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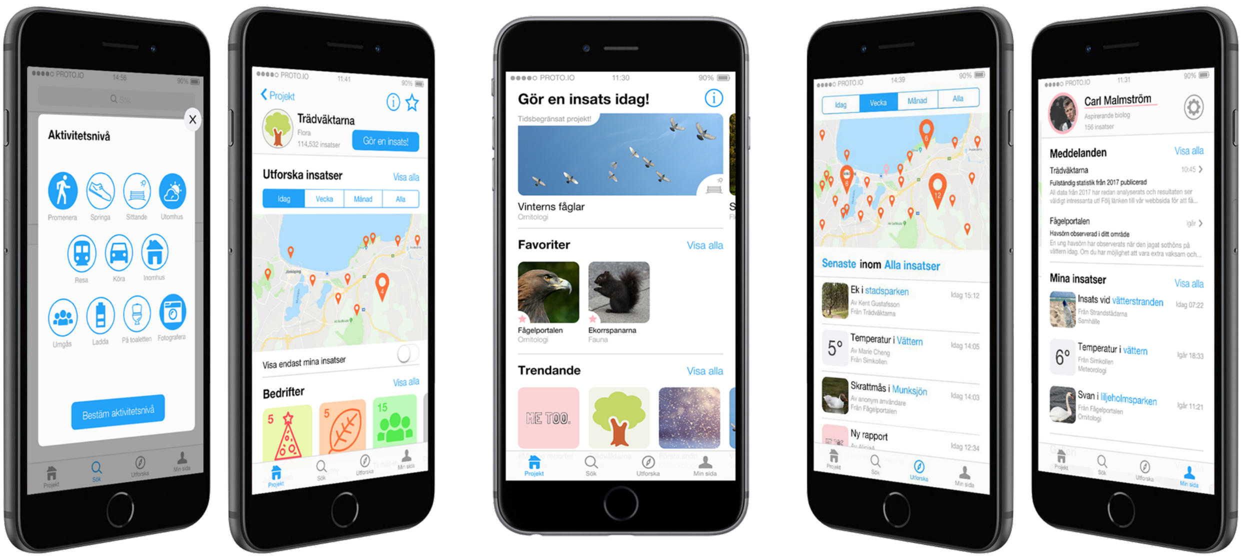

Making People Everyday Scientists

Designing a Context-Aware Smartphone Application for Citizen Science in Sweden

Masters thesis in Interaction Design and Technologies

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2018

MASTER'S THESIS 2018

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Abstract

Citizen science is at the periphery of the public's attention, but sees some participation from volunteers primarily motivated intrinsically. Research in the field has identified a need to better adapt the practice to fit into the daily lives of potential volunteers. This led to the formulation of this thesis' research question:

What should be considered when designing a context-aware smartphone application intending to engage the general public in citizen science practice?

The interaction design process that seeks to build knowledge around this problem is divided into two main phases. The initial phase focuses on extracting information and previous research on the subject, while the latter looks to implement and add to that knowledge. The second phase is an iterative design process, repeated three times, involving users to evaluate and inform the design.

In total 39 user tests and 4 co-designers influenced or evaluated the final design, which is represented by an interactive prototype of a smartphone platform application for Swedish citizen science projects. The design includes substantiated ways for users to find meanings in their interactions with it, most notably through actionable context-aware suggestions, inspiration in planning excursions, and an understanding of their local area and community.

If the design is successful in its intentions, which evaluations indicate that it could be, it would potentially represent a significant increase in public awareness and engagement in citizen science. This would not only advance research agendas but also be beneficial for volunteers' informal science education as they can incorporate citizen science practice in their daily lives.

Acknowledgements

First off, we are thankful to Kjell Bolmgren for sharing his vision and thoughts that initiated and guided this project. We will never forget the lovely moments together over Skype.

Thanks to Marisa Ponti for supervising the project and making our familiarization with the field of citizen science much smoother than it would have been otherwise.

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We would like to take this opportunity to acknowledge Staffan Björk and Thommy Eriksson for their efforts in examining and managing this thesis.

ありがとう to our opponents Tobbe & Pål, work hard and your dreams will come true.

Love and hugs to all our test users and co-designers. You are the best <3

Markus Jarlback & Carl Malmström, Gothenburg 2018

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Introduction

Citizen science is science where some or the whole part of the scientific research is carried out by amateurs or nonprofessional scientists [1]. The field of citizen science dates back to the early days of modern science but has grown rapidly in the latest decades [2]. There are several important underlying trends that have influenced this development. A growing number of individuals pursuing higher educations, an increase in leisure time and a large number of healthy retirees are all important factors [1]. Giving people access to web and mobile technologies have also contributed to the expansion of citizen science. With better and cheaper sensors integrated in modern smartphones, data collection becomes easier and more reliable.

Scientists in Sweden have applied methods involving citizens for a long time [3]. There are a few notable citizen science efforts, the most well-known among them being *Artportalen* (*The Species Observation System*), a database for observing species of animals, plants, and fungi [4]. With over 50 million entries it is impressively large in relation to the population of Sweden [3]. Svenska *Fenologinätverket* (*Swe-NPN*) also have multiple citizen science campaigns, the primary among them being *Naturens Kalender* (translates to *Nature's Calendar*) [5]. The volunteers in this project record signs of seasonal change to be used when studying climate change and its effects on the Swedish environment. *Swe-NPN* also involves school children in an annual citizen science activity named *Höstförsöket* (translates to *The Autumn Trial*) where students engage in tracking the changing color of leaves on autumn trees. Additionally, *Sveriges Ornitologiska Förening* (*Birdlife Sweden*) hosts a campaign called *Vinterfåglar inpå knuten* (translates to *Winter birds in the backyard*) [6] every January where volunteers record the birds present in their backyards. Every year approximately 20.000 volunteers participate to count birds.

Citizen science campaigns like the examples described above aims at achieving scientific progress by relying on volunteers motivated enough to dedicate their free time. Shirky [7] calls such free time that can be put to productive use a "*cognitive surplus*" among the population. Considering all time spent on passive (media) consumption, citizen science has huge potential reach and production capacity if it can find ways to divert attention from consumption and channel it into meaningful creation of scientific data and insights.

If the practice is to fulfill this potential, it is important to consider and counteract exclusion when designing citizen science projects [8]. Educated white men from the middle class are overrepresented in many citizen science efforts [9, 10, 11, 12], which consequently risk skewing the data and introduce biases in research agendas. A homogenous group tend to interpret the world similarly and may therefore miss details that a more diverse group would identify. Lack of diversity also leads to an uneven distribution of volunteers, for example across geographical areas. Many of the problems that citizen science projects aim to tackle affect the lower income communities and minorities harder, which makes the exclusion of their participation and input even more unfortunate [11]. In this regard, one can question the use of the term citizen science as it implies exclusion of one of the most exposed groups in a society: the people that see themselves as non-citizens, for example refugees and asylum seekers [13]. For them and others, citizenship is a heavily connoted concept. Some alternative terms used more or less synonymously with citizen science are public participation in scientific research (PPSR) [14], participatory sensing [15], and crowdsourced science [16]. This is one of many concerns that comprises the research discourse around the practice.

As the literature review in the background of this thesis will show, there has been extensive research on what drives participation in citizen science, especially in terms of motivations and learning outcomes for the participant. This research serves to increase knowledge about who potential volunteers are and why they participate. Recruiting and retaining as many and as active volunteers as possible is of primary concern for scientists, organizations, and other stakeholders in citizen science, as it determines the success of their scientific agenda. In line with more general trends within interaction design, investigating the potential of gamification applied to citizen science is perhaps the most prevalent effort that seeks to do so through elements and mechanics extrinsic to the scientific inquiry. Other notable areas of research interest in relation to citizen science is the use and presentation of open datasets, online community building, and informal science education, to name a few. However, there has not been enough, if any, research on the potential of context-aware mechanics and applications to advance citizen science agendas despite several researchers identifying the need to better integrate citizen science practice into the daily lives of volunteers [17, 18, 19, 20], and adapt it to different personality types or profiles of engagement [21, 22]. These needs motivate the extension of the citizen science discourse to consider context-awareness as a potential solution in this respect. Additionally, while volunteers might (or might not) be laymen in science, they can be experts on issues affecting their daily lives. Leveraging effective context-awareness for citizen science purposes holds not only the potential to increase participation and level of contribution to scientific agendas within established citizen science efforts but could also enable better study of matters closer to citizens and their daily life. To start investigating what role context-aware interaction design can play in citizen science, this thesis is set around the following research question:

What should be considered when designing a context-aware smartphone application intending to engage the general public in citizen science practice?

To gain knowledge relevant for this question the fundamental focus of this project will be to design and evaluate a digital platform application for smartphones, that through smart use of metadata, available open data and context-awareness attempts to increase the reach of citizen science projects in Sweden while providing users with engaging user experiences. Referring to it as a platform application entails that the application should seek to aggregate citizen science projects from different authorities or organizations and facilitate engagement and participation in them through a common interface.

Apart from applying and evaluating context-aware design measures in a citizen science setting, this project also serves a role in its effort to explore how separate citizen science projects can be aggregated and converged into more standardized practices, mechanics and interfaces. While similar efforts have been undertaken [23, 24, 25], calls for research and remarks on the potential resource-efficiency and synergy effects [18, 24, 25, 26, 27, 28] show that there is clearly a need for further endeavors of the sort.

Following this introduction to the problem that serves as a motive for this project, this thesis continues by outlining previous work in citizen science that needs to be considered to appropriately inform and frame the design situation at hand. Following this background, a theoretical chapter describes what it means to design human-computer interaction, context-awareness, and citizen science. After this, methodological descriptions and their implementation in the specific design process of this project are presented, to eventually lead to a resulting design proposal and associated evaluation findings. The contribution of this thesis lies in the knowledge of user experiences, behaviors, and opinions uncovered during the design process. This knowledge is both summarized in design guidelines and exemplified in a design proposal of a citizen science platform application. The thesis concludes by discussing the process and results, to ultimately give some pointers for future work.

Introduction

Background

Theory
Methodology
Design process
Results
Discussion
Future work
Conclusion

The background of this thesis is dedicated to a literature review that aims to introduce and describe the current state of the research area of citizen science to human-computer interaction researchers and practitioners of interaction design. As this project is an application of interaction design, and not a literature review of citizen science, it makes no claim to be exhaustive in this capacity. The underlying approach to source background material followed no strict methodology but originated from a list of 21 research papers and dissertations suggested by the project's academic supervisor, Marisa Ponti (Ph.D. at University of Gothenburg, whose research focuses, among other thing, on gamification in citizen science). The review was organically extended based on findings in these initial papers, and what authors and papers that were consistently cited in them. The process was allowed to continue until the return from examining additional papers eventually diminished as the review approach a relative saturation. The resulting literature sample that formed the basis for the following literature review is just over 70 papers. The findings from this sample is summarized in several subsections based on prevalently recurring themes and terms appearing in the literature. Before these subsections are presented a short section will introduce some basic definitions and terms to establish the vocabulary of the successive text.

Citizen science enables volunteers from the general public to contribute to and influence scientific agendas. This reflects a willingness to take science out of laboratories and researchers out of their ivory towers, in the attempt to make research more accessible by ordinary people, regardless of status, training, or credentials [29]. Despite the critique of the term citizen science, we choose to adopt it for this thesis because it is the most widely used and established term for the practice [13]. The authoring body of a citizen science project, be it professional scientists, governmental organizations, companies, or other individuals, will be referred to as project initiators. This term aims to be neutral to the origin and context of a project and should therefore be inclusive of all variation. Lastly, the non-professional participants that the 'citizen' part of citizen science refers to, we choose to call volunteers. As mentioned in the introduction of this thesis, the term citizen is far from inclusive and while volunteer have connotations to work activities and cheap labor, we find it inclusive and positive enough to use for lack of more established alternatives.

With these notions and terms established, the findings of the literature review can be presented and elaborated on. This background knowledge that previous research in citizen science has provided will be divided into a number of related subsections. Initial sections will consider the motivations behind project initiation and the enabling role that modern technology has played for citizen science. Following these sections, the motivations, level of participation, roles, and contribution patterns of volunteers will be covered, which leads to considerations of underlying factors such as the community around a project and its potential outcomes for science, society and the individual volunteers. After this, the sections on data quality and privacy elaborates on some common areas of apprehension for citizen science. Lastly, the findings on applications of the software mechanics of gamification and context-awareness in citizen science will conclude this research background and lead on to relevant theoretical constructs.

Project initiation

Primary motivations for scientists to initiate citizen science projects revolve around the unique possibilities that the practice offers, that is, producing and analyzing massive datasets at unprecedented rates and reach [30]. For initiators of citizen science projects there are challenges to overcome even after a project is successfully initiated, one of which is in the continuous communication with volunteers. It is the aim of the initiator to increase the volunteers' commitment to the project, and research claims that one of the most effective ways is to inform the volunteers about the goals of the project, the progress and the results [31, 32]. This can be achieved through direct communication such as newsletters [33] or through establishing a functioning community of volunteers that can exchange beliefs and experiences among themselves [31]. Volunteers in a project tend to have an ambivalent relation to the initiators, while they are viewed as trusted experts on the subject that volunteers reach out to for help and supervision [34], most volunteers consider the scientists intimidating [28]. Because of this, it is important to establish a good bi-directional communication to build trust [32]. Even with these challenges, citizen science is currently more accessible than ever to initiators and volunteers alike, thanks to recent technological advancements.

Technology

The increasing abilities and ubiquity of mobile devices, smartphones in particular, in the last decade has opened up new possibilities for citizen science [1]. The smartphones of today has numerous sensors integrated into their highly portable form, making data collection more accessible and comprehensive. Common hardware sensors include Global Positioning System (GPS), camera, accelerometer, and microphone. On top of that, the ubiquity of the Internet means that many smartphone users are constantly connected and have access to an abundance of information. While this represents an unprecedented opportunity, it cannot be relied upon for citizen science projects potentially involve observation in remote locations. In such cases it can be crucial to enable offline use and participation [25, 33]. To further reason about what possibilities modern mobile technology creates within citizen science, it is useful to study examples from a few existing applications.

