented in the development process. However, as such systems are currently neither in everyday use nor the topic of public discussion, there are no obvious current or prospective user groups we could involve in the design process. Given that our work is neither very controversial nor urgently desired by many people, we could not expect intrinsically motivated participants to just turn up by themselves.

A similar, inverse 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. 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 broader audience.

In this paper we describe our experience with a week-long pop-up science exhibition which we used as a platform for participatory design (PD). We call this combination *"pop-up participatory design"* (pop-up PD). In a pop-up PD exhibition, participants learn about a specific topic while also actively and passively participating in further research and design of this topic. Our overall goal was to inform the design and development process by creating

space for a *"collective 'reflection-in-action'"* process [@Simonsen_Robertson_2013, p. 2] mainly serving the following goals:

- ideation (generating 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 recruiting participants for design workshops and user studies).

The exhibition was set up in a gallery space in the old town of a medium-sized European city and comprised interactive prototypes, a guided tour, in-depth conversations, and a structured questionnaire. Over the course of one week, 103 people visited the exhibition. To open up an explorative space for reflection on and discussion of different layers of the project, we engaged with the participants 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 how participants interacted with the prototypes. The data we gathered informed the further design of our system.

In this paper, we describe the general concept of pop-up participatory design and share our experiences with this format. Our work may help designers and researchers determine whether the approach is of use for their PD project and gives guidance for designing similar events.

The paper is organized as follows: in the next section, we give a short introduction to participatory design and the concept of pop-up science, and how these may be combined into pop-up PD. Afterwards, we describe the context of our exhibition, the venue it took place in, our presentation strategies, prototypes, research methods, and outcomes. Building on these descriptions, we reflect on observations and experiences we made during the event in the subsequent section. Finally, we summarize our findings in a list of suggestions for pop-up PD and discuss applications and limitations.

Pop-Up Participatory Design

Pop-up participatory design combines goals and methods from participatory design with goals and methods from pop-up science stores.

User-Centered and Participatory Design

The most common design approaches explicitly involving users are user-centered design (UCD) and participatory design (PD). Both approaches have a common assumption: instead of just designing solutions *for* users, it is better to define and design them together *with* those affected by them. They differ in methods and participation philosophy.

User-centered Design (UCD) [@Norman_1986; @Vredenberg_Isensee_Righi_2002] describes an iterative approach to developing systems and services. It places a high emphasis on involving users throughout the development process with the typical goal of developing a good product or service. However, the primary role of users is to provide designers with the knowledge they need for developing a good solution.

In contrast, *Participatory design* (PD) [@Muller_Kuhn_1993; @Schuler_Namioka_1993; @Simonsen_Robertson_2013] aims to empower designers/facilitators and users to create solutions together. To this end, PD offers a broad set of methods. While its roots lie in involving workers in the design of their workplace, current PD endeavours range from solving concrete problems or developing products to effecting social or political change [@Frauenberger_Foth_Fitzpatrick_2018].

While Schuler and Namioka describe PD as an *"approach towards computer systems design in which the people destined to use the system play a critical role in designing it"* [@Schuler_Namioka_1993, p. xi], Robertsen and Simonsen define PD more widely as *"a process of investigating, understanding, reflecting upon, establishing, developing, and supporting mutual learning between multiple participants in collective reflection-in-action"* [@Simonsen_Robertson_2013, p. 2]. They emphasize that both designers and users learn from each other during the PD process. PD cannot be pinned down to clearly defined formulas or methods [@Simonsen_Robertson_2013, p. 3]. Instead, it encompasses a variety of methods such as co-design workshops, cooperative prototyping, focus groups, ethnographic methods, user studies, interviews, or living labs [@Muller_Kuhn_1993; @Whittle_2014]. Although PD employs traditional user research methods, these are primarily used to inform the collaborative design process, not to produce generalizable scientific claims [@Spinuzzi_2005].

In summary, the focus of PD is not just on extracting domain knowledge from participants but on co-designing solutions, establishing bi-directional communication, facilitating open discussion, and empowering participants.

