Noticing the Environment – A Design Ethnography of Urban Farming

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ABSTRACT

Sustainable HCI attempts to shift focus beyond humans, to care for both ourselves and our environment. In this paper, we build on this growing interest and contribute with a design ethnography of urban farming. We focus on practices of observing and gathering data about the environment which we frame as 'noticing'. In our analysis, three approaches to noticing the environment were identified, and design suggestions were developed for each approach: Green Thumbs (control-oriented), Dirty Nails (sensibility-oriented) and BeeNoculars (appreciation-oriented). The design suggestions, presented as posters, focus on ways to improve the alignment of the acquisition and display of data with the identified approaches. We discuss two themes: the noticing and balancing of systemic relations and needs, and sensory-rich experiences of the environment. The paper contributes to a broader discussion in HCI of how technologies could create a different understanding of and relationship to the environment.

CCS CONCEPTS

• **Human-computer interaction (HCI)**; • **Empirical studies in HCI**; • **Interaction devices**;

KEYWORDS

Noticing, Environmental Sensing, Ethnography, Urban farming

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1 INTRODUCTION

While technologies are often part of sustainability problems, there are possibilities to develop technologies that can help people relate to the environment in deeper ways. Previous human-computer interaction (HCI) research on sustainability has highlighted many opportunities for using sensing technology to notice, understand, and act more sustainably within the environment [27, 40, 46, 47]. However, this approach has been critiqued for being overly "technocratic" and "data-centric" [12, 28, 47] and for not fully supporting social processes [18, 19, 33, 35–37]. For example, by simplifying complex socio-environmental problems to matters of a few measurable parameters, or by distancing the user from the measured phenomena. As an alternative, researchers have suggested that people can notice and understand the environment in richer ways by using their senses and paying attention to the environment over time [7, 50–53], an approach that is described as "the arts of noticing" [80], here signified simply 'noticing'. To notice is to become aware of, and to treat something as worthy of recognition. This kind of noticing is a culturally and politically sensitive skill that recognizes the interconnectedness of ecological, economical, and cultural systems – and how these systems function from the perspective of multiple species. While research on 'noticing' critiques many conventional technologies, it simultaneously recognizes that there is a need for technologies that support a more open, rich, relational, social, and exploratory approach to noticing the environment [6, 50, 51, 62]. However, there are still fewer ideas of what such technology could be more concretely. Fewer studies exemplify how communities work with this deeper approach to noticing the environment. In this paper, we present three distinct design suggestions for 'noticing' based on an ethnography of an urban farming community in Stockholm, Sweden.

We have studied urban farmers as an example of a group that aims to reimagine our relationship with the environment [60, 64, 65]. In this paper, we report on a design project that was based on one year of participant observation. We found that many urban farmers intended to experience and understand their gardens by more deeply noticing the environment. We observed noticing practices such as feeling and seeing soil's moistness, attending to insect and microbial life and appreciating the cultivation site with all senses as a form of relaxation. Further, the urban farmers used technological devices such as thermometers, pH and moisture sensors, plant recognition applications, cameras, microscopes, and laboratory tests of soil samples to support and enhance their noticing practices.

Analysis of the acquired ethnographic data highlighted three approaches that the urban farmers adopted towards noticing the environment, which we called 'controlling', 'sensibility' and 'appreciation'. To better understand, illustrate, and design for these approaches we leveraged the design process as an analytical method through the development of three design suggestions, designated Green Thumbs (control-oriented), Dirty Nails (sensibility-oriented)

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and BeeNoculars (appreciation-oriented). We used these suggestions as points of departure for discussions with urban farmers to check if our design suggestions (based on their practices) were meaningful to them.

There are many ways of using design to illustrate the values and needs of a context, ranging from the functioning, concrete, or pragmatic to the speculative or utopian. In this paper, the purpose of the design suggestions is threefold (1) to illustrate ethnographic findings (2) to serve as discussion pieces (3) to suggest design possibilities that are potentially meaningful in the context. Here, the format as posters allowed us to suggest design ideas that aligned with the ethnographic findings and our research goals without taking into consideration engineering limitations. Nevertheless, we still wanted to imagine and discuss the detailed functionality of the suggested designs. This also implied that the design suggestions were discussed by participants as if they were real products with real use cases. The participants emphasized that this "concrete imagination" acted as a springboard to broader discussions related to sustainability, noticing and "more than human-centred design". Our method thus aligns with a tradition of using design suggestions (or speculative design) in ethnographic studies to characterize and engage with participants' culture, values, and experiences and think through their ideas about design [21, 26, 78] as well as traditions of using design to propose and critique design ideas for possible sustainable futures [18, 29, 69, 71, 77, 83].

The main contributions include the identification of three approaches to noticing the environment (as illustrated by empirical examples), design suggestions that explore these approaches, and a discussion of the opportunities and challenges for noticing the environment which these designs illustrate and provoke, particularly as related to two themes: the noticing and balancing of systemic relations and needs in a more-than-human world; and sensory-rich experiences of the environment.

The rest of the paper is structured as follows. First, background information on design for noticing the environment is presented, focusing particularly on the use of sensors in farming and gardening as guided by the emerging interest in "more than human-centred design" in HCI. Next, the methodology applied in the study is described, including the ethnographic participant observations, the process of developing the design suggestions and their use to engage participating urban farmers. The following (findings) section describes the three identified approaches, with examples from the ethnographic data and corresponding design suggestions. Each approach and design suggestion is discussed, with reflections of participating urban community farmers. A final discussion articulates the overall contributions.

2 RELATED WORK: DESIGN FOR NOTICING THE ENVIRONMENT

Sustainable HCI research is concerned with diverse aspects of how the production, use and disposal of computers and associated technology affect the environment, often focusing on ways to induce behavioural and structural change on individual, institutional and systemic levels [8, 9, 17, 24]. Motivated by this broad agenda, "more than human-centred design" has gained recent interest within HCI research [1, 4, 5, 18–20, 25, 31, 37, 82]. The study object of "more than human-centred design" is the mutual interdependencies of organisms (such as animals, plants, and microbes) and their relation to technologies. This focus on interdependence forefronts that many organisms, including humans, benefit from considering design spaces as holistic and relational. The purpose of "more than human-centred design" is not to focus less on human users but to expand the focus to include a larger set of organisms and their interdependencies. This implies, for example, that food may still be grown for humans (a human need), but this is done in modes that more holistically tend to the needs of the whole ecology or more-than-human system. One aspect that has been identified as important in previous research on "more than human-centred design" is the deep and attentive noticing of environmental needs as a first step in the care for others than humans [7, 47, 50–53]. This stance is particularly grounded in the work by Tsing [80, 81] who highlights that noticing is not only about seeing what is right in front of one's eyes, but also about perceiving how this connects to complex societal, economic and political structures and networks.