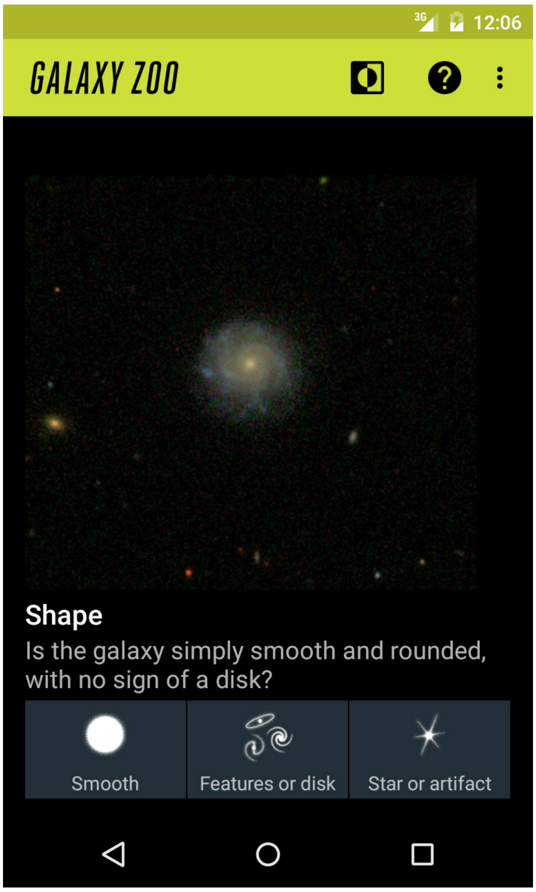

Figure 1. Image: Galaxy Zoo, Google Play Store.

Galaxy Zoo is a citizen science projects that relies on volunteers to classify galaxies. *Figure 1* shows a screenshot of their mobile application where they display a detailed, high resolution, image of a galaxy for effective analysis by the user. The application leverages the high-speed connectivity of smartphones as it quickly downloads new images on demand. And while the image takes up most of the screen real estate the design also accommodates supportive icons to aid the user in their classification, providing clear support in situ. *iNaturalist*, the application pictured below, has another method of volunteer support enabled by modern technology.

In their application, the project *iNaturalist* provides both supportive species information and the ability to record observations. *Figure 2* shows their interface for browsing species information, which effectively can replace the functionality traditionally carried by a physical encyclopedia. The memory and computing capabilities of modern smartphones should ensure quick and responsive user experiences for such browsing, even for large datasets. Additionally, *figure 2* again highlights how the high resolution of smartphone displays enables rich and detailed images which aids classification. In *figure 3* the observation recording interface of *iNaturalist* is depicted. The sensing capabilities of smartphones enable any user to easily record photos to be automatically complemented by time, date, and precise GPS location.

Figure 2. Image: iNaturalist, Google Play Store.

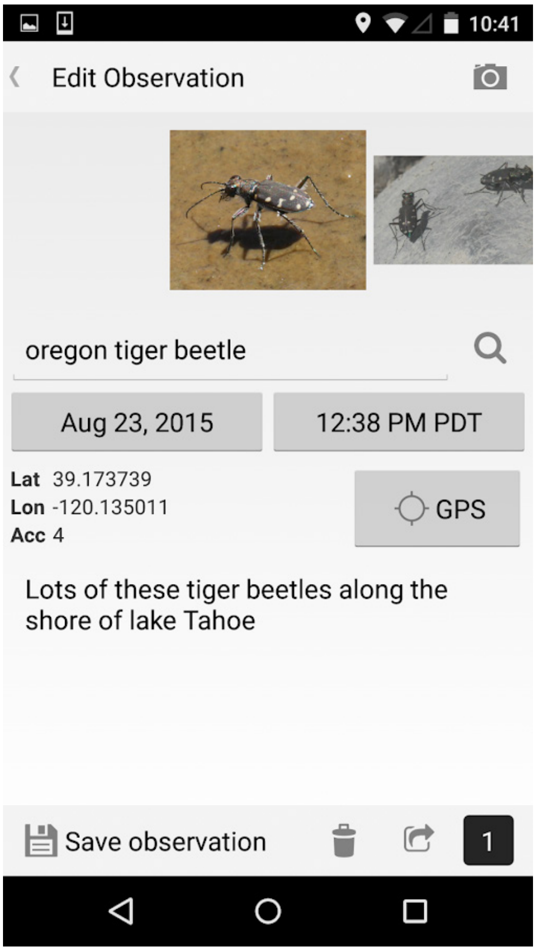

Figure 3. Image: iNaturalist, Google Play Store.

eBird's application is another example of the importance of knowing one's location. *Figure 4* is a screenshot of their app, where the interface is centered around a map enriched with pins marking bird watching locations, both personal and public. Smartphones can support volunteers' navigation, which can be important for citizen science projects if data is to be recorded from specific locations. They can also introduce more social dimensions of citizen science practice by connecting volunteers with each other, or as in the case of *eBird* informing of public bird watching locations. As these examples highlight modern technology opens up many opportunities for conducting and designing citizen science. To examine what these opportunities represent for the practice in reality it is relevant to change the focus towards the volunteers and their motivations to participate in citizen science.

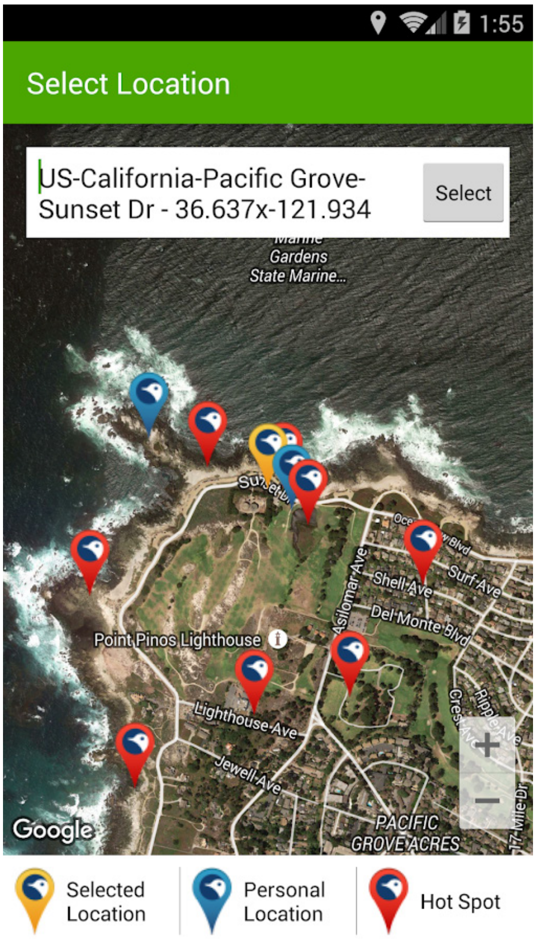

Figure 4. Image: eBird, Google Play Store.

Motivation

In order for volunteers to engage in any citizen science project, they must be driven by some motivation to participate. As citizen science by definition relies on volunteer efforts to sustain itself, there is extensive research focused on finding motivations behind participation and mechanics of recruitment and retention. Strong motivations can inspire volunteers not only to contribute, but also foster a deeper engagement and potential involvement in social activities connected to the project [35]. Motivations can be divided into two main categories, intrinsic and extrinsic. What distinguishes intrinsic motivations are that they are connected to the task itself, whereas extrinsic motivations depend on the result [35]. The participant's interests, values and curiosity are all examples of intrinsic motivations. Some extrinsic motivations are the value of the scientific outcome, the appreciation of the community, or other reward mechanisms. Previous research conducted on factors motivating volunteers in citizen science state that egoistic intrinsic motivations are the most prevalent, with interest in subject area and personal knowledge gain being especially salient [19, 21, 28, 31, 35, 36, 37, 38, 39, 40, 41, 42, 43]. The sense of accomplishing something good by contributing to science, which is an extrinsic motivation, is also a major motivating factor for many participants.

There are also many demotivating obstacles that have been shown to discourage volunteers to become or remain engaged in a project. Privacy concerns [44], a too difficult or boring task [41], anxiety over data quality [35], and difficulty to fit it into one's day-to-day life [18, 35] are all demotivating, but the most salient obstacle is perceived lack of time [38]. However, motivation and obstacles to participate are irrelevant without awareness of a project's existence, and some research suggest that lacking awareness is the main reason for not participating in a citizen science project [36]. If a volunteer is both aware of a project's existence and motivated to participate, this participation can take quite different forms depending on a number of factors relating both to the project and the individual volunteer.

Level of participation

Scientific processes consist of several steps and activities, which means that volunteers in citizen science can be involved in projects at different stages and to varying extents. A widely adopted distinction is that between contributory, collaborative, and co-created projects [14]. In contributory projects volunteers have the least amount of influence, acting merely as contributors of data within a project whose goals and methods have been set by the initiators. If volunteers are given more influence over project design and research questions, or contribute with higher-level analysis of data, a project is said to be collaborative rather than contributory. Lastly, co-created projects, sometimes referred to as citizen inquiry [36], represent the highest level of volunteer involvement and influence. In such projects volunteers have active roles in most, if not all, steps of the project's scientific process and its direction. This represents a potential democratization of science, as volunteers can attempt to influence and drive research agendas based on their personal situation and opinion.

Volunteer roles

The role of volunteers in citizen science differs not only in relation to the initiators', but also in relation to each other. There are examples of citizen science projects where explicit roles have been defined for volunteers to aspire to. Commonly, these roles are earned through contribution but do not represent greater responsibility, for example being promoted to captain of a ship in the Old Weather citizen science project [45]. Research has suggested that structures which pairs greater contribution to greater responsibility and higher task complexity could motivate volunteers and become a mechanism for them to move from the periphery of a community towards the core [31].

Even if such structures are not explicitly constructed by a project's initiator, volunteers might still adopt different implicit roles and take on different responsibilities within a project community [39, 40]. Generally, volunteers tend to take more responsibility and greater ownership in the cause over time [39]. Additionally, they might also focus on different aspects within a project based on their personality and interests. For example, some volunteers will prefer to collect data whereas others might focus their attention on discussing research goals and trends in the data. Because of these different behaviors some researchers question the one-dimensionality of the often-referred community periphery-to-core distinction [40]. They argue that even though some activities might go beyond the explicit goals of the project, they can still be important for its success, and that volunteers in different roles can make contributions that support each other's efforts in more complex ways.

Contribution patterns

As mentioned in the previous section, volunteers engage in citizen science in different ways. A few become deeply engaged and contribute a lot, while the majority contribute only a little [19, 31, 33, 46]. These typical volunteers are described by Eveleigh et al [35] as "*dabblers*" since they are likely to try out several projects for short periods of time, making no lasting commitment to any of them. The longer a volunteer dabble, the less likely they are to transition into a more active role [22]. While it is of interest for design in citizen science to try to convert dabblers into engaged contributors it is also important to adapt the system to encourage long-term dabbling, since most users behave like this. Designing for solitary and intermittent use has the potential advantage of attracting a large number of small scale contributors who can achieve a lot collectively. This is illustrated by the project *Galaxy Zoo*, where more than 200.000 participants by 2009 had classified over 100 million galaxies [42].

Even if participants only engage in a casual manner there is no reason not to design to try to make them recurring contributors. According to Jennett et al [41] volunteers are more likely to sustain their participation if they are involved in more aspects of a project. Initiators can increase the engagement of the volunteers by always offering new tasks [35] or providing a ladder of responsibilities to climb [31, 39]. Additionally, Geoghegan et al [39] states that direct, personal, and specific feedback is the foremost factor in keeping volunteers engaged in a project. Different channels such as websites, newsletters, email lists, social media and conferences are available for this purpose and it is of great importance to understand the volunteers and tailor the communication to their wants, both in the choice of channel and content. Lastly, another important factor determining prolonged activity in a project is the interpersonal relationships and sense of community that citizen science can offer [17], something which will be covered in more detail in the next section.

Community

The social factor is commonly stated as one of the least important motivations to volunteers as to why they contribute to citizen science projects [12, 19, 30]. Still, the sense of being part of a community can play an important role for the participants in some ways. Having other volunteers' reports to relate to increases the understanding of the data and the motivation to participate [34, 47]. Social relationships also play a part in spreading citizen science and creating a stronger sense of community around its practice [18]. Even though many volunteers rank social motivations to participate low themselves, the importance of having a community where interested volunteers can share experiences and beliefs should not be neglected [19, 31]. Being recognized and appreciated for your efforts is the most prominent factor for continued participation [28], and a strong community can provide such recognition and appreciation internally. It is often the most engaged volunteers that both contribute the most data and have the most active presence on the project's forums [35], which suggests that an established community can drive contribution.

This aspect becomes especially interesting when examining projects that are constrained to a limited geographical area. These locally based projects represent an exception concerning the importance of social motivations expressed by volunteers [30]. When the participants are geographically close to each other they tend to value a strong community higher. Studies also show that participants are more motivated to contribute to citizen science when it concerns their local area [37]. Some examples of successful local citizen science projects come from Pepys Estate, London [1] and Tonawanda, New York [26], where projects have tracked local air pollution levels with the intention to keep nearby traffic and heavy industry in check. Complementing wider scientific inquiries with specific and targeted efforts like these represents an opportunity to accomplish social or environmental change locally through citizen science practice. This represents one of the outcomes that citizen science projects can lead to.

Project outcome

What scientific and social outcomes a citizen science project aims to achieve can vary greatly. There are examples, like the ones mentioned above, whose primary goal is leveraging scientific practices to reach social change. Conversely, numerous projects accomplish scientific breakthroughs without any explicit social agenda. Some examples of this would be the Swedish ornithology project *Vinterfåglar inpå knuten* [6] and the astronomy project *Galaxy Zoo* [42].