Participatory Design for Upstream Technologies

PD is especially powerful for investigating the societal impact of *upstream technologies*, i.e, technologies that have not yet reached mainstream adoption. As Dunne & Raby argue, exploring upstream ideas before they become products or technologies allows designers to look into possible consequences before they happen[@Dunne_Raby_2013].

However, upstream technologies initially do not typically catch the public's attention because the majority is not yet aware of their existence, arrival, or implications [@Krzywoszynska_Matt_Buckley_Chiles_Gregson_Holmes_Mawyin_2018]. Wide public discussion of societal impacts often only happens once the technology is already in use and causes controversy. Therefore, involving people in the discussion and co-design of such upstream technologies requires externally triggered and organized processes [@Krzywoszynska_Matt_Buckley_Chiles_Gregson_Holmes_Mawyin_2018]. It also requires finding participants that are interested in discussing the implications of upstream technologies and in contributing to their design. 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 [@Simonsen_Robertson_2013, p. 71f]. Obviously, it is even more difficult to motivate people to participate in discussion and design of a rather abstract upstream technology where participants do not anticipate an immediate personal benefit from their participation.

In summary, it may be desirable to involve the public in the design of upstream technologies not only to improve the technology itself but also to increase public awareness for its implications and to foster public discussion. However, the more generic and abstract an upstream technology is, the more difficult it may be to involve the public in the design process. To address this issue in our research project, we utilized a method from science communication – pop-up science stores. Instead of identifying and personally inviting prospective users ourselves, we set up an exhibition that invited passers-by to enter and rewarded them for their participation by letting them experience the upstream technology.

Pop-up science

The term *pop-up science*[1] emerged in the 2010s to describe temporary science centers that are set up in empty shops [@Dowell_2017; @Streicher_Unterleitner_Schulze_2014]. These *pop-up science shops* allow for engaging communities in science communication that would usually not visit a science museum. One of the more prominent instances of such pop-up science centers are the *Knowledgerooms* set up by Streicher et al. in Vienna [@Streicher_Unterleitner_Schulze_2014]. These *"temporarily offer science center activities in empty shops in underprivileged urban districts — anyone passing by could just walk in and start engaging"*. 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 [@Streicher_Unterleitner_Schulze_2014].

Pop-up science shares a basic vision with PD: both approaches try to empower people through engagement. However, they clearly differ in three aspects – audience, goals, and direction of communication.

PD typically involves a well-defined *group* of participants – 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 different backgrounds, previous knowledge, and goals. While a PD process traditionally aims 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. It may also aim to transfer specific scientific knowledge into a broad public or provide a platform for discussion [@Dowell_2017, p. 9]. Furthermore, 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

[1] We choose not to use an abbreviation for *pop-up science* because the only sensible options, *PUS* and *PopUpS*, might have bad connotations for some readers.

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]. These key differences don't make PD and pop-up science incompatible, however. Instead both approaches are complementary and can be combined into a coherent concept which we describe in the following section.

Pop-Up Participatory Design

As part of our research project, we developed and set up a *pop-up participatory design* exhibition which combines ideas from participatory design and pop-up science in order to engage a diverse public in science communication, ideation, and user research.

As suggested e.g., by Dunne & Raby [@Dunne_Raby_2013], we use a design exhibition as a vehicle for critical reflection about the underlying technology and its implications for individuals and society. However, we go further and use this exhibition not only for reflecting on a vision but also for collaboratively improving this vision. Our *pop-up participatory design* framework can be summarized 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.
- 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[3].
- In order to engage participants in a (lightweight) PD 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
- 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.

This basic framework can be extended with further components, e.g., surveys, small usability studies, short ideation workshops, or recruitment for subsequent PD workshops. It seems especially suitable for HCI research projects which work on or with upstream technologies.

Relation to Existing Concepts

As far as we know, such a combination of presenting outcomes from research and simultaneously involving participants in the ongoing research project, is relatively rare, even within PD. While some researchers conduct user research or participatory design in

[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 (p. 71).

[3] Since the visitors of our exhibition were engaged in a PD process, we choose to refer to them as participants instead of visitors in this paper.

public spaces [@Weiss_Wurhofer_Bernhaupt_Beck_Tscheligi_2008], and some use pop-up science stores for fostering public discussion [@Dowell_2017, p. 9], we are not aware of any in-depth discussion of the properties and limitations of such combinations.