The design work described and discussed in this paper builds on previous research involving the construction of prototype systems to aid such noticing [3, 52, 53]. Here, examples include a hand-worn prototype used to sense moisture in the soil while mushroom foraging [50], and a device that senses temperature, humidity and biometric movement in soil and translates this into musical notes [51].

More generally, there is much work on how technologies can provide environmental information that may help us to act more sustainably [27, 40, 46, 47] and how such technology may be used by non-professionals to probe the environment with assemblages of low-cost technologies and materials [10, 39, 45, 49, 67, 72, 84]. While this research on environmental sensing has typically been technology- and data-centred, the field is broadening to include more social and societal processes and a focus on designing for richer sensory experiences. This broadening aims to involve citizens in the design of cities in a move away from sensor-supported technocratic decision-making to more participatory and sustainable approaches [18, 19, 33, 35–37, 49, 66]. Among several phenomena, this research has focused on urban farming from an explicitly stated 'more-than-human' perspective, in which plants, fungi, microbes, and animals are included as concerns for design. This perspective highlights the potential sustainability advantages of sensing, monitoring, and optimizing technologies while raising concerns about who—including other species—designs, infrastructure, interventions, and services are for, and who benefits from them.

There are additionally many related examples of sensing technology that are not explicitly designed for 'the arts of noticing' or as tools for tending to the more-than-human world. In the context of gardens and farms, systems notifying users when a plant needs water are commonly used in agriculture [23, 76], urban farms [15] and homes [63, 85]. For automation, these sensor systems are often combined with actuation devices such as microcontrollers [68], autonomous vehicles, or drones [42]. Some designs of such systems focus on the creation of completely controlled growing environments [75, 86] while others focus on the acquisition of environmental data in situ [50]. On a more detailed level, a related study [76] has identified four modes of commercial farmers' relation to environmental data: vigilance, seeking to control all aspects of

farming through data; efficiency, seeking to optimize the profitability and sustainability of farm operations; enlightenment, seeking "harmony with nature" via data-driven insights; and empowerment, asserting ownership of farm-related data and its use for personal and community benefit.

Overall, the opportunities for using computational technologies in urban farming and gardening are well researched within HCI [2, 34–36, 54–56, 58, 61, 62, 68]. However, they tend to focus on practical and social organization, while fewer studies focus on sensors, particularly beyond the most easily available such as light and moisture. These previous studies have found that sensing technologies are rarely adopted because, for example, sensors measure what growers can already perceive with their senses (e.g., moisture and light) or are experienced as impairing the aesthetics of gardening [55, 60, 62]. The design suggestions presented in this paper propose design modes that would better fit the context of urban farming in line with 'the arts of noticing' as called for by previous research. As such, this paper is situated in a diverse strand of HCI research that aims to leverage the opportunities of sensing technologies in ways that are experientially rich and meaningful when people relate to the more-than-human world (while being mindful that more technology is not always the right solution).

3 METHODOLOGY: DESIGN ETHNOGRAPHY

The work presented here involves an ethnographic study based on participant observation, development of design suggestions, showing them to urban farmers, and recording their responses (see Figure 2).

3.1 Research Site: Odla Ihop - "Grow Together"

This paper is based on one year of data from a four-year participant observation study of the urban farming community Odla Ihop ("Grow Together" in English) in Stockholm, Sweden. During our studies, the community has grown to five garden locations in or near the city. Most of our observations reported in this paper occurred in the first, largest and most central location in the English-style park Tantolunden. The community was selected for the study due to its particularly visible and central location in the city, which highlights its role in disseminating ideas about sustainability and urban farming. Urban farming is typically described as diverse practices of cultivating food in the city. Cultivation (or growing) is the practice of creating environments in which certain organisms (typically plants) can thrive. 'Gardening' is cultivation with aesthetic goals. 'Farming' is cultivation with the goal of food production. In the studied urban farm, both these motives were present. Hence, both 'gardening' and 'farming' is used to describe the practices of the community. The broader goal of the study is to understand these urban farmers' underlying values and motives, and their use of, and ideas about, interactive technology. The research inquiry particularly focused on the group's emphasis on community and permaculture (a cultivation philosophy and methodology based on mimicking and working with naturally occurring processes). It was communicated to the urban farmers that we were there to study their use of technology and that we were interested in understanding their needs and values to suggest or develop technology if suitable.

A common motivation for participating in the community is illustrated by the following quote "*I believe in this, a different way of growing than what is happening in many places today. The usual way, the conventional way. I want to be part of a different way of growing*." (W5). The urban farmers can thus be framed as activists who concretely act to change society. They imagine, explore, and act out practices that could be more widespread in a future sustainable city. In this public enactment, citizens (including design researchers) collectively explore alternative ways of producing food, noticing the environment, and being in the world.

3.2 Research design and motivation of method

Our broader studies with the urban farming community involved a variety of approaches. We observed actual technology use in the garden, developed physical prototypes and arranged co-creative workshops with members of this community, in which we applied chemical tests to measure nutrients in soil [64]. While some of these methods provide insights into experiences of using available technology, this paper reports a study where we used design to imagine possible near-future technology.

Our selection of this method builds on ongoing discourse in HCI research about the relation between ethnography and design [22, 41, 70, 74] that we briefly summarize before describing our study. Ethnography was introduced to HCI research as a method to inform the design of technological systems and recommend changes [70]. It is used to problematize existing settings and envisions future settings [70]. Insights from design ethnography have often been presented as "implications for design". However, this has been criticized as being reductionist concerning the rich material acquired in long-term ethnographic studies [22, 26, 41, 74, 78]. Instead, it is suggested that ethnographic findings could inform and be illustrated by more fully developed design suggestions because designs can embody rich aspects of studied contexts and are open to interpretation in a similar fashion to 'thick' [30] ethnographic descriptions. Design suggestions (i.e., not fully developed prototypes or products) are particularly suitable for this purpose as they facilitate focused attention to the essence of a practice [41, 45, 50, 78]. Instead of being limited by practical constraints, researchers can focus on formulating the optimal design given the culture of a studied context. Presenting design suggestions rather than more functioning prototypes or products is further beneficial when you are not sure whether these kinds of technologies should be developed for the context (in this case gardening and farming) for example due to the sustainability tradeoff in terms of resource use, or potential unintended consequences once the technology is in use. This method thus allows a balancing of the exploration of technological opportunities on the one hand and the risk of overt and misplaced technological solutionism on the other.