Regardless of project goals there has to be a scientific analysis of collected data in order to approach any scientific conclusions. This can be accomplished by a project's initiators, volunteers or collectively between both groups. Even if the analysis is carried out in collaboration with volunteers it is important to publicize the results [35] so that the community can see what they have achieved and how they contributed to the scientific process. The collected data can be of use for other purposes than what is initially expected, and therefore it might be of value to release it as open data [34]. This is also in line with the generally open approach to science that citizen science projects tend to adopt. In the case of data reuse or publication, volunteers who contributed data should be notified so that it is apparent when, where and for what reason the data has been used [28]. Apart from a project's collective outcomes it can also have important outcomes related to the individual volunteers, perhaps most prominently in the shape of informal science education.

Learning outcome

Citizen science projects have been shown to contribute to the informal science education of the participating volunteers [14]. Studies show that the most common outcome of participating in a citizen science project is personal knowledge gain, mainly in the scientific field of the project but also in the scientific process in general [48]. In family-oriented projects, volunteers state that they engage for their children to develop and gain new knowledge [37].

According to Bonney et al [49], citizen science projects are excellent for developing scientific skills, even if the volunteers only engage in collecting data. Jennett et al [41] claim that the development of scientific literacy increases even more when volunteers engage in social activities in addition to contributing with data collection. In their view, the most important learning occurs when a novice formulates questions, acquires answers from the community and transforms into an expert volunteer, able to answer questions from new novices. In this process the volunteers also develop their social skills [48].

The development of skill sets and acquirement of both broader and deeper interests empower the volunteers as they can bring their new experiences and networks into new contexts [38]. It also represents an opportunity to make their voices heard to achieve social change through scientific practice [1, 26]. All of these learning and empowerment mechanisms are important to both individuals and society at large, but also within citizen science internally as experienced and skilled amateurs engage in new projects. Having volunteers build upon previous experiences and a developed scientific literacy is one way to achieve respectable data quality in citizen science.

Data quality

Since citizen science projects recruit volunteers from the general public, participants can be untrained and inexperienced in scientific practices. This circumstance has led to widespread skepticism about data quality in citizen science among initiators and volunteers alike [10, 44, 50]. However, studies have shown that volunteers can collect data of comparable quality to that of scientists and that it is always relevant to apply caution when examining data regardless of who collects it [10, 44]. Several methods to improve data quality have been proposed for implementation within citizen science. As a first step, participants should receive basic training in data collection, subject knowledge and the methods used in the project [28, 30, 44, 51]. Clearly defined data collection protocols that focus on objective measures is one way to ensure that the planned course of action is carried out and that the data should be reliable [44, 50, 51]. Predefined vocabularies and value ranges can further determine data input and eliminate errors like mistyping [52]. Personalized feedback on contributions can be given to volunteers to promote data quality [35], as it is an effective learning mechanism that also increases motivation to participate.

Furthermore, projects can implement data validation protocols carried out by experts on all submitted data [33] or by applying spot checks [30]. Volunteers that have a long and solid engagement in the project where they have shown to provide data of high quality can be recognized as expert users [11, 52]. Accounting for volunteer experience enables data validation to be achieved more efficiently as the data of expert volunteers likely is more reliable than that of novices. Furthermore, expert volunteers can also be given increased authority to participate in data validation alongside scientists [30].

Validation can also be volunteer driven, either by considering data to be valid after multiple independent and coherent reports, or by having volunteers themselves validate the data by marking others' reports either correct or questionable [30]. Having amateurs collect data can affect biases. On the one hand, such data can be less biased, as novices just report what they see, while experts tend to adapt their observation approach based on previous experiences [33]. For example, experts might "know" where to (and where to not) find certain species, and therefore conduct observations with preconceptions. On the other hand, volunteer participants are less likely to report negative results or absences [49]. In any case, involving volunteers from the general public makes it important to account for population distributions and how data collection protocols can influence the participants' confidence and abilities [46]. For example, if a project utilizes data validation through photographs, bias might occur if some sightings are more difficult to capture on photo. In cases where the data is not validated, data validation procedures are not communicated clearly, or the consequences of faulty data appear to be critical, the volunteer might refrain from contributing data at all if they feel doubtful about their ability. This is an important consideration and communication challenge for project initiators. Another discouraging anxiety that volunteers experience relates to their privacy in relation to data reporting, which is something that warrants its own section to explore.

Privacy

The issue of privacy must be taken seriously when handling data, especially when that data is collected by volunteers among the public. There are several possible issues connected to such data. The data could reveal details about the volunteer: current location, home address, patterns of behavior, or identity being some examples [34]. In some scientific areas the data itself can also contain sensitive information, for example revealing the nesting place of an endangered species [33].

The issue of privacy can be tackled from several angles, and initiators need to take it into consideration when designing a system. An interesting discussion is that of possible trade-offs between data accuracy and privacy [53]. While privacy concerns favor collecting as little metadata as possible, such data can be useful to improve data quality. One compromise is using different levels of data granularity for different purposes, where more accurate data is used for scientific analysis, while granular data is used for feedback and visualizations. Volunteers can also receive privacy training in the project, so that they understand the risks and what safety measures they can apply [34].

When data has been submitted there should be some form of review to make sure that it is safe. If the data contains pictures, faces should be blurred or removed [53], or if it contains a geographical position the submission could be delayed to avoid revealing a real time position of the user [34]. Location obfuscation, "fuzzy locations", could be used to further protect the integrity connected to a user's position. If data is being recorded over a period of time, it can be buffered until the volunteer explicitly submits it [53]. This way it is possible to review the data and avoid submitting sensitive or incorrect data. If no action is taken to submit the data, it should be discarded. In addition to all this, the system needs to be robust enough to withstand attacks, be able to sense if data is genuine, make sure that users cannot tamper with the data submitted by others, and prevent spam [20].

Bowser et al [54] contribute with some guiding principles regarding privacy in citizen science. Their suggested default practice is to strive towards collecting the minimum amount of data required for the project's scientific agenda. As such, they advocate for making deliberate choices concerning which data fields can be compromised with and clearly communicating these decisions together with what it means for the volunteers' integrity. Lastly, Bowser et al [54] promote giving volunteers control over their own data so that they are able to hide, anonymize, modify and delete their submitted data as they see fit. However, since data used in published research likely is archived to ensure reproducibility of results, volunteers' control has its natural limitations which are important to communicate clearly.

Gamification

The trend of gamification within the wider subject area of interaction design [8] has also attracted interest in citizen science as a possible answer to some of the issues with motivating, recruiting, and retaining volunteers [17, 19, 31, 39, 55, 56]. Gamification is often used as a collective term for the introduction of various game elements and mechanics in non-game applications [56, 57]. The extent to which something is gamified can vary from simply adding a contribution leaderboard to designing an entire game world and storyline around the scientific inquiry. In citizen science, the applications that have been gamified to such an extent that they are perceived as legitimate games on their own are commonly referred to as serious [55], purposeful [56] or scientific [25] games. Currently, purposeful games are far more common than gamified citizen science applications despite that not all tasks within citizen science are possible to make into games in an effective way [55].

An important realization in order to understand the appeal of gamification in citizen science is that reliance on intrinsically motivated volunteers imposes limitations on who can be recruited as a volunteer. While intrinsic motivations have been consistently found to be the most prevalent motivation among current citizen science volunteers, there are areas of scientific interest that fail to capture the imagination and curiosity of a significant number of members of the general public. In such cases citizen science initiators are forced to seek other means of motivation to gain any traction, but leveraging multiple motivating mechanisms should really be desirable in any and all cases, to increase the potential reach and success of volunteer recruitment and retainment. So, when further exploring motivating factors for citizen science contribution several researchers have found that the entertainment in the task itself is another important factor in driving contribution [17, 19, 31, 55]. Leveraging this potential to motivate volunteers through other means, purposeful games or even effectively gamified citizen science applications have been shown to be able to bypass the limitations imposed by reliance on intrinsic motivations [55]. It is however important to note that gamification, just like citizen science in itself, has problems with retaining interest over longer periods of time [28, 58].

While gamified elements might be crucial to motivate some volunteers, it can be uninteresting or even bothersome to those who are intrinsically motivated and participate out of scientific interest [17, 39, 55, 56]. As there are concerns that gamification can decrease convenience of use and increase the time-demands put to users [58], two of the previously identified demotivating factors, citizen science project initiators should carefully consider the risk of such effects before introducing elements of gamification, and perhaps employ opt-out mechanisms [17].

A relevant consideration for gamification in citizen science is the use of diegetic and non-diegetic rewards. This is a distinction between where the rewards have meaning and value, within a game setting (diegetic) or mostly outside of it (non-diegetic) [56]. Reconnecting to the different motivations among volunteers, diegetic rewards, for example unlocking new game worlds, can be important to retain volunteers interested in the game while coming across as useless to volunteers interested in the science. [56]. Non-diegetic rewards, for example achievements, can however hold some value to both groups, though it might be limited.

Research on how gamification can affect data quality in citizen science seems to indicate that there should not have to be an opposition between the two [56]. That is, as long as project initiators have considered the potentially corruptive effects of introducing scores or other metrics [58] and how to discourage and identify cheating behavior [56]. In conclusion, elements of gamification should not lead users to formulate goals that are in opposition with the scientific agenda and protocol [56].

Context-awareness

The origins and specifics of the term context-awareness will be explained in further detail in the theory chapter of this thesis, so for now an introductory definition will suffice to enable discussing its application within citizen science. Digital systems and applications that are responsive to their context of use are said to be context-aware [59]. Considering that citizen science encompasses a wide variety of contexts, deriving from the variety in research areas and practices, digital tools for citizen science are used in situations with diverse characteristics. Furthermore, as the practice relies on volunteers' motivation and effort, it should be of concern to initiators to make participation frictionless and flexible to avoid any demotivating experiences. Several researchers have identified the need to better integrate citizen science practice into the daily lives of volunteers [17, 18, 19, 20], and adapt it to different personality types [22]. As context-awareness has the potential to achieve this through adaptation based on individual users' context(s) of use, it is interesting to note that we could not find any examples of context-awareness being implemented in tools or systems for citizen science when conducting the literature review of this project. The investigation of context-awareness as a potential answer to the aforementioned problem, of integrating citizen science practice into daily lives of volunteers, encouraged the direction of this project. Subsequent chapters of this thesis will specify and frame this investigation theoretically and methodologically.

Introduction
Background

Theory

Methodology
Design process
Results
Discussion
Future work
Conclusion

This chapter will provide theoretical background to place the project in relevant analytical frames and substantiate its process. As it is a project in interaction design, situated in the research area of human-computer interaction (HCI), the chapter commences with some theoretical trends that has shaped HCI research and practice. This underpins the phenomenological approach that establishes and permeates subsequent sections on interaction design and its associated theories on participatory design, usability, and user experience. Introducing these theories should inform the reader of what the project considers important to know and how that knowledge can be attained and legitimized. It also serves a purpose in manifesting general design practices and processes, that predicate the specific implementation within this project.

Moreover, this theory chapter introduces definitions and theoretical constructs that allow for explanation and abstraction of context-aware behaviors and mechanics, notions which are central to the research question and design problem at hand. These theories help establish the design space and provide a language to use when considering context-awareness. To give further substance to the design space, the chapter concludes by outlining preceding guidelines and theoretical models specifically targeting citizen science. While such guidelines on citizen science project initiation might lack theoretical substance, they are succinctly summarized conceptions of established knowledge and best practices within the research area, and worthwhile to consider as such.

Human-computer interaction

Despite being a relatively novel research area, human-computer interaction (HCI) research has already seen several major changes in its epistemology and methodology since its inception in the early 1980s [60]. An interesting observation and abstraction to be made with the benefit of hindsight concerns how the metaphor for interaction has evolved during this time. Harrison et al [61] explains how the interaction metaphor within HCI has moved from a coupling of man and machine, through a symmetrical model of mind and computer being information processors with different characteristics and constraints, to reach the contemporary metaphor of interaction as phenomenologically situated, defined by the experiences of actors in contexts.

Taking this evolution of interaction metaphors as a starting point, Harrison et al goes on to draw up the development of HCI research into three paradigms, each building upon the last [61]. The notion of such paradigms is based on theories presented by Thomas Kuhn [62], who sees scientific revolutions as being built through succeeding waves of new insights that with the foundation of established ideas introduces novel perspectives and framings that does not replace, but fundamentally changes, the discourse. In Harrison et al's argument, each HCI paradigm contains an accepted set of significant properties of interaction, related questions that are judged as interesting and answerable, a spectrum of methods used to reach valid answers to those questions, and finally a general recognition of how to understand the results of those methods.

In what is called the first paradigm of HCI, the focus is on how well humans and machines fit together in their interaction [61]. This follows from the metaphor of a coupling between them and leads to questions about mismatches and poor fits in the interfaces between computer parts and human bodies. Answers to such questions can be reached by leveraging the methodology of ergonomics and human factors, and results are interpreted as pragmatic solutions to the ill-fitting coupling.

Harrison et al goes on to describe how the evolution of the interaction metaphor into a symmetrical model of mind and computer is crucial to what they call the second paradigm in HCI [61]. In this analytical frame information is central, and questions emerge from how information is communicated, interpreted, and processed by a computer as well as the human mind. This brings HCI into the realms of cognition, and from the metaphorical description of interaction it can be inferred that the human mind is considered a machine for rational thought and analysis.

Acting within an analytical frame built on a common understanding of significant properties of interaction and what questions are relevant means that other properties and questions risk becoming marginalized. While this is hardly done on purpose, focusing on some aspects inevitably leads to other areas ending up in the periphery of attention. Harrison et al highlight some questions that are mostly kept at the margin during what they call the first and second paradigms of HCI. These questions mainly concern non-task-oriented activities and things difficult to analyze as information [61]. This would mean that aspects such as human emotions and fulfillment are overlooked. Furthermore, it is questioned how context, in the full richness of the term, is allowed to take its appropriate place in HCI of the first and second paradigm. Instead they imply that both situated use and social aspects of use have been neglected on the grounds of being unspecifiable and uncontrollable.