The relationship between pop-up participatory design and the aforementioned existing concepts – UCD, PD, and pop-up science – can be characterized within three aspects outlined in the following section: goals, audience, and direction of communication. While UCD, PD, and pop-up science each encompass a broad range of practices, we refer to their most common manifestations (in our experience) to highlight the differences.

Goals: The primary goal of UCD processes are good *artifacts* – systems, processes, or user interfaces. In contrast, PD aims at involving and empowering *people* in a design process in order to generate better solutions. Pop-up science aims at increasing *scientific knowledge* in people without regard for immediate utility of that knowledge and with limited interest in people's own knowledge. Pop-up participatory design places equal emphasis on artifacts, participants, and scientific knowledge but also allows for focusing on some of these goals.

Audience: In UCD, participants in the design process (interviews, user studies) are ideally those who might be affected by the system to be developed. Whether they are intrinsically interested in the design process is less important because the design process is driven by the researchers. In PD, participants are ideally both affected by the system and intrinsically motivated. 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. Pop-up participatory design also reaches a broad audience which is at least a little bit interested in the topic. Depending on the topic, this audience might range from being affected only slightly by the system or technology to being affected in a major way.

Direction of Communication: In UCD, researchers extract domain knowledge from participants. In PD, researchers both extract knowledge and facilitate knowledge transfer between participants. In pop-up science, researchers convey domain knowledge to the public. Pop-up participatory design offers a platform that allows for all these flows of communication. However, due to the intentionally small groups of participants, knowledge exchange between participants is very limited.

Relation to Technology Probes

The research prototypes demonstrated in the exhibition are very similar to *technology probes* [@Hutchinson_Mackay_Westerlund_Bederson_Druin_Plaisant_Beaudouin-Lafon_Conversy_Evans_Hansen_Roussel_Eiderback_2003]. They, too, 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 design

complements technology probes and is especially useful if the usage context for a technology is not yet well-defined. In the following sections we present our concrete implementation of the concept and the observations we made in the process.

A Pop-Up Participatory Design Exhibition on Interactive Projected Tabletops

Context

In our research project, we investigate how physical (inter-)actions at and around tables may be supported and enriched by projecting interactive content onto a tabletop. We develop a projected augmented reality (PAR) system for tabletops which integrates personal digital devices and multiple table surfaces. Building on this technical foundation, we aim to develop interaction techniques as well as digital tools to support common activities on and around tables. To this end, we investigate how people use tables in everyday life. The primary research methods we employed previously were online questionnaires to document how tables are currently used in everyday life and design workshops for in-depth exploration of the topic. To complement these methods, we presented our prototypes in a public pop-up PD exhibition.

Venue

The exhibition took place over the course of one week in September 2020 in a cultural and creative center in [medium-sized European city]. The exhibition space (~40m^2) has a large window front that faces towards a small alley connecting two large squares in a central pedestrian area. This alley is mostly frequented by residents, shoppers, or 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"* [@Dowell_2017, 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 enough.

Demonstrations

In the exhibition, we showcased three hardware/software prototypes developed for demonstrating core aspects of the research project (Figure {@fig:prototypes}). The prototypes illustrated different application scenarios ranging from rather concrete use cases to more abstract representations of possibilities.

We presented three different prototypes of interactive tabletops with projected augmentations in the exhibition: a) first prototype: illustrating object recognition and projection of informational content; b) second prototype: projecting of cutting patterns onto fabric, adjustable by manipulating a paper proxy with optical markers; c) third prototype: two separate tables virtually linked and objects dynamically mirrored onto each other.

Prototypes

All prototypes used a similar setup consisting of a video projector (2160p or 1080p), a depth camera (Intel Realsense D435), 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.

The first prototype (***Augmentation***, Figure {@fig:prototypes}a) 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 [@Echtler_Wimmer_2014]. Participants could also put a mobile phone onto the table. A mock-up screen extension was projected next to the device, showing a digital clock, message notifications and a photo.

The goal here was to introduce the concepts of PAR and of linking digital devices to the table. This gave participants a basic understanding of the context and showed 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 themselves.