3.2.1 Analytical approach. Our analytical approach involved a creative process focused on core themes raised by the studied community, and potentially interesting design qualities and functions identified through design ideation. Insights were formulated by combining the ethnographic material and design suggestions on various levels of specificity by repeating, varying, and contrasting the design suggestions as representing competing perspectives embedded in the ethnographic data. The design suggestions can thus

Table 1: Individuals quoted in the paper.

abr.	Characteristics
M1	Man 20, studying at a technological university (reflected on the design suggestions)
M2	Man 50, working in a creative industry (reflected on the design suggestions)
M3	Man 40, teacher
W1	Woman 50, working in a creative industry (reflected on the design suggestions)
W2	Woman 30, working in healthcare (reflected on the design suggestions)
W3	Woman 70, retired
W4	Woman 50, founder of urban farm

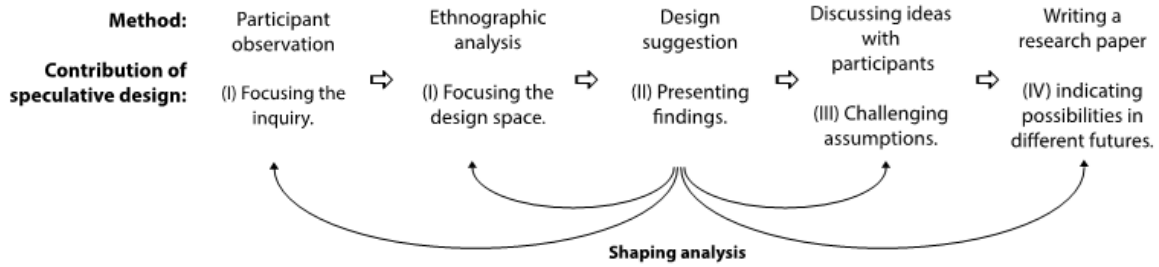

Figure 1: Stages where the design suggestions iteratively contributed to knowledge production.

be seen both as results presenting ethnographic findings (designerly thick descriptions) and analytical tools that provide further insights about the design space. As established in previous research [41, 44, 73, 79] the design work contributed to knowledge production by focusing the research inquiry and design space, presenting findings from the ethnography, challenging assumptions about the studied community, and indicating possibilities in different futures (see Figure 1).

3.2.2 Participant details and collected data. This paper is based on data acquired during the first year of a 4-year participant observation study, in which the urban farming association had 103 paying members. The community had an open Facebook group for public outreach with 366 followers and a closed group for more frequent updates with 382 members. Individuals in these groups partially overlapped. Workdays were arranged twice a week with typically 3-12 urban farmers participating. These participants varied between occasions and sometimes included citizens who happened to walk past and became interested. The 32 most frequently participating community members called themselves "The Stem" and had a third more closed Facebook group for discussing organizational matters. Much of the analysed ethnographic material consists of recorded observations and comments of these 32 individuals. Within this relatively engaged group, many still preferred to be assigned tasks (rather than taking their initiatives) by particularly engaged individuals. It is these most strongly engaged individuals who reflected on the design suggestions since they practised more advanced forms of noticing the garden (e.g., using sensors or articulating more profound emotional connections to what was noticed) (see Table 1).

Other collected data include field notes from 30 weekly visits to the urban farm, notes from 12 group meetings (60 pages), 347 images (excluding duplicates of the same event), seven videos of interactions at the urban farm (totalling 8 minutes), two audio recordings of group meetings in the garden (totalling 312 minutes), three audio recordings of guided tours (totalling 68 minutes), four audio recordings of open interviews about urban farmers' motivations (totalling 154 minutes), audio recordings of a vision workshop (180 minutes), and recordings from urban farmers' reflections on the design suggestions (totalling 107 minutes). All recordings have been transcribed.

3.3 Phases of the study

3.3.1 Participant observation. A main method of ethnography is participant observation, in which researchers not only observe the research participants but also actively engage in their activities [21]. The first author practised such participant observation both physically on-site with weekly visits, and virtually in the community's Facebook groups. Data from the participant observation are presented in the findings section as rationales for the design suggestions. Before ideating and developing the design suggestions, data from the participant observation study were openly coded by the first author by assigning thematic codes and reflections to sentences, paragraphs, and images from the ethnographic data [57]. The first author looked for general themes, but also more marginal examples that could act as inspiration or "fragmented images"'[3] of sustainable practice that could be more widespread in the future and be supported by novel design. This analysis revealed a broad set of potential themes related to the design space. The practice of noticing the environment emerged as a distinct theme in the data and was chosen by all authors to be explored further through design ideation. The three approaches of 'controlling,' 'sensibility' and 'appreciation' emerged during the design process when the

Figure 2: A continuum of speculation in design.

ethnographic data was analyzed in more detail as guided by the design work.

3.3.2 From observations to design. The design suggestions are grounded in the culture of the community rather than imposed by us as design researchers. However, as in any qualitative analysis or design process, it is our subjective interpretations of these practices that resulted in the design suggestions. Here, findings from the participant observations prompted us to seek alternative ways to approach interaction design for noticing the environment. For example, urban farmers expressed difficulty in interacting with touchscreens with soiled and wet fingers, and how smartphone apps intended to support the practice of gardening disturbed the overall experience of attentive engagement with the garden [65]. We thus wanted to ideate alternative forms of interaction design that were not only bound to the screen. We further found that the urban farmers were interested in knowing the composition of specific chemicals in soil, such as nutrients and pollutants. However, instruments for measuring concentrations of specific chemicals in soil are only present in laboratory settings [14]. Despite this limitation, we wanted to ideate on the possibilities for design and gardening if such technology was available in a consumer setting.

3.3.3 Design process. The design process included numerous iterations by the first author during six months of ideation, sketching and concept development. Approximately 40 rudimentary design ideas were sketched before the three design suggestions presented in this paper were refined to illustrate the approaches that emerged in the analysis and design process. The final design suggestions were chosen as they illustrated the three distinct approaches to gardening while being relatively technologically feasible compared to other initial design ideas. The final format of each design suggestion is a poster image and text describing the functionality of the suggested designs (Figures 3, 4 and 5). In this stage of our overall research project, we were more interested in the participants' general ideas about the design space, rather than their actual experiences of specific functionality. We thus discarded the idea of developing rough and half-finished prototypes that tested parts of the suggested functionality. Instead, the poster format was selected since we could present designed images of products that seemed real, thus encouraging participants to discuss the designs as if they were existing.