Addressing the problematic consequences of such a position, and to complete an evolutionary description of HCI, a quote from Harrison et al [61] succinctly outlines a fundamental stance in what they call the third paradigm in HCI:

"... the way in which we come to understand the world, ourselves, and interaction derives crucially from our location in a physical and social world as embodied actors."

In this paradigm, "*the goal for interaction is to support situated action in the world*" [61], and neither interaction nor users or systems exist in isolation. Interaction is deemed too complex and rich to narrow down and evaluate through task-based efficiency judgements, as doing so risks losing the crucial influence of context. Furthermore, it is argued that doing things in the world cannot be seen isolated from thinking. This implies both that interpretation and abstract thinking is a crucial step in the doing, and contrary that thought processes can be embodied into actions. This analytical frame and phenomenological matrix of what is called the third paradigm of HCI is where this project is situated, which motivates a more thorough exploration of its essential viewpoints.

In contrast to earlier paradigms, the construction of meaning is central to the third and viewed as something that develops dynamically both for and through interaction based on the specifics of situations and users [61]. Furthermore, the shift towards a perspective of users as situated actors calls for an acknowledgement of Haraway's theory of situated knowledge [63]; that one's understanding of the world and oneself depends on physical and social situations. In consequence, this means that users will have different outlooks and a designer should study, understand, and allow for this diversity rather than try to design and validate a single correct understanding and usage [61, 64].

When considering what implications Harrison et al's [61] third paradigm of HCI has for systems and interfaces, it is appropriate to return to the notion of everything being situated and in consequence ineffectively studied in isolation. This prompts for adaptation to context in the design of systems, either by adapting the design to a set of probable situations or by implementing context-aware behaviors to enable the design to adapt dynamically. How to define and consider context and context-awareness in design is explored further later in this theory chapter, and for now it suffices to note the central role context has for problem definition, design, and evaluation within the third paradigm of HCI [61].

To conclude the theory of a third paradigm of HCI and make its implications for this project clear, it is relevant to look at what questions can be considered interesting to ask and how to interpret results to measure success within this analytical frame. Harrison et al [61] touches upon some such questions, for example "*what existing situated activities in the world should we support?*" and "*how do users appropriate technologies, and how can we support those appropriations*?". Another question that should be relevant considering the research question at hand is in what potential ways users can find or construct meaning in using a system like this, and how to design to enable that. Considering the centrality of context, both in the definition of a third paradigm of HCI and in this project, answering questions of which aspects of context is significant and how should also be of utmost interest. According to Harrison et al, the way to answer this kind of questions is to strive for situating design and evaluation methods in contexts relating to the real world and real uses, and look for results, i.e. knowledge, in the form of rich descriptions and "care-abouts" [61]. This knowledge can then through interpretation and discussion be related back to the questions and an attempt to build an understanding of the answers can be made.

Interaction design

The previous section explored theories of human-computer interaction (HCI), and how different metaphors for interaction can yield different agendas and approaches to research within the field. Interaction design is intimately related to this discourse around HCI, as it can concern the design of such interactions [65]. In this context it can be worthwhile to further examine how the term can be defined and what theories on its application that exists. Design is a notoriously difficult term to define [66], but a widely recognized definition that the authors of this thesis also identifies with is that formulated by Charles Eames [67]:

"One could describe Design as a plan for arranging elements to accomplish a particular purpose."

Picking this definition apart, one might ask what elements are to be arranged and what arranging them means. This is not a particularly interesting question, because the elements and their methods of arrangement simply vary depending on what is to be designed. The elements can be said to be the material of the design situation, and naturally different materials allow for different methods of transformation and organization in order to reach a desired arrangement. Here an uncomplicated way to constrain the general term design into the more specific term interaction design is exposed; interaction design can simply be said to be design where the material of the design situation is both digital and interactive [66].

A more interesting question that follows from Eames's definition is what purpose the act of design attempts to accomplish. Here, one can relate design to the theories of wicked problems that Rittel & Weber [68] introduced in 1973. In short, a wicked problem is one where finding an accurate definition of the problem is a problem in itself. In relation to design this means that the purpose that is intended to be accomplished might be difficult, or impossible, to know at the inception of a design process. From this follows that the process of design not only concerns the evolution of a solution in terms of arranging the materials of the design situation, but it also includes an exploration of the problem space and the advancement towards a more complete understanding of what problems are to be solved, and what purpose the solution should serve.

Human-centered design (HCD) is a well-established approach to this process. It places the people that a design is intended for in central focus [69, 70], and seeks to find their needs and requirements to inform the design process [66, 69, 70]. The methodology of HCD spans across user research methods, idea generation approaches, prototyping, usability testing, and ergonomic evaluation [69, 70], with the goal of reaching effective and efficient solutions that improves human well-being, satisfaction, and sustainability [70].

Designing is an inevitably iterative endeavor [71] where progress is achieved through both cognitive and representational iterations. There is a multitude of research on the benefits of explicitly iterative design processes, which show benefits such as quicker development [72] and more realistic user validation [73], to name a few. Apart from the previously exemplified methodology of HCD and iteration as a natural characteristic of design, it can be worthwhile to search for further consensus on the make-up of design processes. Moggridge [66] elaborates on a generalized interaction design process, shown in *figure 5* below, consisting of ten steps: *constraints, synthesis, framing, ideation, envisioning, uncertainty, selection, visualization, prototyping,* and *evaluation* [66].

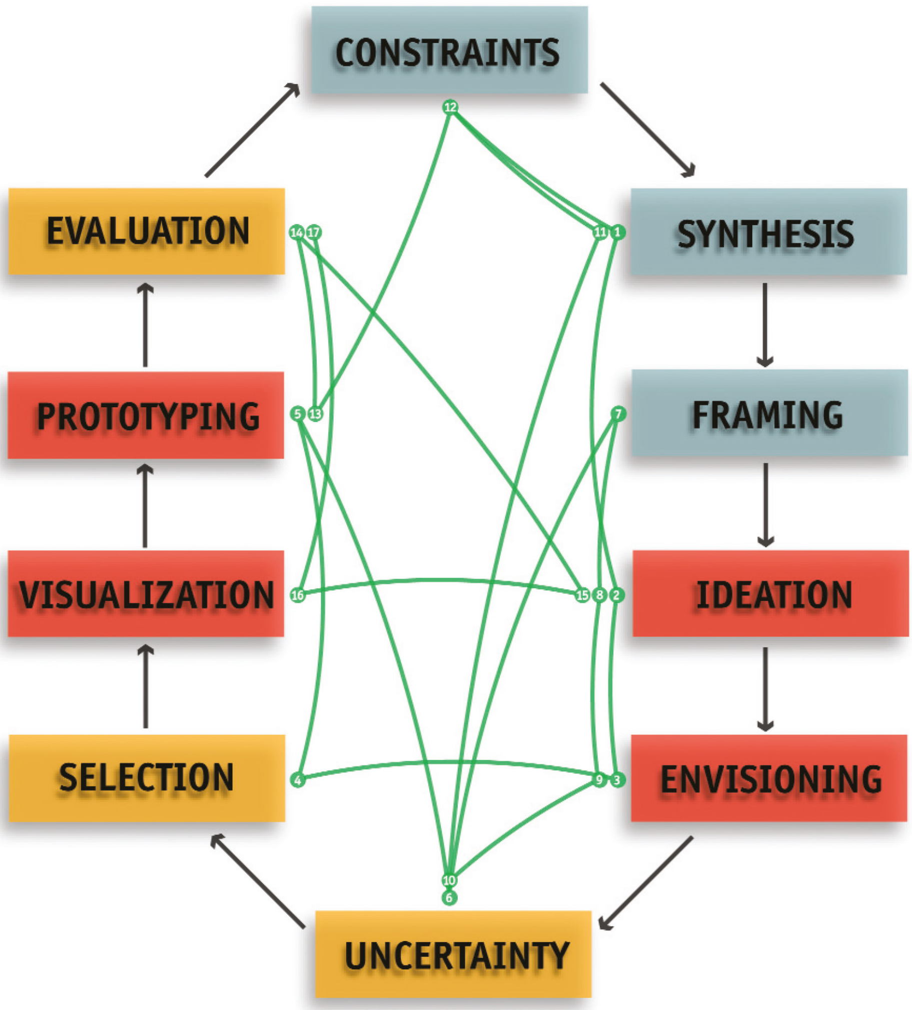

Figure 5. Moggridge's general design process [66].

The commencement of his process is finding and understanding what *constraints* apply to the design situation. If related back to the theory of human-centered design this would concern ethnographic research or other user research methods implemented with the purpose to investigate user wants and needs in their contexts. From this step follows subconscious *synthesis* of the knowledge gained to eventually reach a deliberate and explicit *framing* of the problem. With a framing in place, *ideation* and *envisioning* of ideas is possible, and should carry the momentum of the design process forward to a second stage of subconscious synthesis, this time concerning the idea space, which Moggridge calls *uncertainty*. Eventually a deliberate *selection* of ideas moves the process forward to representation, which Moggridge divides into the steps *visualization* and *prototyping*. These are distinguished by the fact that prototypes should serve to evaluate some functional aspect of the design, whereas visualizations can be mere representations for the senses, without any functionality. To complete the circle, a design process goes through an *evaluation* phase where the current state of the design, represented by visualizations and prototypes, are evaluated to seek better understanding of the design problem and a direction for further iterations of the process.

Moggridge's process is cyclical, but also describes numerous shortcuts or jumps, seen in green in *figure 5* above, between different stages of the process that can appear naturally depending on the situation. The inclusion of these in combination with the methodological vagueness of his stage descriptions makes this process quite general but also rather theoretical. In any actual design situation, designers are faced with applying the general process through adaptation to the specific context. Depending on the goal, prerequisites, and characteristics of the design situation different parts should demand different saliency and be accomplished through different methods. As such, a range of different but comparable design processes are to be expected from the variation in situations of design. An example of such variation is the extent to which users are allowed involvement and influence in the design process, this distinction is elaborated on in the next section.

Participatory design

Participatory design is the practice of extending the roles of non-designers, usually among potential users, from primarily being subjects of study for the designer to be given more active roles as co-designers [74]. The origin and establishment of the practice can be traced back to the 1980's [75] and has seen considerable evolution since [74]. The extension of roles mean that non-designers are invited to do design alongside the designers which can, among other things, imply taking part in brainstorming sessions, idea refinement activities and prototyping [74]. As such, co-designers are involved in stages of the human-centered design process that users generally are not expected to be involved in [76], with the rationale that it should serve to increase the centrality and understanding of users and their needs.

Sanders et al [74] briefly mentions some of the considerations that apply when implementing co-design sessions. An example is the difficulty of maintaining a continual relationship and engagement with co-designers, which depends on what their motivations to participate are. While it is stated that continual relationships are the ideal, the benefit of including new co-designers with fresh perspectives is also highlighted. Other important considerations in the planning of co-design sessions are what background information and preparation co-designers need, as well as how much attention, time, and energy that are reasonable to ask of them.

Usability

A prevalent definition of the term usability comes from the *International Organization for Standardization* (ISO) and dates to 1998 [77]:

"The extent to which a product can be used by specified users to perform specified goals with effectiveness, efficiency and satisfaction in a specified context of use."

Notably, this definition extends the term further than what the layman would call user-friendliness by connecting the usability of a product to how well it helps its users accomplish their goals. This sets ISO's definition of the term apart from some other definitions, for example that proposed by Nielsen in 1993 [78]. In his definition Nielsen separates usability and utility [78, 79], which means that usability no longer concerns the functional and result-oriented aspect of the use, the effectiveness or utility. In consequence, this narrows down the focus to efficiency and satisfaction, or as he calls it, the ease and pleasantness of use. In any case, usability is by definition a dynamic property that emerges within specified contexts and situations of use [77, 78, 79]. As such, the property is influenced by the characteristics of the user, the context, the goals of usage, and the product itself respectively. Consequently, it is impossible for a product to intrinsically possess good or bad usability. Instead, it can be said to have varying degrees of potential for good usability across different use cases and contexts.

Patrick Jordan [80] picks the term usability apart further to make it more concrete and applicable in an analytical frame. He introduced the subdividing aspects of: *guessability, learnability, experienced user performance, system potential,* and *reusability*. They refer to the product's potential of good usability in relation to the users' evolving experience and knowledge of how to use it. *Guessability* represents usability at first use, whereas *experienced user performance* concerns experienced users. A plain conjecture is that the relative influences of interface intuitiveness versus efficiency on the overall usability can vary greatly between these aspects. *Learnability* refers to how well a product facilitates advancement of users from beginners to experts, and what the potential for good usability is when a user starts repeating tasks. Related to this is *reusability*, which is similar but importantly distinguished by the condition that users return to use a product again after a period of absence. Lastly, *system potential* is an aspect acknowledging the potential, rather theoretical, usability of a product during what is considered optimal use. Across all of Jordan's aspects of usability the same considerations of effectiveness, efficiency, and satisfaction are relevant. Given all this, usability is a rather well-defined term used to evaluate a highly complex and dynamic property. A more abstract notion that has gained traction in the third paradigm of HCI is user experience. This need not be seen as a replacement to usability, but rather as a complementary analytical perspective.

User experience

The term user experience refers to the individual user's perception and interpretation of experiences related to a specific system [81]. In this framing, an experience consists of a collection of emotions, insights and impressions derived from an interaction, encounter, or event. The system can be one or many interconnected products and services that the user is exposed to and interacts with. Its system boundaries can vary in their saliency, and in any case one might look to the user's interpretation of what makes up the system to find an effective delimitation of it.