The second prototype (***Tool***, Figure {@fig:prototypes}b) 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 wooden blocks with markers were lying on the table. Participants could move, scale, and rotate a projected cutting pattern by manipulating the paper proxy. Once participants were comfortable with the scenario, the presenter introduced another tool: By placing a tangible with a printed marker on it on the table, a rewind feature was activated and a timeline appeared on the surface. By moving the tangible along the projected timeline, participants could rewind or forward a two minute long cached recording of what had just happened on the tabletop and the actions that had just been performed by them or the guide.

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 {@fig:prototypes}c) 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 an extraction of objects on the table so that only these would be projected onto the other tabletop instead of the whole camera image. As both tables had big cardboard letters on them to play around with, the 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.

Selection

The selection of prototypes was mostly pragmatic. The *Tool* and *Collaboration* prototypes had been developed earlier in the research project. They were slightly adapted in order to be showcased to the public. The *Augmentation* prototype was specifically developed for the exhibition.

The *Collaboration* prototype was motivated by an example scenario of a fictitious family living with an interactive table which was written for the initial grant application. The idea for the *Tool* prototype was conceived in discussions with handcrafters early on in the 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 exhibition, we intended to balance this contrast and round off the overall concept. It, too, depicted a more abstract and generic concept of interactive tables but, through the use of foodstuffs 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.

Order

The order in which we presented the prototypes was determined by multiple considerations and external factors. The *Augmentation* prototype was the starting point of the guided tour as well as the one that was best visible through the window front, and thus the natural focus of interest for new participants. As most of them had no or only a partial understanding of what an interactive table could be, we gave them the chance to figure it out themselves. The table's surface was initially empty, and no information was projected on it. This allowed for introducing the exhibition without participants being distracted by objects or projections. By starting with a simple application like this we intended to allow

the participants to understand the technology and ask questions about it. As the second prototype to be presented to the participants, the *Tool* prototype 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 third prototype 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. Placing this prototype at the end of the guided tour created an open end where participants could choose how much longer they wanted to stay.

Presentation

COVID-19-related hygiene regulations restricted the maximum occupancy of the room to five persons at the same time, including our staff. Participants had to write down their contact information, wear masks, and disinfect their hands before entering the space. In order to minimize contact between groups of participants, we defined a one-way route through the exhibition space (Figure {@fig:exhibition}). 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 in-depth conversations with small groups of participants at a time. We reflect on our experiences with this presentation format in the following section.

Participants were welcomed at the entrance, given a very short overview of the exhibition, and asked to follow the required hygiene guidelines. Then a staff member guided the participants from one prototype to the next. For each prototype, they first gave a short explanation, then invited the participants to try them out, and finally started an open conversation with the participants about their opinions and ideas. At the end of the tour, participants were asked to leave a short feedback message that was then projected onto the wall, and to fill out a questionnaire. Finally, the staff member thanked the participants, contact information was exchanged, and/or the participants were given the option to subscribe to the project's newsletter. The tours took around 20 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 outside for their tour or not.

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 the requirements and opinions of prospective users (user research), and establishing a dialogue between researchers and public (outreach). To this end, we combined ethnographic methods of varying openness: observations, conversations, and a questionnaire. Table 1 provides an overview of methods and documentation/questioning techniques used as well as the kind of data we gained from applying them:

Overview of ethnographic methods, corresponding documentation/questioning techniques used, and the kind of data we gained.

Method	Documentation / Questioning techniques	Data gained on
Participant observation	• Field notes	• How do participants interact with and perceive the prototypes • How do conversations and interaction dynamics unfold • How the concept of Pop-Up PD unfolds
Semi-structured in-depth conversations	• Open questions asked as part of a guided tour • Results documented in field notes	• Ideation regarding possible application scenarios and use cases • Opinions on presented scenarios and the project itself • Opinions on technological configuration • Opinions on broader sociocultural and ethical context of the project
Standardized survey	• Participants were given the option to fill out a questionnaire after their visit • Open-ended and closed-ended questions	• Statistical information on age, profession and technical affinity • Feedback on guided tour • Feedback on project and prototypes • Collecting contact information for collaborations and participation in future workshops

The 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 all team members had

experience applying them to similar projects before. Nevertheless, when it came to applying these methods on site, further discussions evolved and adjustments needed to be made during the event (see section 4.3). Our team consisted of five researchers who took turns throughout the week. One of us was present for the whole time of the exhibition and the others were flexibly present depending on the number of participants to be expected in certain time periods.