Here, it is important to note that all design is speculative until developed as an artefact. As illustrated in Figure 2 the design suggestions in this paper are placed somewhere in the middle of a continuum of speculation in design from commercial products to design fiction. Here, Figure 2 is used to illustrate a general tendency while real design projects are often more complex (for example, a speculative design may be developed as a functioning prototype).

3.3.4 Engaging with the community through design suggestions. An important aspect of using design as discussion pieces is to engage participants in the design suggestions and make sense of their engagements [44]. A central element of this process is the co-creation of narratives that emerge when the designer's materializations of ideas are experienced by participants or users [21]. Previous research has investigated user narratives created through engagement with fully realized artefacts in 'experiential scenarios' [16] or 'speculative enactments' [59]. Other research focuses on the narratives that can be spurred through presenting design suggestions as images, videos, posters, or brochures (e.g., [11, 13, 38, 43, 48]). The research presented in this paper aligns with the latter strand through the presentation of the design suggestions as poster images.

The poster images and textual descriptions of each design suggestion were presented individually to four urban farmers. For the Green Thumbs design, a sketch of a static web interface was presented, and additional clarification of functionality was provided if needed. The urban farmers were asked to expand on both positive and negative opinions and feelings towards the designs, compare the three designs and express ideas about their potential uses. The participating urban farmers highlighted that the design suggestions helped them to focus on the possibilities of interactive design and sensing devices, which they would otherwise have found hard to imagine or have an opinion about since three of them lacked experience of concrete examples of using sensing technologies in the context of gardening *"It has never occurred to me that you could sense all these things"* (M2). While the design suggestions propose data that could be sensed, they did not suggest what the data should be used for. It was up to the participants to imagine potential uses of the data.

Although the design suggestions were inspired by ethnographic findings, such as needs explicitly expressed by the urban community farmers, the urban farmers were not directly involved in the design process of these suggestions. Nevertheless, the design suggestions contributed to building long-term relations with the community by establishing ongoing discussions about design. For example, the urban farmers approached us with design ideas several months after participating in the discussions about the design suggestions:

> "We just got an idea for a cultivation/IT project we want to develop, and I think you might be the perfect collaborator! [We imagine it to be] like GoPro [cameras] on our heads when we grow, twisted into game and interaction /. . ./ I thought that you might like this idea, thinking of those designs that you made. (W2)

The design work presented here thus acted as the first step towards a more participatory engagement with the community (see our related studies [64, 65]).

4 THREE APPROACHES TO NOTICING THE ENVIRONMENT

In this findings section, three approaches to noticing the environment are presented and illustrated by a corresponding design suggestion. Before describing each design suggestion, its rationale is grounded in ethnographic findings. The presentation of each approach and design suggestion is followed by a summary of the participating urban farmers' responses to the design. The design suggestion and related approach are then discussed based on the overall ethnographic findings and participants' reactions to the design suggestion.

4.1 The controlling approach

4.1.1 Practices of controlling. The 'controlling' approach refers to efforts to control environmental conditions as much as possible. This approach aims to decrease the uncertainty of cultivation by monitoring and controlling the whole growing process, thus supporting more consistent modes of production (as commonly applied, for example, in industrial monoculture). The ethnographic findings show that control can be increased by minimizing the risk of changes in the growing environment (for example by growing indoors) or by gathering data about a changing environment to respond accordingly. Some practices were quite simple, such as measuring the temperature of compost to enable appropriate care:

> "We had an IT guy who had a sensor in the compost and could sit at home and check the temperature. Then you rush down to intervene. You must pee on the compost [laughs]. And it's not just the heat of the urine, it contains water and nitrogen that the micro-life needs, their metabolism then increases the heat." (M3)

Other practices were more advanced, such as creating controlled and automated indoor growing environments with sensors and actuators to add exact, appropriate amounts of liquid fertilizers. A common element of these measuring and sensing practices was an inclination to discuss data and best practices for maximizing crop yields. Although the urban farmers described themselves as a permaculture community, which is typically associated with more holistic approaches to environments and meeting both human and ecological needs, not everyone within the community understood or adhered to these principles. The community was thus open to anyone interested in growing, including those who practised controlled indoor farming, for example. Given these findings, the intention of designing Green Thumbs was to highlight current and identify potential opportunities and challenges of a controlling approach to noticing the environment.

4.1.2 Design suggestion: Green Thumbs. Green Thumbs (See Figure 3) sense Ph-value, moisture (H_2O), oxygen (O_2), phosphorus (P+), potassium (K+), and nitrogen (N+) in the soil in addition to temperature (°C), light, humidity, and carbon dioxide (CO_2) in air. Several Green Thumbs can be connected in a network to sense the environment of a larger cultivation area. Acquired data are sent wirelessly to the social media application Common Ground, through which suggestions for improving cultivation conditions based on the current data are generated by Artificial Intelligence

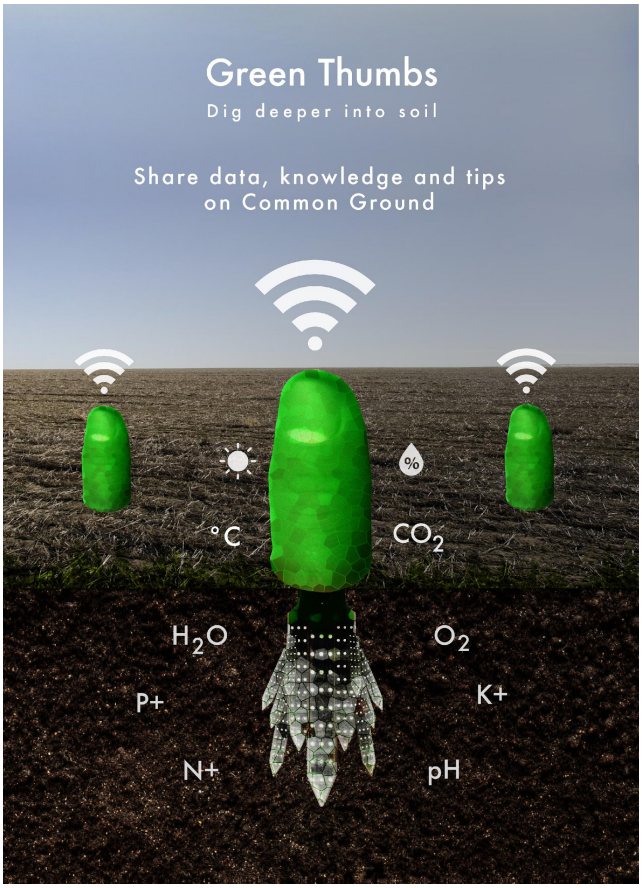

Figure 3: Green Thumbs design poster.