The user experience can be said to start before the first use of the system. As a future user builds expectations and preconceptions of the system they not only precondition their future experiences with the system, but already experience thoughts and feelings related to the system [82]. As a user starts to explore the system they will have what is commonly called momentary user experiences, which for each period of use can be combined and summarized into episodic user experiences to facilitate analysis [81]. Over time a cumulative user experience will be shaped by all previous experiences. The umbrella term user experience can refer to any of these temporal frames.

By this definition follows that user experience, just like usability, is an individual and dynamic attribute that is influenced by a multitude of factors that change between users and over time. Some of these factors are related to the individual user, such as their personality, mood, motivation, previous experiences, expectations, and mental and physical resources [81]. Others relate to the context of each event or interaction, for example the time, space, task at hand, or inclusion of other people. Lastly, the design of the system affects the user experience, and here terms like usability and aesthetics are relevant considerations. Given all this, designing user experiences is an impossible task for a designer, as they can merely influence the likelihood of having different user experiences and relationships between users and systems develop for different users in different contexts. Given the centrality of context to user experience design, and for third paradigm HCI in general, attempting to design for context-awareness is highly relevant.

Context-awareness

Context-awareness is a term in system architecture that refers to systems that are responsive to their context of use. It first appeared in literature in 1994 [83] and has grown along with the discourse around ubiquitous computing. Baldauf et al [84] has a succinct definition:

"Context-aware systems are able to adapt their operations to the current context without explicit user intervention and thus aim at increasing usability and effectiveness by taking environmental context into account."

Integral to the concept of context-awareness is what to include in the term context, which by no means is a straightforward question. For this project we align with the definition of context brought forward by Dey and Abowd [57]:

"any information that can be used to characterize the situation of entities (i.e., whether a person, place or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves."

These rather wide definitions require further distinctions to enable meaningful consideration and application of context-awareness. A popular, and somewhat intuitive, distinction is that between the context dimensions of external/physical and internal/logical context [84, 85, 86]. In short, the external context refers to what is measurable by hardware sensors while internal context is what can be inferred about the user's goals, processes, emotional state, et cetera. Perhaps this dimensionality is a bit rigid and fails to consider the numerous "software sensors" that can provide external context factors such as calendar events, available time, and social networks.

Another common distinction to make is that between different abstraction of context, from sensor-driven small context to logically aggregated and deduced large context [59]. This distinction of abstraction can also be described using the terms low-level and high-level context [87]. This appropriately places context classification on a scale and separates it from the sources of contextual elements or factors.

High-level context, i.e. the more complete picture of a situation, requires logical deductions to be made based on the low-level context. The low-level context consists of so called contextual elements, for example a geographical location or the current time, that are acquired from context sources [87]. Context sources is commonly referred to as sensors [84, 87, 88]. However, in this case the term sensor cannot be constrained to hardware sensors that measure data about its environment but should be extended to account for all types of context sources. A suggested classification is that into the three groups of physical sensors, virtual sensors, and logical sensors [88]. Here, physical sensors represent hardware sensors and thus stay close to the traditional meaning of the term sensor. Virtual sensors extend the term to include software sources such as applications, databases, and services. This group of sensors also includes monitoring user interactions. Note that these contextual elements still represent low-level context. Finally, logical sensors approach higher-level context by combining multiple context sources and contextual elements and apply prescribed or learned logic.

With the advanced sensing capabilities of smartphones today, sourcing contextual elements from a great number of physical and virtual sensors is no longer a problem. But to create software that can make intelligent deductions and use logic to ascend from low to high-level contexts is more difficult. Research commonly puts hope to pattern analysis and learning algorithms that with the availability of historical context data and user reaction should be able to learn to proactively adapt to the present context as it is sourced and logically deduced from sensor data in real-time [59, 84].

If a software is able to successfully analyze patterns in user context and behavior, this data not only becomes powerful for the application in its aspiration to context-awareness but also extremely sensitive for the integrity of the user. Managing privacy policy and practice to clearly define and protect ownership of context information is crucial to build and maintain user trust [84]. Without the trust of the user the ability to source contextual elements will be impeded and the application will ultimately fail to adapt to context from lack of information.

Citizen science

Previous research, a sample of which is summarized in the background chapter of this thesis, has revealed some benefits of citizen science and proven its applicability and capacity of advancing scientific agendas. However, it has also made clear that citizen science is not without its drawbacks and challenges, some of which might be unique to it. Sharing your, and taking note of others', results and insights within citizen science can help to advance the methodology, reduce redundancy in research, and repetition of mistakes in application. In this section some of the theoretical models and guidelines that have been constructed to aid and guide initiators and designers through the understanding, creation, and design of citizen science projects will be summarized.

Model for self-reinforcing participation

Volunteer motivation, learning and community are prevalent terms and areas of focus for citizen science research. Set with such previous research as background, Jennett et al [41] conducted an interview study that enabled them to infer relationships between motivations to participate, learning from participation, volunteer identity, and creativity that they present as the Motivation-Learning-Creativity (MLC) model [41], shown in *figure 6*.

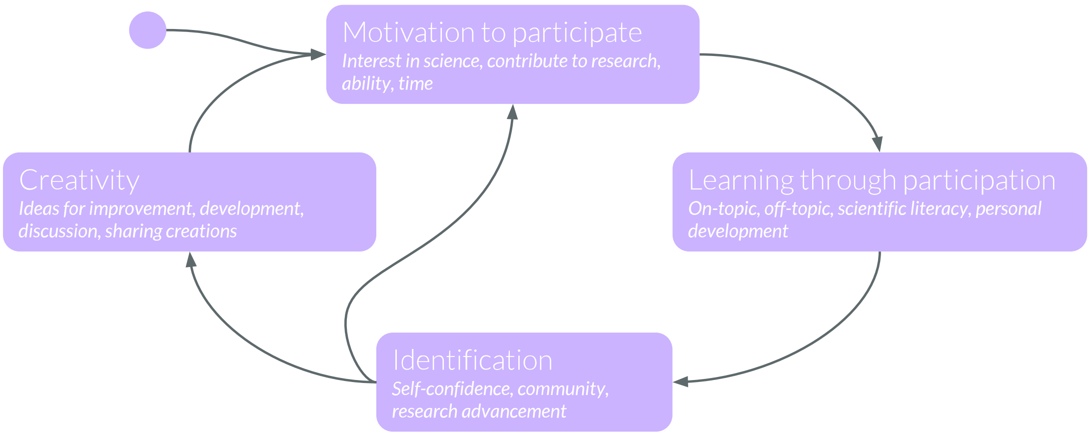

Figure 6. Jennett et al's MLC model [41].

Some motivation to participate is an inevitable precondition to involvement with a citizen science project, and therefore the cyclical model has its origin there. The most prevalent of such motivations have been summarized in the background of this thesis. In a successful citizen science project, as described by the MLC model, a volunteer can learn and improve related knowledge and skills through participation in the project [41]. Completing research tasks and receiving reassuring feedback should in consequence increase the volunteer's self-confidence and strengthen their identity as part of the project. Having a community to share progress and to get and give support in advances this development further. An increasing identification with a project and identity within its community leads to greater motivation to participate, which brings us back to the beginning of the cyclical MLC model.

Apart from the primary virtuous cycle that the model describes, it also includes creativity as a secondary self-reinforcing mechanism. Some volunteers with a strong project identification and enough confidence might share creative ideas or creations with the intention to advance the project agenda [41]. In doing so, they not only help the project directly but also strengthen their own involvement going forward by growing their project identity. This is especially true if there is an established project community to share and receive feedback within. With this theory on the mechanics of citizen science volunteer motivations established, project initiators can begin to understand what underpins retention and continuous engagement in projects. To help move between theory and practice, numerous frameworks and guidelines have been proposed, some of which will be presented here.

Guidelines for implementation

Moving from a research problem to an implementation of citizen science is a complex process with numerous considerations and decisions. Yadav and Darlington [25] divide the procedure into five main stages and present frameworks to help initiators move through each of them. In the first stage, categorization, their framework extends across scientific workflows (data collection/processing/analysis) and types of volunteer participation (active/passive) to create six distinct classifications of participation modes in citizen science: *scientific games, observation/identification/classification, on/offline data contribution, automatic data collection, personal computing,* and *cloud computing*.

One should note that not all research problems are well-suited for solution through citizen science applications. Yadav and Darlington's decision framework, which is presented as the second stage of their five-stage model to implement citizen science, consists of four questions that are meant to highlight some of the characteristics and requirements of research cases that makes a citizen science approach inappropriate [25]. The questions cover spatial and temporal requirements, safety, frequency of participation, and task granularity. They claim that citizen science is a suitable approach only if the research requires participation across wide geographical areas or over longer time periods, can be carried out safely, will not require frequent participation from the same volunteer, and that tasks are, or can be divided to be, small enough in terms of time demands.

If the decision to initiate a citizen science project is reached, project initiators can move through to the last three stages of the aforementioned five-stage model [25]. These are deployment scenarios, cost-analysis, and implementation/deployment. The later stages of the model become quite stakeholder dependent and will not be delved deeper into here, but it is worth mentioning that the deployment framework that the authors present is a model that connects the six citizen science classifications mentioned above to different deployment scenarios that consists of hardware-software configurations.

Another model attempting to outline the main stages of citizen science project development comes from the *Cornell Laboratory of Ornithology's* (CLO's) experience across their numerous projects and consists of nine stages [49]. They begin by looking at how to choose an appropriate scientific question and note that questions should be answerable through data collection which does not introduce great requirements on skills or knowledge. The next two stages in their model revolves around forming administrative teams with diverse knowledge and developing protocols and support materials through iterative testing. Here the different emphases of CLO'S model [49] and the one described above, authored by Yadav and Darlington [25], becomes extremely evident. Where CLO begins by looking at the research question and the project-initiating team, Yadav and Darlington seems to take those as given beforehand. However, CLO then moves straight on to protocol development, which is comparable to the last stage of Yadav and Darlington's model. Because of this, the two models can be seen as complementary.

It should be noted that CLO's model [49], despite being presented as a model for citizen science development, covers a greater part of the process of citizen science project creation and management. Stage four and five in their model considers how to recruit and train participants, and later stages reflects on how to handle data records, analyze data, disseminate results and measure scientific outcomes. In these stages, the authors share insights and experiences that has implications for the design of citizen science applications, this will be covered in the coming section.

Design implications

Previous research provides background on various aspects of citizen science and how different design measures in citizen science applications yields different outcomes. This has implications that should be taken into account for the design and management of future endeavors. In this section we attempt to summarize some of these implications and guidelines that stem from research findings, theoretical models, and implementation frameworks within citizen science.

I. "Facilitate independent working and participant choice" [35]. Volunteers are motivated by different things and prefer different types of tasks, rewards, methods, and mechanics. Some people want to be alone whereas others like being part of a community. Another example is gamification, which can be motivating to some but a hassle for others [17]. Design for the users' different outlooks on use, as the third paradigm of HCI research suggests [61].

II. Inform about the scientific outcomes of projects [35], visualize the data that can be made public [49], and highlight how the data is used and who will see it [28, 54]. This is important not only as a motivating factor but also to alleviate anxiety about privacy.

III. Shape participation to fit into the daily lives of volunteers [35], "*Sell citizen science snacks, not gourmet meals*!" [35], break tasks up into smaller pieces [28]. Limited time and ability to fit citizen science practice into the lives of volunteers hinders participation. Support and consider the user's existing situated activities in the world.

IV. Simplify observing processes and provide enough support to make it easy to start participating [23, 41]. Getting started on projects is important to learn and increase identification, as the MLC model (described in previous section) makes clear [41].

V. Provide purposeful and personal feedback to affirm data quality [35] and build self-confidence in volunteers to increase their involvement [41], as shown in the MLC model.

VI. Make things local [28], and/or enable a community to build around the project where data can be shared and reviewed [23, 41]. Cornell's Laboratory of Ornithology saw increased contributions after implementing the ability for volunteers to relate their data to others [49]. The self-reinforcing mechanisms of the MLC model also benefit from an active project community [41].

VII. Consider which data fields can and cannot be compromised with, both for scientific precision and public display [54]. For example, exact location might be a requirement for scientific research but can be compromised with for the data that is publicly visible. Photographs might be deemed necessary for both datasets. Based on this, it is advisable to enable users to selectively reveal or anonymize information to as great an extent as possible [23, 54]. If applicable, implement technology (for example fuzzy locations, anonymized user identities, and automatic face blurring in images) to further minimize the risk of privacy concerns and anxiety among users [54].

VIII. Good privacy practice is to collect a minimum of personal data about volunteers and allow them to modify or delete the data they have contributed [54].

Apart from these guidelines, Yadav and Darlington [24] lists some further design implications to consider when looking at developing citizen science platforms to house more than one project. Some of these, for example to ensure simple project participation and interaction between initiators and volunteers can be related to the implications listed above. The others are mostly focused on project initiators or other stakeholders, rather than volunteer users, but is still worth mentioning: Make it cost effective and easy to create projects, enable multiple categories of projects, show comparative project performance to enable evaluation, ensure adequate security, and facilitate easy maintenance so initiators can update project materials and manage their data. With these rather applied and practical conceptions, the theory chapter of this thesis concludes after having established a background and theoretical framing that situates the ensuing descriptions of design methodology and implementation in this project in relevant frames of reference.

Methodology

This chapter will describe the methods used in this project. The selection of methods is based on prevalence in design practice, although some have been influenced by specific approaches designed for the field of citizen science. For example, the PLACE framework [89] has been adopted when designing the prototypes and evaluative studies. The next chapter, *Design process*, will describe how these specific methods been executed and motivate their selection based on how they help to find an answer to the research question.

Interviews

Interviewing as a user research method involves an interviewer asking a respondent questions [90]. An important dimension of interviewing is what line of questioning the interviewer leads. Standardized questioning implies closely adhering to a prepared script and staying focused on the intended subject [90]. Such an interview can follow an elaborate template and has the potential to generate more focused, deeper, datasets and can even collect quantitative data. Another approach is iterative or emergent questioning, which allows for a freer discussion around a subject to emerge based on answers to previous questions. This promotes an explorative agenda and tend to generate wider datasets of qualitative data with richer descriptions [90]. It also allows the interview to commence generally to later increase the specificity of the questions gradually when the interviewer knows better what to ask.