In the semi-structured in-depth conversations, we explicitly asked the participants for feedback on the presented prototypes, new ideas for possible application scenarios, and concrete use cases. We documented their ideas in field notes together with additional information on the situational context they arose from.

The field notes were noted down in a central protocol all team members had access to, but occasionally notes were written down on paper and later transferred into the central document. Whenever more than one researcher was present, one took the role of guide and the other(s) quietly observed the ongoing interaction and/or documented their observations. If there was only one researcher present, they had to write down the observations from memory after the guided tour was over. From participant observation, in-depth-conversations, and the questionnaire, 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 are briefly discussed in a later section.

Participants

Over the duration of six days and a total opening time of 40 hours, 103 participants visited the exhibition in 28 groups[4]. On Saturday, there were twice as many participants as on an average weekday (4.2 vs. 2.1 participants per hour). 50 participants filled out the questionnaire afterwards, telling us about their experience, their background, and the reasons why they visited the exhibition.

Our goal was not reaching a specific target audience with this exhibition. Instead we wanted 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. We advertised the event 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, less than 19% percent of the participants who filled out the questionnaire came because of our advertisements. 23% mentioned that they had heard about the event from friends or acquaintances, and a majority of 58% were walk-in participants who spontaneously decided to enter the exhibition when passing by the

[4] At 20 minutes per group and a maximum of four visitors per group, the exhibition would have been able to accommodate up to 600 visitors in theory. In practice, a maximum of 250 visitors per week might be realistically achievable.

window front. The majority of participants who filled out the survey were between 26 and 35 years old (36%), followed by the age group 18-25 (28 %). Only 4% were older than 65 years[5]. While families with small children actually made up a significant proportion of all participants, they are underrepresented in the survey because usually only one parent filled out the questionnaire, and oftentimes parents did not have time to fill out the survey at all.

While participants worked in a variety of occupations, such as engineering, media design, journalism, or healthcare, 30% of respondents were students, and 16% worked in education. 30% of respondents stated that they highly engage with technology. We did not collect potentially sensitive information about ethnicity, education, or social status.

Results

In the following we summarize and illustrate the findings from observations, in-depth conversations and the survey in regard to ideation, user research and outreach.

Ideation

In total we collected 90 ideas from 28 participant groups with altogether 103 participants. Since the ideas unfolded as part of a conversational dynamic between researcher and participant (group), ideas could not always be attributed to individual participants. As we often only had time to write down the ideas after the tour, some ideas might have been lost or slightly misrepresented in our notes. Only one of the new ideas had already been included in our original scenario comprising 17 distinct ideas established at the beginning of the research project.

Qualitatively, the 90 ideas represented a wide variety of possible new application scenarios and use cases which we condensed into 42 distinct ideas[6]. 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”).

[5] Remaining age groups: 56-65 (16%), 46-55 (10%), 36-45 (4%), under 18 (2%).

[6] See Appendix.

A researcher (right) demonstrates an interactive exhibit to a group of two people who already knew each other. The shared personal background fostered more open and personal conversations.

The ideas were highly influenced by the participants' personal backgrounds, everyday life experiences, and interests. For example, 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.

At the *Tool* prototype, an interaction design student suggested carpentry work and collaborative drawing as potential application scenarios, whereas a participant working in the film industry added the idea of using a tangible user interface to re-arrange scenes when editing a movie or using any kind of media player.

At the *Collaboration* prototype, a participant thought of a friend who is a passionate player of the tabletop strategy game Warhammer and who could present their self-designed game pieces to other people at different locations via virtually linked tables and even place them in a digitally projected environment. And a teacher of disabled children reflected on how virtually linked tables could be beneficially applied in the classroom to support learning experiences.

The examples illustrate the variety of angles from which the participants approached the question of how the technology we presented them with could and should affect people's everyday life practices.