(AI) and a linked community of farmers and gardeners. The suggestions can be filtered by various farming philosophies, including permaculture, use or prohibition of genetically modified organisms, industrial monoculture, companion planting, biodynamics, and ecological farming. In a mockup interface (shown to the participants), application of the filter 'industrial monoculture' results in a display of an AI-generated suggestion to "add 1 dl liquid nitrogen fertilizer" to increase nitrogen while application of the "ecological farming" filter results in displays of suggestions from users in the community regarding composting or use of diluted urine to increase nitrogen contents (these suggestions are fictional but based on real observations in the study). Users can vote on the quality of suggestions by giving them a 'green thumb' or 'red thumb'. Users' suggestions are also accompanied by profile pictures and an indicator of other users' assessments of their suggestions.

4.1.3 Participant responses. All participants highlighted the practical benefits of the Green Thumbs concept. One urban farmer commented that *"It feels like a precision tool when you want to be sure that the crop will have a certain nutrient for it to be optimal"* (M1). However, the extent to which the urban farmers would use the tool was challenged by another participant who highlighted that she did not have the time or energy to thoroughly monitor and

control the cultivation process "*You can only cope scientifically to a certain point, then I let it be"* (W1).

Further, the different farming philosophies presented in the Common Ground application spurred discussion. For example, one participant said, *"It is interesting to present the philosophies in this way"* (M2). Two participants advocated for 'their' philosophy of permaculture, while the other two were more open to a diversity of philosophies. One urban farmer reflected: *"The philosophies seem to have a goal conflict, or how you get there. I don't know, I get the feeling that if you had Green Thumbs, it would be like a path for them to meet /. . ./ Green Thumbs feels like a scientifically developed thing that would lead to concrete answers to these questions"* (M1). Another participant raised concerns that diverse philosophies and focus on data may contribute to portraying cultivation as overly complex *"Is it only me who thinks that it is harder to cultivate the more you learn? It's good to have data but not necessary /. . ./ I want to tell all beginners not to be scared because of complex instructions. Continue to experiment and be happy about that which succeeds"* (W2).

Notably, the urban farmers were not sure if the product should be developed due to sustainability concerns. One addressed the negative environmental impact of producing new technologies, as follows, *"I like the idea of creating a network of sensors, but it seems very expensive and wasteful to produce all these sensors" (M2).* Another worried about a more specific environmental impact *"would the wireless signals damage insects?" (W2).*

4.1.4 Discussion: Diverse approaches to feeling in control. The Green Thumbs design illustrates how the same data can be perceived as providing various degrees of control, depending on how they are framed. Full control is impossible to achieve. In farming and gardening, unexpected events can always change the growing conditions. Thus, the perceived control is more about feeling up-to-date and capable of responding to the changing growing conditions than fully controlling them. Sensing technology can contribute to this feeling of control.

The filter function of the Common Ground application illustrates how responses to what is noticed in the environment depend on the farming philosophy applied. A power struggle involved in deciding the 'right' cultivation actions is highlighted by the voting system, which enables diverse farming philosophies, approaches, and practices to be advocated and juxtaposed with each other. More control-based types of farming (and associated philosophies), such as industrial monoculture, are contrasted to those rooted in appreciating, fostering, and developing relationality, such as permaculture, anthroposophy, and ecological farming. In the latter cases, the goal is to create conditions that promote relational ecological processes and allow the organisms involved to thrive, rather than controlling exactly what is going on. The participants claimed that these aspects of the Green Thumbs design contributed to portraying gardening as an expert practice with many rules and different philosophies that some urban farmers worried might discourage beginners from gardening.

While the Green Thumbs design portrays gardening and farming as complex practices in terms of philosophies, it simultaneously ignores many other aspects. Through focusing solely on what is numerically measurable with current (or currently feasible) sensing technology, the design simplifies the complex reality of gardens, providing no information on various other important and commonly discussed factors, such as insects, pests, and soil microbes. These factors are more difficult for digital devices to sense and interpret, since no single measurement can make sensible the interactions between billions of microorganisms in the soil, for example, or the visual and chemical communication between insects and plants.

In sum, the findings regarding Green Thumbs and the related Common Ground application illustrate the varying degree to which urban farmers aim to control the environment. In this process, interactive design may provide some control, while the perceived control may simultaneously be deceptive given the complex reality of gardening. The design further illustrates how the underlying farming philosophy influences what is noticed in the environment and how it is interpreted.

4.2 The sensibility approach

4.2.1 Practices of sensibility. The 'sensibility' approach refers to gardeners focusing on developing tacit and embodied knowledge, skills, and sensibilities over time. The ethnographic findings show that a core element of many urban farmers' practices was incremental development of gardening knowledge through practical work year after year, which fostered deepening sensibility to the local environment "*I go in and out every day to check on the plants and then some evening you forget and oh my god now they have frozen"* (W4). Urban farmers oriented towards a 'sensibility' approach were driven by the same desire to increase crop yields as those oriented towards 'controlling'. However, the sensibility approach was more intuitive and driven by trial-and-error practices. Further, the pure enjoyment of sensory engagement with the cultivation was a considerable motivating factor in this approach. For example, many urban farmers preferred to garden and touch soil without gloves, since this provided a richer sensory experience. Others used smell to notice aspects of the environment, e.g., fermenting leaves that were identified as rich in anaerobic bacteria *"most people think it smells good. Like a wet field. These bacteria are neither beneficial nor harmful, but an indication that the soil is running out of oxygen because it's too compact"* (W1). We also found that interacting with apps on touchscreens with dirty and wet fingers poses practical challenges. Touch interfaces on smartphones are simply not practical in a garden environment, and participants often mentioned that they impaired gardening aesthetics. Thus, alternative forms of interaction are needed. Given these ethnographic findings, the intention of designing Dirty Nails was to focus on situated, embodied and multisensory approaches to noticing the environment.

4.2.2 Design suggestion: Dirty Nails. When sensors attached to Dirty Nails rings, illustrated in Figure 4, are stuck in the soil, they measure phosphorus, nitrogen, potassium, pH, and oxygen, all of which play vital roles in the health of plants and soil microbes. The rings can connect to a user's smartphone through Bluetooth so exact measurements can be retrieved. If the 'play with soil' mode is activated the smartphone can present the acquired data in a sonic form.