Questionnaires

Another user research method is the questionnaire, which is a structured set of questions that a respondent can answer independently [90]. In cases where it is desired and appropriate, it can be widely distributed to remote respondents through various media, for example the internet. The design of a questionnaire concerns choices around what to ask, what kind of open and closed questions to use, and their mutual order. Closed questions are such questions where the respondent is given a set of answers to choose from, as opposed to open questions where the respondent is asked to formulate and express their answers freely. By design these questions types result in different types of data; quantitative from closed questions and mostly qualitative from open.

The design choice of what questions to include does not just concern what data best suits the purpose, it is also important to understand how the choices affect the respondents. Open questions generally require more effort to answer, but in contrast to closed questions they give the respondent the ability to freely express their thoughts and feelings [90]. Having established methodological descriptions of some user research methods, coming sections will focus on relevant methods for other phases of a design process.

Brainstorming

During the idea generation phase of a design process no ideas should be rejected and solutions need not be complete. The goal is rather to break into new ways of thinking, and here brainstorming is a common method implemented to generate ideas. The basic premise is that a group of people get together and focus on creative thinking and idea generation. Some rules commonly advised to ensure the effectiveness of a brainstorming session are that it should be time-limited (around 60 minutes), negative criticism is banned, one conversation is kept alive at a time, and everyone is encouraged to build upon each other's ideas [66, 91]. Within that framing a brainstorming session can take many forms and include several different stimulating activities.

Starting off a brainstorming session with some warm-up exercises can get people in the right mindset and dismantle distractions [91]. What kind of warm-up is advisable depends on the context, in some cases it can be of utmost importance to get people comfortable working in new group constellations, whereas it at other times can be a comfortable group needing to break out of an established discourse. Generally though, warm-ups should strive to get people talking and focused on the session.

When the session is in progress it is advisable to maintain a momentum [91]. Applying stimulating activities as the process approaches stagnation can be crucial to achieve this. Some examples of such activities are conversation starters, analogous inspiration, journey maps, and mash-ups. Conversation starters work by proposing radical ideas or new contexts to spark reactions and questions that can stimulate the conversation. Analogous inspiration means to draw on products or services that have something in common with the problem area or solution of concern for the idea generation process. By focusing on this commonality, which can be however small, the method aims to infuse inspiration from products or services which might be vastly different overall. Journey maps are a way to succinctly describe a user's interaction with a product. Introducing such descriptions in the idea generation process can serve to broaden or shift the focus to consider all imaginable users and use cases, common as well as extraordinary. Lastly among those mentioned here, mash-ups concern posing thought-provoking combinations of the problem at hand and existing things that has a quality valuable to introduce into the context. The combinations need not make sense as they stand but should aim to stimulate the idea generation in a meaningful direction.

It is important to consider how ideas resulting from a brainstorming session are documented. As sketching on pen and paper can serve not only as documentation but as a way to externalize thought and free up cognitive resources [71], something which will be covered in greater extent in the next section on prototyping, it is common to let each participant write and sketch down their ideas on paper as the session goes along [91]. Another approach is to assign a dedicated secretary that documents all ideas, however the person assigned to this role can have a hard time getting their own creative thought process going to contribute to the session with ideas [91]. An advice on documentation that is advocated by some is to number the ideas generated, this serves both as a motivation to reach a goal of a large number of ideas but also as a way to facilitate easier communication when re-visiting or referring back to ideas during the session.

Prototyping

Prototyping is the act of creating representations of the current idea of a design. This serves not only to improve communication and evaluation possibilities among designers and potential users, but also as an extension of the designers' cognition [71]. The first prototypes should be created early in the process to aid in the exploration of different solutions to the design problem [66]. By frequently creating new prototypes the design improves steadily from low fidelity representations in a basic medium such as paper, to high fidelity versions in a much more realistic and suitable medium, for example 3D-printed parts or interactive pixels. To start with low fidelity prototypes is advisable for a number of reasons [66]. First off, it means less time spent on something that will be discarded as the design process moves on. Secondly, the designer's relationship to the prototype is likely to become less affectionate, decreasing the bias when deciding which elements to keep and which to discard. Lastly, a low fidelity prototype communicates that substantial changes of the design are still allowed, making it easier for both designers and participants in evaluative studies to question the larger structures of the design and not focus on the details.

Bowser et al [89] have developed a process for prototyping location-based games and applications abbreviated PLACE (**P**rototyping **L**ocation, **A**ctivity, **C**ollective experience, and **E**xperience over time). In their paper, this process was evaluated with the design of a location-based citizen science application. Central to the PLACE prototyping process is the notion of considering the fidelity of a prototype and its evaluation using four different perspectives, or aspects, in order to reach a holistic understanding of the state of the design and its relation to the intended real-world situated use. As hinted in the abbreviation, one of these aspects is the location. This aspect concern how closely a prototype and its evaluation mimics the intended geographical and contextual locations of use. Secondly, the activities of use that a prototype support represents another aspect of the PLACE framework and a high activity fidelity implies a closer resemblance to the full complexity and diversity in high-level tasks that real-world usage can entail. Additionally, the framework highlights collective experience, i.e. social use, as an aspect of its own. To increase the fidelity in this regard the prototype and its evaluation should strive to simulate or include other users visually, interactively, and physically, in line with what kinds of social use is ultimately intended or expected. Finally, what Bowser et al. [89] call experience over time represents the temporal aspects of use. Interesting considerations here relate both to episodic and collective user experience, in other words both the active periods of use and the frequency, intermittency, and engagement patterns with a design over longer temporal frames. In conclusion, the PLACE principles advocate to start small and scale up the fidelities of the different aspects over time and iterations. Additionally, they suggest extending the roles of participants in evaluative tests to treat them as co-designers and recommend striving for as much creative reuse between prototypes as possible.

Usability testing

To evaluate the potential for good usability of a product or prototype it can be tested with a selection of representatives from the final product's target group of users [79]. The tests familiarize volunteering test users with the product or a representative prototype of it, as they are asked to use it to perform a set of tasks that aim to emulate common or critical use cases [79]. How well the tasks can be executed, in terms of effectiveness, efficiency and satisfaction of the test user, provides a basis for evaluating the product's potential for good usability within the context that the test emulates. Observations of the test can be supplemented with questionnaires and interviews to gather both quantitative and qualitative data that can be analyzed to gain insight into the product's usability [77]. An example of qualitative data that can emerge from a usability test is test user's attitudes to different parts of the interface, while the number of errors or time taken on a task is a typical quantitative measure.

A so called formative usability evaluation intends to identify problem areas and characteristics of an interaction between user and product, to inform an unfolding design process [92]. Summative usability tests are instead carried out with the purpose to evaluate a product in relation to some sort of goal, requirements specification, or research question [92]. In any usability test there will a variety of data collected for later analysis, for example through the affinity grouping method.

Affinity grouping

Affinity grouping is a method to sort out what is important and what trends and relations there are within a dataset that can be oversized or consist of multiple data types [93]. This method can be implemented in many forms, but the basic idea is to get all available data into the same medium (usually on pieces of paper or post-it notes) and start grouping the data records bottom-up, assessing the records one-by-one [93, 94]. The grouping is done through association, where each record is sorted in relation to the already processed ones by assessed affinity. It can also be influenced by a predetermined outlook or focus for the groups, for example problem areas, potential solutions, goals of use, et cetera [93, 95]. Groups can be split up if they grow too large but also be combined into larger categories for more structure [94]. The method can be implemented in an iterative manner, which means that the associative groups are re-iterated upon even after all records have been assessed [93]. By trying to see things from different perspectives new, potentially more effective, groups can emerge. Affinity grouping can also be applied in a participatory design scheme where the users that are the subjects of the research can share their own associations within the data.

Design process

This project is an application of research through design [96]. In this case it will manifest itself as an iterative design process, where the design (represented through prototypes) holds not only a vision of potential answers to the challenges of the specific case, but also clues to more generalizable design knowledge. This derived knowledge relevant to the research question at hand will be sought in the process of designing a digital platform application for finding and participating in citizen science projects, leveraging context-awareness to engage users in positive user experiences. The deliverables are a synthesis of the data collected through user evaluations in three design iterations, a list of succinctly formulated design guidelines, and an interactive digital high-fidelity prototype demonstrating and exemplifying this knowledge.

Designing an engaging and intuitive digital tool to involve volunteers in science projects is a complex issue, a so-called "*wicked problem*" [68]. Part of the problem lies in understanding data reporting requirements from different projects initiators and satisfy them in a user-friendly way to make a solution as versatile as possible. Another part lies in how to engage people to use and interact with the solution and construct meanings in their relationship to citizen science practice. The constraints and demands put on the solution come both from the initiators, that is the researchers and institutions behind the projects, as well as the end-user, whose participation relies on interest and commitment on their own terms.

Designing and attempting to address wicked problems [68] inevitably yields some uncertainty about the outcome. When can such a problem be considered solved to a satisfying degree? The research question that this project revolves around is intentionally formulated to recognize the impossibility of a complete, correct solution to a wicked problem like this. Instead the focus is on the process which through multiple iterations and significant user involvement should enable the design to manifest a good-enough solution. There is no predetermined stopping condition other than what is imposed through time-constraints.

The design process of this project, seen in *figure 7*, is divided into two main phases. The initial phase focuses on extracting information and previous research on the subject, while the latter looks to implement and build upon that knowledge. As such, the second phase is an iterative process of design and will be repeated three times. The overall process carries similarities to Moggridge's [66] design process previously described in the theory chapter and can be viewed as an applied version of said model. In some cases, several steps in Moggridge's process have been fused, for example, *constraints, synthesis* and *framing* have been reformulated as *problem framing* and are treated as one activity. The structure also differentiates the processes. While Moggridge's process is entirely cyclical and urges designers to dynamically adapt the path between activities, the process in this project is stricter as it explicitly defines two cyclical phases. Instead, it places problem framing centrally to include it in both phases, which emphasizes the importance of re-visiting the problem definition as the increasing knowledge of the design situation allows for a better understanding. The individual steps of the process will now be introduced briefly and later elaborated on further in separate implementation sections following just below.

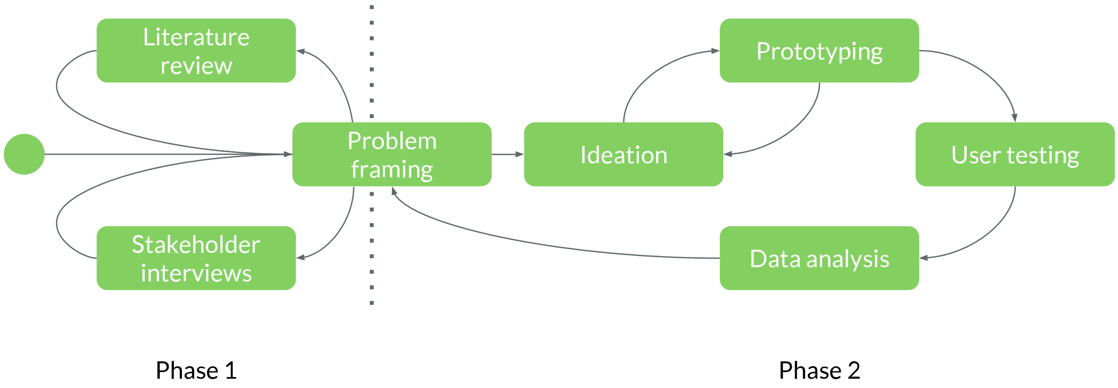

Figure 7. Model of the design process of this project.

An initial literature review aims to create a foundation of previous research for this project to build upon. This ensures that the design is informed by the results from relevant studies on aspects of citizen science such as volunteer motivations, privacy, data quality, gamification, et cetera. The implementation and results of this literature review was presented in the background and theory chapters of this thesis.

To find some of the "care-abouts" among potential project initiators their thoughts and experiences of citizen science will be gathered through interviews. This will help anchor the project in real issues and ideas, while providing rich descriptions and anecdotes that serve to build a nuanced understanding of the design situation. It can also hint at wants and needs among this important group of stakeholders.

The decision not to involve users in any formative user studies before the first ideation and prototyping activities is based on the anecdotal experience of the authors, which is in line with Lewandowski et al's [97] findings, that there is relative unawareness and inexperience of citizen science among the general public. The fear is that too much of such a study would deal with the explanation of terms and giving of examples, which in turn could influence opinions. Being on a time-budget, the potential value of such studies was deemed too low in relation to its required effort.

It is important to recognize the often stated and often overlooked significance of involving users to gain true understanding of a problem [90], so the absence of formative studies to explore user wants and needs puts demands on the design process to remain responsive to this input going forward if it should claim to be human-centered. Because of this, the second phase of the design process will be cyclical and iterated three times. Each cycle will include ideation, prototyping, evaluative user studies, data analysis, and idea/problem refinement. Furthermore, the ideation process which is primarily based on brainstorming sessions and affinity grouping of the results, will be made partly participatory and involve users as co-designers.

Prior to testing ideas, a representation is required to demonstrate scenarios where the ideas can solve potential problems for the user in a context. A representational prototype will be created for each design iteration, increasing in fidelity and complexity with each round. The project will apply the PLACE approach to prototyping [89], as it is designed to consider the holistic experience of location-based applications and developed in the specific context of citizen science.

The evaluative usability tests will be framed within scenarios and focused on the user solving several objectives while their interactions and paths through the interface of the prototype are examined. The datasets generated from these evaluations are analyzed using affinity grouping methods but are also unconsciously synthesized as described by Moggridge [66]. These results inform the new problem framing and are used as basis for ideation in the next iteration of the process.