We used the ideas gathered during the exhibition together with ideas collected by other means in further brainstorming sessions.

User Research

The in-depth conversations, survey, and observations also enabled us to better understand participants' demographics, their attitudes towards interactive tables, and how our design choices affected their interaction with the prototypes.

Demographics: Age distribution and occupations of participants have already been described above. These are not necessarily representative of the group of prospective users for our systems. Therefore, we only use this information for interpreting the results of the survey.

Usability Problems: Observing dozens of participants interacting with our prototypes allowed us to identify usability problems and typical usage patterns. For example, we noticed that several participants had trouble with using the rewind feature of the *Tool* prototype. As reasons for this we identified a lack of visibility due to the table's wood grain as well as the design of the feature itself. Furthermore, sometimes participants occluded projected content when leaning across the table or reaching for something on the tabletop. We documented such issues and will use the information to improve the systems.

Public attitudes: Participants' reactions to the first prototype (*Augmentation)* – depicting calorie and nutritional information of foodstuffs – can serve as an illustrative example of the kind of data we gathered. As the participants explored the prototype, several discussions arose on the question whether depicting calorie information might support techniques of digital self-tracking and quantification of the body that may have negative effects on some people, e.g. by promoting eating disorders or leading to incorrect assumptions about achieving or maintaining a healthy body weight.

However, those participants who rated this kind of information negatively were in turn positive in favor of using such information if medically necessary, e.g. for people with diabetes, food intolerances or other conditions that require close monitoring and classification of the food consumed. The different and opposing opinions we found caused us to reflect on whether and how to display such information. Another example: in several cases, the virtually interlinked tables of the *Collaboration* prototype caused participants to discuss whether digital technologies might facilitate social alienation processes by reducing direct interpersonal communication.

In the survey we aimed to collect public attitudes by asking the following four questions:

(1) What did you like about our prototypes and what can we do to improve them?

(2) Would you have concerns when using an interactive table with a camera-projector system? And if so, which ones?

(3) What would you want from an interactive table in order for it to enrich your everyday life?

(4) How did you find our exhibition? Do you have any suggestions for improvement?

As expected, the results we got from the survey were much less detailed and informative compared to the in-depth conversations. For example, regarding question (2) about participants' concerns, 22 of 50 respondents mentioned data security as one of their main concerns regarding the use of interactive tables. However, they rarely explained what specific concerns they had in regard to it. Thus, the results of the survey with regard to public attitudes rather served to identify topics for further investigation in upcoming workshops, interviews, and exhibitions.

Outreach

The third main goal we pursued with the pop-up PD exhibition was showcasing our research to the public and establishing new communication channels with participants.

According to the survey, 86% of respondents had not experienced interactive tabletops so far; for 58% this concept was entirely unknown.

83% of respondents who offered feedback 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.

We also asked participants to leave their contact information afterwards in case they would like to stay in touch with the project or want to participate in further studies. Unfortunately, we lost this list of contacts due to human error.

To us, this suggests that the exhibition at least reached the goal of getting people interested in our research and that our presentation concept was well received. As we had no way of following up with most of the participants, we do not know whether the exhibition had a lasting effect, however.

Discussion

As the exhibition was our first attempt to combine science communication with participatory design, 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.

Participant (Self-)Selection

The primary reason for setting up a pop-up PD exhibition is to reach new, diverse audiences. Interviews and questionnaire 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 seemed to be 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 PD formats. 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.

Participatory-ness

While the most ostensible goal of the exhibition was to showcase our research project and prototypes to an interested public, a major goal for us was also to use this opportunity to initiate a PD process. The in-depth conversations gave participants the chance to explicitly shape the direction of the research project and the applications to be developed. 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.

Nevertheless, the conversations and demonstrations established a relationship between participants and the research project, serving as a first step towards including them in future PD events. For example, several participants actively suggested collaborations or asked to be involved in further design workshops. Thus, 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* [@Frauenberger_Foth_Fitzpatrick_2018].

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 allows us to iteratively improve how we approach these interactions and serves as a foundation for further developing the concept of pop-up PD as well as future PD methods in general.

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 started our 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 PD 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 in-depth 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"* [@Niewohner_2016, 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 within the team.