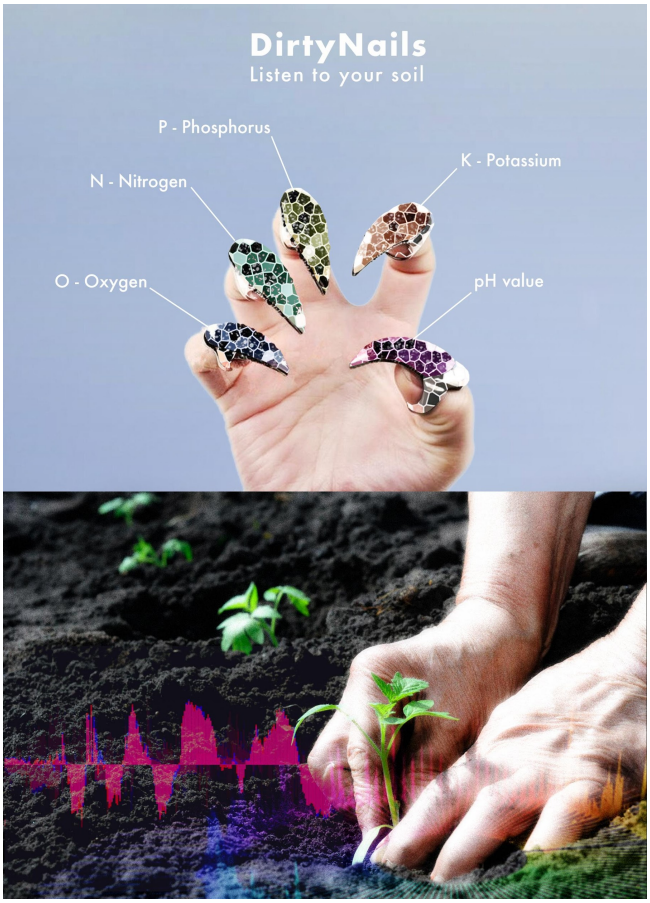

Figure 4: Dirty Nails design poster.

4.2.3 Participant responses. Opinions on the Dirty Nails design varied. One participant was "delighted" (W2) by the approach oriented towards sensory experiences, while more critical comments regarded the practicalities of the design and data presentation.

In terms of presenting data, participants were ambivalent about the representation of data through sound. They highlighted the value of "*being able to learn to think in a new way, experiencing things in new ways*" (W1) while showing caution that it might be *"a little more impractical"* (M2) to present data sonically since it could be hard not only to interpret the sounds but also to share the data with others. One participant related this to the general challenges of expressing tacit gardening knowledge. "*I think that gardening can be allowed to be something that you do, guided by intuition, but it can be hard to communicate that to others*" (M1). Another reflected on the concrete character of the sounds *"What would it sound like? Would it be harmonic and synchronized or would it be chaotic? Would it be more chaotic if the soil nutrients were not balanced?"* (W1). Given the relatively advanced character of the design, all participants highlighted that it seemed to be oriented towards particularly interested or expert growers. For example, one was not personally interested in using data in sonic form, although she highlighted its potential benefit for more *"established"* (W2) urban farmers who want to accelerate development *"I think that when you become more established in gardening and you want things to go faster, then the soundscape seems to have a function /. . ./ There is potential in this, that you may learn to assess things through sound. It may be like learning a new language and that can really have value, but it feels quite far away in the future"* (W2).

Further, one urban farmer highlighted a practical challenge related to cleaning the rings *"I would rather use Green Thumbs, this [Dirty Nails] seems flashy and a bit more impractical. Because it will. . . if you permeate the soil, the sensor rings will get dirty and you must clean them individually, I guess (M1).* He also mentioned a more personal reason for not wanting to stick his bare fingers in moist soil as this led to an uncomfortable feeling of dried out skin after a while *"I get phobia when my hands get like soil dry"* (M1).

4.2.4 Discussion: Sensory-rich and situated data collection. The Dirty Nails design shifts the focus from reading data on a screen to the experience of data collection. Using the design, the imagined user would be in touch with soil since the rings with nail-shaped sensors afford more direct contact with soil than, for example, a glove or shovel (see also the hand substrate interface in related research on mushroom foraging [50]). While one participant commented that such sensory experiences were uncomfortable or overwhelming, the other participants appreciated the idea of *"being part of the environment" (M2)* by sticking fingers in the soil. Further, the sonification of data in the Dirty Nails design can be conceptualized as both literal and metaphorical polyphony. Polyphony is a type of musical texture consisting of two or more simultaneous lines of independent melody. Polyphonic representation of data would force users to pick out separate, simultaneous melodies and listen for the moments of harmony and dissonance they created together. The design thus provides a very literal example of a previous observation that polyphonic noticing *"is needed to appreciate the multiple temporal rhythms and trajectories of the [environmental] assemblage*" [80]. Nevertheless, a polyphonic representation of data would require users to develop a skilful sensibility to the interactive context and the modes in which information about the environment is made perceptible. As expressed by the participants, this kind of sensibility is not necessarily easy to learn or share with others, so the design mirrors the engagement and hard work needed to develop the sensibility of an experienced gardener. An obvious limitation is that we did not present a potential soundscape to the participants, which makes the discussions about data perceptualizing through sound particularly speculative. In sum, the idea of Dirty Nails is to provide a sensory-rich experience including sound, touch, and vision, enabling the acquisition of environmental information through sensual perception rather than through reading data from a screen.