Risk assessment

There is always a risk that parts of the design process require more time and effort than what is anticipated, which in turn could affect the outcome negatively. When assessing the planned process and its parts, the evaluative user studies stands out as the single biggest risk factor to the overall project progression. Not only does it involve people external to the project to stand in as potential users, which always poses a logistical challenge, but the design of the studies themselves is indefinite and will be iteratively improved. Should the study design be delayed, or create delays in the recruitment of participants, the time plan might be challenged. This is especially problematic as any progress towards a solution is highly dependent on the evaluation through usability tests with users. Since we aim to apply some participatory design methods there will also be higher demands put on some participants who will expect to take on roles of co-designers, this increases the challenge of recruitment. To address this risk, participant recruitment will be prioritized as early in the process as possible, all while being mindful of time demands when designing the study itself.

Ethical considerations

When involving potential users in user studies, the design and implementation of the study must follow ethical research guidelines. If the targeted user group includes children or families with children these users should also be included in the user studies, which could present additional or more delicate ethical issues to address during that phase of the project [98].

One of the primary concerns for the design problem at hand is that data collection in any citizen science project must come second to privacy and integrity of both participants and nonparticipants alike. With the possible importance of metadata such as location and rich data such as photos, this could become an issue. Since some stakeholders are governmental agencies this issue becomes even more delicate and important, and care must be taken to ensure user integrity and an approach in accordance with PUL (the Swedish personal data act) [99] and other data protection regulations. However, some of these privacy concerns have been addressed in previous research. The same goes for the question of ownership of collected data, which is not straightforward either.

Lastly, as some users might be underaged there are potential issues with so-called "predators" if the design is to be location-based to some extent, this must be considered in the implementation of such mechanics.

Stakeholder interviews

Seven people, potential stakeholders, from different governmental agencies were reached out to with the intention to interview. The selection of people to include came from suggestions by this project's originator at the *Swedish University of Agricultural Sciences* (SLU), Kjell Bolmgren. His selection of stakeholders with potentially valuable input was based on who he had talked to, or heard talk, about citizen science or open data in some context professionally. Out of the seven stakeholders originally contacted, four were available and willing to participate in an interview. In addition to these four, two more stakeholders could be interviewed based on suggestions from one of the originally contacted. The stakeholders who participated in the interviews worked for the *Swedish Meteorological and Hydrological Institute* (SMHI), the *Research Institute of Sweden* (RISE) *Service Labs*, and a few different sections of SLU.

The interviews were held with each stakeholder over video chat and documented by writing down comments, quotes, and questions that was deemed noteworthy. There was no prepared script or set of interview questions, instead the interviews utilized emergent questioning and were allowed to take what direction came naturally. This approach was chosen to use the interviews as a way to explore, rather than examine, current efforts and thoughts about citizen science among people and organizations who could have a potential interest in the project. However, some preparation was done before each interview, such as looking up what projects each stakeholder was involved in and what their professional role was about. In the cases where they had been involved in citizen science in some professional capacity, finding out their experiences and what potential obstacles they had encountered was a prominent focus of the interview. Discussing examples of existing and potential future citizen science projects was also of central concern, both to get inspiration but also to inform the design to make it accommodating. A concrete example lies in finding out what types of data the projects would handle, to find potential constraints or demands on recording protocols.

The interviews ranged in time from 20 minutes up to almost an hour. Especially when there were many, or particularly interesting, potential citizen science projects to talk about the interviews tended to be longer. Because of the emergent questioning of the interviews each tended to cover a different set of topics. A methodical analysis with the intention to reach any conclusions would therefore be ill-advised given the scarcity of overlapping data and the small number of interviews conducted. Instead, a short summary, presented in the results chapter of this thesis, could be compiled by boiling down the interview notes to a more concise form. The insights drawn from these interviews with stakeholders also motivated and informed the information flow mapping that was conducted as a complement to the design proposal.

Information flow mapping

As part of the design process a diagram showing the information flows between user, application (design proposal), back-end, and project initiators was maintained. This was a method of facilitating communication with potential stakeholders and forcing reflection about what demands design choices puts on underlying data and networking structures. Considering this purpose and the thesis' delimitations regarding implementation and back-end systems design, the information flow mapping was allowed to be done independently from any established methods such as *Unified Modeling Language* (UML) diagramming [100]. However, despite it being freely composed based on nothing but logic it resembles the UML definition of an information flow diagram in content but not quite in form. For future development more structured efforts in mapping out underlying structures will be necessary, but this is deemed to be outside the scope of this project.

Idea generation

Throughout the project, design ideas were generated through organized brainstorming sessions as well as discussions that emerged organically from latent synthesis at various parts of the process. As the design process moved through its iterations, the background knowledge and problem understanding accumulated from literature, usability tests, and associated data analysis that informed the idea generation grew increasingly substantial. While most brainstorming sessions were limited to include only us, the thesis students, two sessions were expanded in an effort to include users into the design process to a greater extent. The rationale for these co-design sessions was to expand the overall spread of ideas, counteract potentially constrained perspectives, and include users into roles with greater agency. Each iteration of idea generation was to eventually result in a design specification for a prototype, a list of features to be included or tested in the process of prototyping. This was achieved by sorting and assessing the whole spectrum of ideas with the background of literature and usability studies in mind. Exclusion and refinement of ideas allows for a compressed list to serve as a design specification for prototyping.

The premise for the initial idea generation brainstorming sessions was the research question along with the background knowledge of citizen science theory and practice that was gained through the literature review. Three brainstorming sessions were held at this stage, each ranging between 40 and 90 minutes. None of these sessions included users, as no evaluative usability tests had yet to be conducted to introduce users to the project. After the first two sessions, affinity grouping allowed for categories to emerge from the ideas. Iteration to find groupings that covered the entire idea spectrum while maintaining effective internal consistencies led to the following idea categories: *Activation, Activities, Rewards, Data quality, Feedback, Context-awareness, Social, Support,* and *Project initiator.* A thematic analysis of these categories emerging from all different idea generation and data analysis phases during the design process is included in appendix B. Based on the distribution of ideas across the categories, the last brainstorming session at this stage was focused on the feedback and data quality categories to improve their relatively limited spread of ideas.

As the overall design process revolves around three iterations of user evaluation, quickly reaching a design specification for the first prototype was prioritized over spending too much time weighing ideas against each other at this stage. The process allows for trying and failing ideas through each iteration, and ensures that ideas are evaluated on effective grounds, i.e. through actual user testing, rather than on the designers' own judgements. Another important concern when specifying the design of the first prototype was to limit the range of functionalities and activities to implement. This can be related to starting with a lower fidelity prototype to work your way up, as recommended by the PLACE framework [89].

After the first prototype had been evaluated with users, the subsequent rounds of idea generation could be made more focused. When generating ideas for the second and the final prototype, most of the foundation for this creative process was data and insights gathered from rounds of evaluative usability tests with external participants; users. This knowledge can be seen as an additional and more applied type than the background knowledge of citizen science theory and practice that was gained through the literature review. As a result of this, prior to any structured brainstorming sessions several ideas for improvement naturally emerged from latent synthesis in connection to evaluations. Furthermore, there is a growing number of ideas awaiting implementation as the design process iterates. As such, they remain untested but deserve consideration in relation to new insights gained.

As a consequence of the process having an initial prototype to consider and being better informed of user preferences, the second stage idea generation could be made more structured. A number of areas of focus were defined prior to the brainstorming sessions, inferred from the current understanding of the problem and the most prominent issues that emerged during evaluation data analysis. The areas of focus were: *social*, *make it local*, *suggestions and notifications*, *events*, *searching for activities*, *project support and output*, *mental/ system model*, *visualization of activity*, and *rewards*. The intention was that these areas to focus on, or take as starting points, for idea generation would help steer the design process into areas that the evaluative tests had shown were important to explore.

At this stage of the process two brainstorming sessions were initiated, one within the project group and one co-design session with two of the volunteers that participated in the evaluation of the first prototype. The benefit of recruiting co-designers among the test volunteers is that they have already been informed of the project and introduced to the prototype, and therefore have a basic understanding of the context of the design and some of the problems with the current design. The idea was to have co-designers engage in a discussion around different subjects connected to the identified problems and come up with new ideas and solutions. The co-designers were supplied with post-it notes, pens, and papers to externalize ideas or draw figures. By combining the resulting ideas from internal and participatory brainstorming sessions, a specification for the second prototype could be approached as the design process again moved on to prototyping.

When the idea generation phase was revisited for the last time after evaluations of the second prototype concluded, the approach to it was carefully premeditated. While the design process is better informed than at any previous stage, thanks to the multiple evaluative tests with users, it is also more constrained by previous design choices. While most of those choices should be motivated by findings in literature or user research, it is naive to think that they represent the only route choice leading to an effective design solution. This, together with the finality of the third and last idea generation phase motivates a questioning of previous design choices. To address this the idea generation is given two separate focuses which are allotted their individual share of time and cognitive effort.

The first focus is on solving problems and improving the design based on the results from evaluating the second prototype. The analyzed data from the evaluations feeds and informs this process with aspects to target during brainstorming. During this idea generation phase, one brainstorming session is dedicated to looking at solving these problems within the categories (*project communication, feedback features, UI feedback, social, mental/system model, visuals, language, feature priority, support, rewards,* and *interface intuitiveness*) that emerged during data analysis. As a result of the higher fidelity prototype, some of the identified problems are quite specific and have solutions close at hand, or even hinted in the problem depiction, while other remarks can lead to original ideas.

The second focus for the idea generation at this stage was to ensure that the design process was heading in a constructive direction, and that no important ideas had been overlooked or excluded by earlier unjustified design choices. With this in mind the intention was to make part of this final idea generation process more open and less constrained by the progress made so far. To achieve this the co-design session organized at this stage was crucial by having designers largely external to the project, other than that some had participated as test users in previous evaluations, bring in new perspectives. At large, the previous co-design session was not as productive as anticipated, possibly due to its close connection to the usability tests and lack of stimulating exercises. The problem with priming co-designers with existing designs and prototypes, for example by having them participate in a usability test, is that they can have a hard time distancing their creative thought process from the current state of the design. Drawing on this experience the implementation of the second co-design session was adjusted accordingly. This time the brainstorming session was held in isolation from any evaluative tests, and the co-designers had different levels of previous engagement with the project. One co-designer had a large involvement, having participated in both rounds of evaluation, while another had participated in the first but not the second round. The third and final co-designer had not been involved in the project at all up to this point. The motivation behind this recruitment was that having varying levels of previous knowledge, and priming of design progress, could make for a more open idea climate where things were not taken for granted. To bring everyone somewhat up to speed, the co-design brainstorming session commenced with a description of citizen science and the design challenge of this project. Furthermore, several stimulating techniques for brainstorming had been prepared beforehand to establish and maintain an effective momentum through the creative process. These included a warm-up guessing game, conversation starters in the form of radical ideas about the future of research and science, inspiration from mechanics in other digital services, mash-ups of citizen science with other activities, and examples of extraordinary users or contexts of use.

Because of the limited time allowed for a co-design session where people volunteer their time and effort, there were lots of promising ideas that came up during that brainstorming but not pursued much further. These ideas became compelling starting points during a final internal brainstorming session, which also kept the focus on opening up the idea space to question previous choices and ensuring the constructiveness of the current design path. Again, the resulting ideas from all internal and participatory brainstorming sessions were revisited and combined in the formation of a design specification for subsequent prototyping, which in this third iteration seeks to create a representation of the final design proposal.

Prototyping

Prototyping is an important part of the design process, as it enables externalization of thought and efficient exploration of ideas [71]. Additionally, creating visual representations tend to demand more specificity and can uncover design problems remaining to be solved. As the overall design process revolves around three iterations with corresponding evaluations, the prototype that emerges from each cycle of idea generation also serves an important function as it enables evaluation that guides the future direction of the design. The design specifications that were produced as the outcome of each cycle of idea generation became the starting point for the subsequent prototyping. The design specifications guided each prototyping process but were treated as live documents, responsive to modifications triggered by new insights and design decisions. While the fidelity of the prototype was to increase with each iteration, the prototyping processes all started with sketching wireframes and design elements on paper to be able to quickly assess ideas and iterate, before moving to the digital medium.

At the outset of this project a few different software tools for interactive digital prototyping was tried out to see which option yielded the best results in relation to effort. The prototyping software tried were *Axure RP, Adobe Xd,* and *Proto.io*. In our assessment *Proto.io* stood out as the most effective and efficient tool for prototyping mobile applications in our use case. While *Axure RP*, which is designed for prototyping web pages, had powerful collaborative functions the overall interface and workflow was a bit tedious to get into as a new user. But most importantly the prototypes showed disappointing performance when run on actual smartphones. *Adobe Xd*, on the other hand, had impressive prototype performance but seemed severely limited in what functionality could be implemented in the prototypes. The decision to use *Proto.io* was based on the fact that it had good prototype performance while providing more advanced functionality than what would be needed even for the final prototype, all through an intuitive user interface.

After enough paper sketching to find a general direction for the first prototype, the prototyping process moved to using digital tools. The thought of creating an interactive digital prototype without too much effort appealed, but the attention to detail that such an attempt spurred led to the realization that it might not be an effective approach for the first round of evaluation. The rationale was that the early stages of development should not take the design too far, possibly imposing constraints or directions without foundation in user research. Having a prototype with too high fidelity risks that test users remark on details while refraining from questioning fundamental design decisions. This could be especially detrimental in this case, seeing how the design at this stage had not been informed by any formative studies. With this in mind the decision was made to create tidy paper sketches for each screen of the application and use them as a prototype for the first round of evaluation, as shown in *figure 8*. With this approach users should be willing to question the design more while still being able to imagine that the paper sketches represent interactive screens and interact with them accordingly.