Moreover, while we documented people's reactions to the exhibits, we opted not to interpret them as indicators of actual enthusiasm. It does not make much sense to collect isolated reactions such as, *"oh, that's exciting"*, *"very interesting"*, since they might function more as a communicative device to affirm and support the ongoing conversation than as an opinion on the presented scenario or use case. Nevertheless, the very positive feedback from the questionnaire indicates that participants indeed did enjoy the guided tours.

Group Size

Due to COVID-19-related hygiene regulations, 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 (Figure {@fig:group}).

While we initially worried about the lower throughput of participants, we found that this restriction supported our goals very well. The in-depth 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. For example, a participant might start a dialogue with their partner about how a certain scenario might be of use for their personal work routine or a hobby of the partner. In the questionnaire, several participants explicitly mentioned the personal atmosphere within the individual guided tours as a very positive experience.

For pop-Up PD exhibitions we therefore found it surprisingly valuable to conduct guided tours with very small groups of participants where members already knew each other. Reasons include:

- Conversations grow more organically than in diverse groups
- It is easier to adapt the conversation to different participants and their respective interests
- It stimulates more open, intimate and self-reflexive discussions
- Interaction dynamics and their influence on the data gathered can be documented easier and in more detail
- Repeating the same choreography many times a day creates more opportunities to refine presentation, documentation, and observation methods compared to more elaborate formats such as focus groups or design workshops.
- Staff can customize the presentation and questions for groups of participants, such as families with small children, professionals, students, the elderly, or couples.
- People might feel less “caught” in the situation or/and under pressure to deliver “valuable” information

Given these positive experiences, we would not suggest adapting the format to increase participant throughput. Making the groups larger would make in-depth conversations harder. Letting visitors explore the exhibition on their own would lead to less engagement and less opportunities for ideation and user research. Conducting multiple tours in parallel would limit the time for in-depth discussions and would require significantly more personnel and coordination.

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, and the projection setup was mounted on the ceiling, participants oftentimes did not notice the setup at the beginning. When the guide then handed food items, such as

an orange, to participants and asked them to place these items 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 tried it out 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 the second application featured by the *Tool* prototype – scrolling through a video replay of their previous interactions on the table – 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 tried out 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, 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 in society or how to involve the public in scientific research endeavors.

Overall, we were very satisfied with the order in which we set up the demonstrations. It seems 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 food items on the first table caused initial conversations to focus on application scenarios and use cases regarding food preparation. For this reason we sometimes had to highlight that the depicted scenario was only one of many possible application scenarios.

As this was the first public showcase of our research, we did not want to include explicitly dystopian use cases – e.g. concerning surveillance or information overload. However we think that presenting scenarios that highlight potential problems and dangers of a concept 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.

Observing Users

In our experience, this format fills a gap between laboratory studies and in-the-wild evaluations [@Hornecker_Nicol_2012]. Compared to lab 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 the encountered problems and possible solutions.

Generating Ideas

One of the main goals we pursued through the conversations was to learn more about novel use cases for interactive tables as well as to identify issues that are important for a subset of users. In order to learn more about novel use cases, 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. The discussions revealed numerous 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.

As mentioned above, many of the concrete ideas were in some way new to us and help us in developing realistic and practical usage scenarios for interactive projected tabletops.

However, the ideas, opinions and/or doubts of most participants stayed within the context of the examples we presented. For example, when discussing the *Tool* prototype, some participants talked about how its application could help increase efficiency in workflows and how the system could avoid fabric to be wasted. However, none of the participants questioned the environmental footprint of the projector system itself. Therefore, we often asked follow-up questions. This eventually led to a mixture of rather abstract and very concrete ideas and scenarios.

Overall, pop-up PD is able to document a larger number of diverse experiences than traditional focus groups or in-depth interviews. However, the information is much less structured than that of a survey. In order to make the heterogeneous ideas gathered through a pop-up PD exhibition usable within the design process, researchers need to invest significant effort to filter, structure, and reflect on the outcomes.

Interest in the technology itself

A noticeably large number of participants[7] showed interest in our technical setups. For example, we were asked how object recognition works, what neural networks are, or how the camera-projector-system will be able to recognize personal objects it was not trained to recognize.