4.3 The appreciation approach

4.3.1 Practices of appreciation. The 'appreciation' approach focuses on the appreciation of, and direct sensory engagement with, other organisms through immersive and exploratory experiences that do not necessarily have a practical purpose. The findings show that many urban farmers valued relaxation and *"just being"* (W2) in the garden, as expressed both by signs on the cultivation site stating, "meditation space welcome" and by interviewed urban farmers "*to me, the purpose of gardening is more like ... a relaxation ... like*

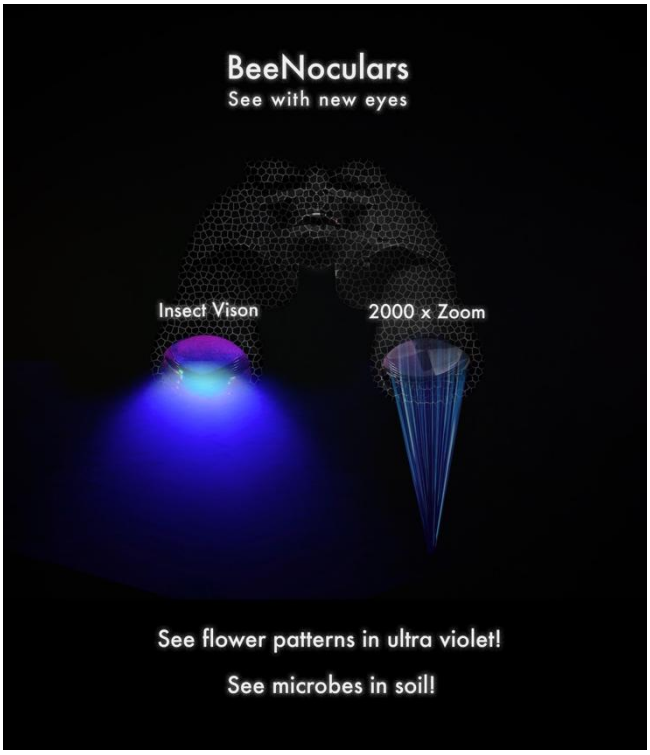

Figure 5: BeeNoculars design poster.

the meditative" (W5). From this perspective, the garden acted as a relaxing environment, but also as an engaging space to direct attention. Another urban farmer posted on Facebook *"It is a sacred ritual, working with the earth, and eating its fruits together to have the energy and strength to create an abundance we share. A sacred ritual disguised as a food production."* (W4). Further, many urban farmers valued exploration and experimentation for its own sake, motivated by experiences such as beauty *"this soil sample is so beautiful that I will hang it on my wall"* (M2). Given these findings, the intention of designing BeeNoculars was to create a tool with a particular focus on appreciating the aesthetic aspects of noticing the environment through expanding the human senses.

4.3.2 Design suggestion: BeeNoculars. BeeNoculars (see Figure 5) enable users to 'see with new eyes' aspects of the environment that cannot be experienced solely with the human senses. The first mode of seeing visualizes the ultraviolet (UV) spectra, revealing for example UV patterns on flowers. The second mode of seeing provides magnification up to 2000 times, enabling for example visual examination of microbes in the soil.

4.3.3 Participant responses. The urban farmers expressed that it would be "*super fun"* (M1), "*interesting"* (W1, M2) and *"exciting"* (W2) to see flower patterns in the ultraviolet spectra. However, some were concerned that the UV vision did not have practical utility *"Ultraviolet, I actually don't know what value it can have"* (M1). Others saw value beyond concrete use *"This shows just how precious flowers are. It's so magical that you want to grow even more"* (W2). Two participants recognized how UV-vision was presented in the poster as a capacity of bees, one claimed that it was *"interesting to see the world as a bee, in some ways they know more than us"* (W2). While reactions to the UV-vison varied, all participants found the microscope functionality more directly *"useful"* (M2). For example, one commented, *"You will perhaps be able to see microbes. If you get better at seeing what functions they have in the soil, it can also have a purpose."* (M1). However, it is usually difficult to tell a microbe's functions simply from its morphology, why this urban farmers' imagination of the benefits of using a microscope does not necessarily align with the benefits of actual use.

One participant further discussed the potential benefits of using Green Thumbs and BeeNoculars together, since this would couple *"causal relationships"* (M1) between observed phenomena (e.g., the composition of soil microbes) and sensor data (e.g., nutrient levels) *"like, if you used them together you would learn these kinds of causal relationships /. . ./ If you use them together long enough you would eventually, just through using BeeNoculars, be able to predict [the health of the soil]"* (M1).

4.3.4 Discussion: Expanding perception. BeeNoculars do not sense or present data. Instead, it provides a different lens through which to see the world – a shift of perspectives. The participants appreciated the BeeNoculars design both as potentially supporting aesthetic experiences and as concretely supporting their growing practice. The UV-vison was expressed to enable appreciation of the beauty of 'the other' (flowers) and the consideration of what it might be like to be 'the other' (bees). Seeing UV patterns on flowers was expressed by some urban farmers as a layer adding more beauty or *"magic"* (W2) to the experience of appreciating flowers. Arguably, appreciating the beauty of a flower or any other organism can increase motivation to take care of it, and in extension the whole environment. Further, the design triggered participants to empathize with bees not only on an intellectual plane (e.g., through awareness of the negative effects of habitat loss and toxins) but also through considering the experience of being a bee, of having 'bee vison'.

More practical benefits were ascribed to the microscope's functionality. Seeing microbes in soil was expressed to be an important way of assessing soil health and knowing what further actions would be required to care for it. However, the design suggestion also fostered a greater emotional connection to the microbial networks in soil, as one participant explained as follows, *"You become totally religious from reading about the network [between microbes, fungi, and plants] in soil. It feels like it will solve everything"* (W1).

Lastly, these participant responses show how the two modes of seeing enabled by the BeeNoculars design illustrate two different approaches. The participants' reflections on the UV vision most clearly illustrated the 'appreciation' approach, while reflections on the microscopic vision had a more practical character, aligning more with the 'sensibility' or even 'control' approaches.

5 DISCUSSION: NOTICING THE ENVIRONMENT

Like related HCI studies [21, 26, 78] we found the design to be a particularly useful way to characterize and engage with the participants' values and experiences and think through these ideas in a design form. We made several design suggestions to recognize differences and plurality within the urban farming community. In this

manner, the design suggestions fostered deeper attention to issues the urban farmers valued and found meaningful: sensory richness, attentiveness, and care for the environment. In this section, we discuss two particularly strong themes that emerged through our overall work with the community. One was noticing and balancing changing systemic relations and needs, while the other concerned sensory-rich and situated noticing that supports the feeling of being part of the environment. Both themes tie the practices and ideas of 'noticing' the environment more broadly to Sustainable HCI and "more than human-centred design".

5.1 Noticing and balancing changing systemic relations and needs

One aspect of living sustainably is understanding the consequences of one's actions over time and across space. While technology is often causing environmental destruction, it is also true that without technology we would not be aware of the cause of this destruction. Perhaps the most striking example is the global network of CO_2 and temperature sensors that provide data which shows the cause of climate change. Similarly, on a smaller scale in gardens, sensing technologies can help people to connect the cause and consequence of otherwise imperceptible phenomena.

Gardens are particularly interesting arenas for experimenting with sensing technologies for noticing since they are relational environments that host myriads of organisms. In these environments, humans are never fully in control, although some of the design suggestions, and many commercially available designs, might initially suggest this. Further, a garden is not a cohesive system with a set of fixed parameters. Instead, it encompasses multiple self-modifying systems that are constantly evolving and changing, with interacting variables that cannot be isolated. Given the character of gardens, it is not possible to crystallize general principles that provide universally best practices. Instead, the conditions of each garden must be situationally noticed and responded to in ways that tend to the needs of multiple organisms.

In such contexts, we need to present data to humans, so that they in the next step can act on this data and care for the more-than-human world or create designs that tend to the needs of several organisms. The design suggestions in this paper target this first step of noticing the environment. Here, the design suggestions raised questions about how sensing technology that enables zooming in on measurements of specific factors in the environment can simultaneously help users to zoom out, to see the broader and overarching connections and relations in a more-than-human system. The participants imagined many uses focused on noticing relations, networks, and entanglements in the garden. This could be associated with preconceptions of the participants who were committed to relational growing philosophies such as permaculture. Other kinds of gardeners might have imagined the meaning and implications of the same designs and data in different ways (i.e., less focused on systemic and more-than-human perspectives).

In sum, gardening is a practice of constantly balancing goal conflicts and tensions in a local system (e.g., using harmful pesticides or accepting lower yields), this implies that 'noticing' is about seeing not only what is right in front of one's eyes, but also complex relationships (including cultural, political, and economic) over time and across space. This is an approach that does not present simple black and white truths but rather weighs the pros and cons. It is "staying with the trouble," to use Haraway's [32] seminal phrase that has been adopted by design researchers [29, 73] to recognize use contexts as messy and full of conflicting needs. Ultimately, noticing in this context is about responding to a dynamic and open environment and learning from it. In such settings, design involves taking an explicit moral stance. However, this stance cannot be taken without awareness of the diverse needs in the design space. An awareness that could be strengthened by using sensing technology (while it is not only limited to technology). This paper contributes to the understanding and development of such technology by suggesting three potential ways forward (controlling, sensibility, appreciation) for designs that focus on noticing more-than-human interdependencies.

5.2 Sensory-rich and situated noticing

In the above section, we discussed how the design suggestions embodied and enabled the refinement of ideas regarding ways to notice gardens as interdependent systems. However, the design suggestions also triggered reflection on the situated experience of noticing itself. The design work based on the ethnography thus contributes specifically to HCI work that aims to create designs that help us to notice and relate to the environment in richer ways [3, 52, 53].

As exemplified in our ethnographic findings, humans can already experience environments in rich ways with their bodies and senses. Nevertheless, the design suggestions highlighted potential value in sensing technology that reveals aspects of the environment that are not directly accessible through human senses (e.g., UV patterns and nutrients in the soil). The urban farmers further appreciated design suggestions in which the interaction was physically close to the phenomena of interest and data were presented in sensory-rich ways. These findings suggest that to develop a deep understanding of the environment urban farmers do not only need data and structured information. They also need first-hand experience of being part of the environment and its interdependencies. It is important to ensure that data are correct, clearly presented, widely available, and contextualized, but this is not necessarily enough to provide a deeper understanding. Arguably, situated, and sensory-rich noticing can contribute to a richer understanding of a garden, and in extension design interventions that are more holistically attentive to the needs of the organisms in it. We need to design for "being with" the environment, in which bodily consciousness is an aspect of environmental consciousness. Related HCI research has studied the importance of such experiences that blur or dissolve boundaries between the experience of self and the environment [6]. They highlight the value of experiences of feeling part of the environment since people are more inclined to care for matters that they feel part of and connected to. Accordingly, we see designing for experiences of feeling part of the environment as a promising direction (e.g., sticking the sensor rings of Dirty Nails in soil or having "bee vision").

Regarding this aspect, the design suggestions highlighted a tension between the 'controlling' and 'sensibility' approaches. The controlling approach may reduce the need for labour through its

efficiency, at the cost of alienation from the context of use (and extensive resource use). In contrast, the sensibility approach requires much labour. However, this kind of attentive and sensory-rich labour was framed by the participants as an enjoyable and meaningful part of life.

In sum, the design suggestions illustrate that urban farmers see immense value in designs that let them explore their environment with all their senses (and beyond) in ways that support experiences of feeling part of environmental systems.

5.3 Opportunities for further design research on noticing the environment

While the main contribution of the design suggestions is discursive; they also encourage engineering efforts to digitalize and miniaturize chemical sensing to produce more meaningful soil-sensing technologies. Accordingly, a valuable step would be to explore the same issues with more tangible and functioning prototypes to gain insights into actual user experience as the ethnographic data indicate that facilitating the acquisition of sensory-rich and situated noticing is a particularly promising approach.

6 CONCLUSION

This paper presents an ethnographic study in which design methods were applied to explore and enhance 'the arts of noticing' [7, 50, 51, 53] in urban farming. While the need for technologies that provide a richer approach to noticing the environment has been identified in previous studies [6, 50, 51, 62] there is a need for a diversity of ideas on what these alternatives could be. The design suggestions presented here provide three concrete directions for future design.

The design suggestions were developed to align with the diverse motives, values and needs of urban farmers, expressed as three approaches. The controlling approach aimed to make exact measurements of as many environmental factors as possible (illustrated by the Green Thumbs design). The sensibility approach aimed to facilitate the development of embodied knowledge, skills, and sensibilities for noticing the environment over time (illustrated by the Dirty Nails design). The appreciation approach aimed to provide immersive and exploratory experiences of noticing the environment that does not necessarily need a practical purpose other than pure enjoyment (illustrated by the BeeNoculars design).

The Green Thumbs design prompted discussions on the construction and sharing of gardening knowledge based on diverse farming philosophies, in which the degree of assumed control of the environment was the main divider between philosophies. The Dirty Nails design highlighted how data collection can be a more active, embodied, and sensory-rich experience including several senses of sound, touch, and vision. The BeeNoculars design prompted discussion on aesthetically appreciating the environment through sensory engagement, particularly through technologies that reveal what users cannot otherwise perceive with their senses.

The main contributions are the identification of three approaches to noticing the environment, design suggestions that explore these approaches, and discussions of the opportunities and challenges for noticing the environment these designs illustrate and provoked, particularly regarding two themes. One of these themes was noticing and balancing systemic relations and needs. The other concerned the value of sensory-rich experiences in the environment.

In sum, the ethnographic findings and design work suggest that we might want to move from designs focused on controlling, and measurements that provide discrete environmental data, to designs that help users to notice interdependent relations in changing environments in sensory-rich ways.

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