[7] No quantitative data collected.

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 [@Lawson_Kirman_Linehan_Feltwell_Hopkins_2015]. We had the opposite experience. A large number of participants were both interested in technical details and 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.

Strengths and Limitations of Pop-up Participatory Design

As discussed in the previous sections, the combination of demonstrations, observations, conversations, and questionnaires facilitates ideation, user research, and outreach at the same time.

Instead of providing clearly structured answers, pop-up PD especially helps to raise questions and bring forth ideas that would otherwise not have been asked or found. Furthermore, planning and conducting a pop-up PD exhibition requires that developers and ethnographers make their understanding of the topic of research explicit. Especially in the early stages of a project, a pop-up PD exhibition therefore might serve as a catalyst for internal reflections and alignment of mental models among team members.

As interactions with participants are short and repetitive, they allow for iteratively improving communication strategies and observational methods. Furthermore, frequent and diverse shared observations during the tours allow team members to gain and ensure a shared interpretation of phenomena.

Pursuing all three goals at the same time requires good planning and necessarily reduces the amount of time spent on each of the goals. However, 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 pop-up PD exhibition is 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. Therefore, constant reflection of these effects is necessary.

The target audience must be appropriate for both PD and pop-up science formats. They need to be both intrinsically interested in the concept and knowledgeable enough to provide valuable comments. Compared to traditional PD formats, such as design workshops, pop-up PD offers a typically larger and more diverse audience that can be recruited for further workshops. However, it requires significantly more planning, standardization, and preparation. It also requires more communication both between researchers and with participants. This additional effort is rewarded with opportunities for science communication and community-building.

We also found three additional benefits of pop-up PD for our research project that might apply to other projects:

- 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. Also, the exhibition required us to optimize the prototypes so that they would keep working smoothly the whole week.
- The exhibition was not only a chance to engage with the public but also to invite collaborators, stakeholders, and colleagues and discuss the project with them. These scheduled demonstrations helped strengthen and refresh professional connections.
- Planning and setting up an exhibition together proved to be a valuable team building exercise that helped with integrating new team members. The process of conducting a pop-up PD exhibition and reflecting on the process contributed to the mutual understanding of scholars coming from different disciplines.

We found the primary and secondary benefits of this format to outweigh the additional effort required to set up the exhibition. Especially in early stages of an interdisciplinary research project, a pop-up PD exhibition might serve to build a shared understanding of the topic and determine a roadmap.

Especially for upstream technologies, pop-up PD offers an effective way of involving the public in ideation and discussion. It might be less suited for technologies and topics that generate very little public interest or require domain-specific knowledge that cannot be transferred within a short conversation. Therefore, the ideal candidate topic for a pop-up PD exhibition is easy to explain and of interest to a general public – e.g., AR/VR experiences or industrial design projects. Furthermore, pop-up PD might be a helpful framework for facilitating public political participation, e.g. on sustainable development or smart cities.

Conclusion

In this paper we presented our approach to pop-up participatory design and shared observations about the process and outcomes. While we can only report on one instance of such an event, the many guided tours we conducted allowed us to reflect on our approach 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 prototypes which showcased different aspects of our development goals at different levels of interactiveness and abstractness, allowed us to gain both concrete and abstract ideas. Providing an easily-accessible and interactive showcase of our work attracted a wide variety of intrinsically interested participants.

While pop-up PD can not replace deeper and longer PD methods, we find that it is useful as an early step in a longer PD process as it fosters internal reflection and allows for collecting a wide range of ideas from a large group of potential users. The exhibition format not only facilitates collaborative ideation but also observational methods, usability evaluations, and outreach.

Future Work

We see further need for research on the following issues:

- exploring how well pop-up PD works for different topics
- qualitatively and quantitatively comparing the outcomes of such an exhibition to similar events that focus purely on ideation, user research, or outreach
- experimenting with group size, number of prototypes, and modes of advertisement
- finding ways to identify and involve under-represented groups

Furthermore, we think it is necessary to further discuss the ethical implications of taking ideas and demographic information from visitors who might not be fully aware all the time that they are participating in a research project.

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