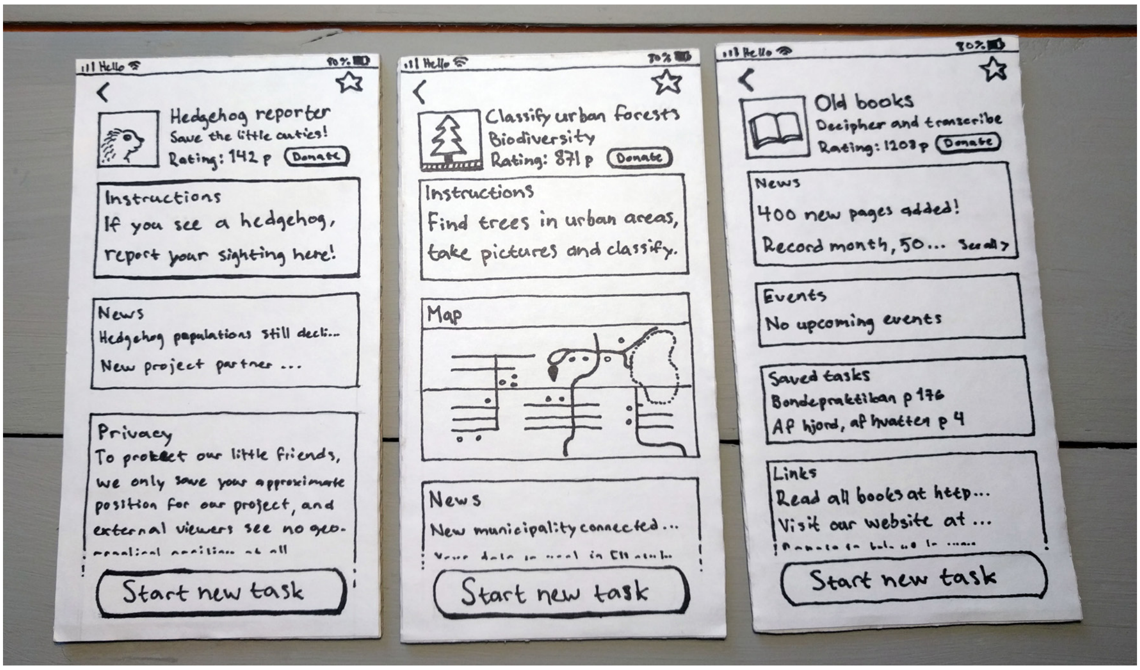

Figure 8. The prototypical representation of the first design iteration.

However, as the design specifications for both the second and the final prototype were more grounded in user research the fidelity of these prototypes could be increased to the point where they were digital, interactive, and with a look-and-feel not far removed from a finished product. Some example of screens from the second prototype can be seen in *figure 9*. The prototyping process evolved organically from predominantly revolving around discussions of major design choices and sketching on paper, to producing digital interface elements and screens of increasing fidelity. The fidelity of the prototypes and decisions about their feature completeness is discussed in more detail in the evaluative study design section below, in its context within the PLACE prototyping framework [89].

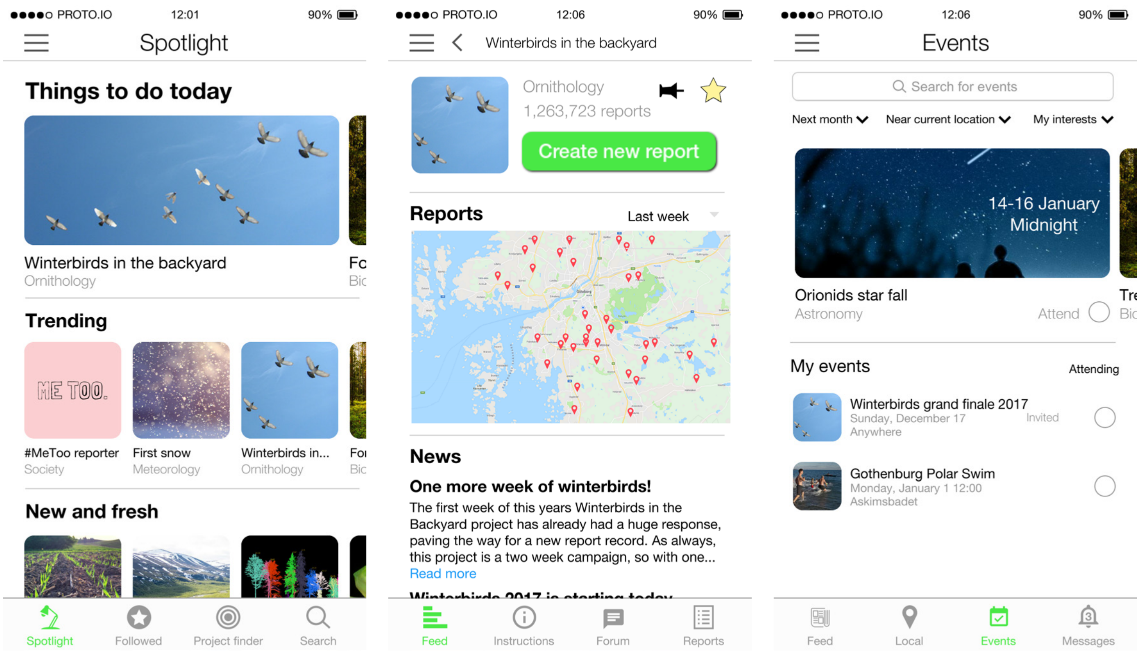

Figure 9. The prototypical representation of the second design iteration.

Evaluative study design

To conclude each design iteration and find the direction for subsequent iterations the prototypes are to be evaluated in terms of usability with potential users. The PLACE framework [89] heavily influenced the design of these evaluative studies, and the framework's four dimensions (*location, activity, social context,* and *time*) guided discussions around possible evaluation ideas and implementations. As is recommended by the authors of the framework, the first prototype and round of evaluation has quite low fidelity in all four aspects, and with each subsequent iteration follows an increased fidelity in one or more aspects. The continual improvement of the prototype and evaluation means that the tests need not be designed to be of a comparative nature. Even if the test remained the same, it would not be straightforward to compare results to assess improvements between the design iterations simply because the different fidelities of the prototypes. Some benefits of this approach are that the earlier evaluation rounds can be made to serve a more formative agenda and inform future design, whereas later evaluations can be made to act summative and validate that design. Furthermore, the background of experiences from previous evaluation rounds is allowed to inform the design of future evaluations, and prototypes of higher fidelity can enable increasingly complex and open tasks.

To enable adaptive probing and ensure the ample qualitative data collection needed for formative studies, evaluations are carried out co-located with users throughout all design iterations. This is also necessary to ensure enough support to test users as they interact with a prototype that has its limitations in terms of functionality and responsiveness to input. However, the higher fidelity of the final prototype, in conjunction with experiences gained through earlier evaluations, enables the co-located evaluations to be complemented with remote tests of a more summative nature for this last iteration.

The process of recruiting users for prototype evaluation was separate for each iteration, the consequences of this is discussed at length in the discussion of this thesis. For the co-located tests this recruitment was primarily based on convenience, with little regard for the representativeness of the sample. The limited amount of time allowed for evaluating each design iteration was part of the reason behind this decision, but most important was the possibility to validate the design through summative remote testing of the final prototype. An online remote test increases the freedom and independence of participating test users while also lending itself well to being shared and spread through different online services and reaching a larger sample of users. Because of this, an extended recruitment of users for remote testing intended to compensate for the potential lack of diversity and representativeness in the sample of test users for co-located tests.

To allow reasoning about test user distributions and sample representativeness, the test users will be asked to answer an anonymous questionnaire in connection to the start of each evaluation. This questionnaire, found in appendix A, is mostly demographic but also covers potential previous experiences of citizen science. The overall structure of the usability tests is similar throughout iterations. They all begin with an explanation of the context of citizen science, the thesis project, and the test itself. Following this introduction, the user is asked to fill in the aforementioned demographic questionnaire, at the completion of which the prototype evaluation itself starts. For the co-located evaluations this part consists of scenario-building and the giving of tasks for the user to perform using the prototype. Apart from some short tasks consisting of few steps, two scenarios are played out in each test by describing a setting and playing associated sounds. This approach aims to situate the use in relevant contexts. In each scenario the user interacts with the prototype to complete some more complex tasks. The remote test is more focused on shorter tasks, but include a basic scenario described in text.

The evaluations of the first design iteration are carried out using a paper prototype that relies on the user imagining and faking its interactivity. The responsiveness of this prototype is achieved by having the test leader switch out screens or describing what happens on the screen based on the user's actions. When evaluating later prototypes the application is represented through an interactive digital prototype running on a smartphone, which makes for an experience closer to the real-world use case. In remote tests users are able to open the same interactive digital prototype on their own smartphone or on an emulated smartphone running in the web browser of their computer.

During the co-located tests, the test leader asks the user to think out loud and also adaptively probes the user to gain further feedback. This feedback along with other observations about the test user's actions and reactions are noted down for later analysis. After all tasks and scenarios are completed the user will be asked to sum up their thoughts and opinions by answering a post-test questionnaire, found in appendix A, which concerns their overall experience, reflections about how the application could fit into their lives, as well as some detailed inquisitions into different aspects. In the first iteration, the detailed inquisitions concern the user's reactions to the application's potential use of different context sources to feed context-aware mechanics. The intention was that this data could hint at conflicts between context-awareness functionality and data privacy concerns. Since the results from this question was not expected to change between design iterations, the subsequent evaluation round instead included test users ranking the importance of eight different features of the prototype, from most important (rank 1) to least important (rank 8) based on their needs and wants. The intention was that data from this ranking could assist in prioritizing between different areas and features of the application for future iterations.

As the remote tests are done independently from any test leader, users rely on an online questionnaire, found in appendix A, both to get task descriptions and to give their feedback. This questionnaire is structured to pose associated questions in direct succession to each task and consists of both multiple-choice questions and free text fields. The combination of questions intends to seek validation on usability and user experience judgments indicated in co-located tests, while also enabling users to give more open and rich feedback. The remote testing questionnaire ends with the same summarizing questions as the co-located test, complemented with questions about the time required to complete all test tasks, as this information is otherwise lost by condition of the test being conducted independently from any test leader.

As part of the first prototype, emails containing fake feedback about the contributions that each test user made through the prototype as they participated in the evaluation was created. The test users that agreed to participate again in later evaluation rounds received this email a day after they participated in the first test. They were then probed for their reactions to it before the start of the next round of evaluations. This process was not repeated for subsequent rounds because of the administrative difficulties of recruiting recurring test users and the consensus around feedback mechanisms that could be seen in the literature review and confirmed through this first evaluation.

In each iteration the usability test design was piloted on ourselves to examine it for any faults or areas of improvement before external test users were invited to participate. This was particularly helpful initially to make the test more concise and rearrange the tasks to get a better flow. An example is the exclusion of a free exploration session of the prototype that was included at first. This change was motivated by a fear that it would lead users to go "too deep" into the prototype before being engaged with any task, which would then render the tasks slightly redundant while taking valuable time.

The tests aimed to evaluate the usability of the prototype in the five aspects described by Patrick Jordan, namely *guessability, learnability, experienced user performance, system potential,* and *reusability* [80]. Focus was put into testing both guessability, to aid in the process of designing an intuitive solution for first time users, and system potential, so that the demands of a great variety of citizen science projects could be contained in one platform. The first prototype, being a paper model, lacked many interface elements that users are accustomed to, therefore it proved helpful in testing guessability. The second prototype inclined more into evaluating system potential, thus testing which features were required, or to the contrary obsolete, in this type of application. As the prototypes changed between every iteration, experienced user performance and reusability was never properly evaluated even if some test users participated in multiple evaluation rounds.

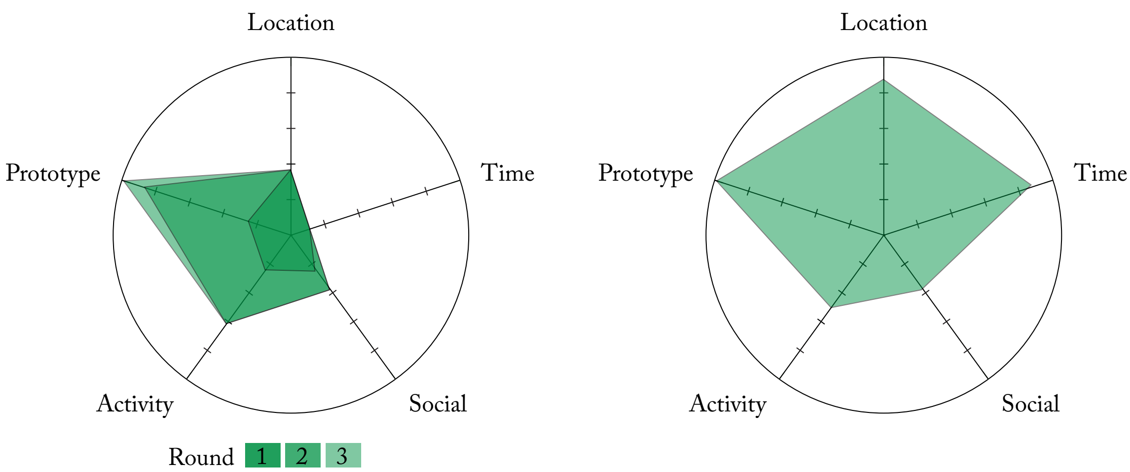

Figure 10. PLACE fidelity graphs. Left: co-located evaluations. Right: remote evaluations.

Situating the evaluations within the PLACE framework [89] allows for reasoning about the fidelity of the prototypes and usability tests, which appropriately situates them in relation to the real-world use cases they are meant to simulate. *Figure 10* visualizes the different fidelities of each evaluation. Where a high-fidelity location would be wherever someone is in their everyday life, and concern different locations both in- and outdoors, the lower fidelity implemented in the co-located tests represent a set test situation and location indoors. While it would be possible to extend these tests to the outdoors there was a fear that it would increase the time demands put on test users and could be uncomfortable because of the current season and its weather. However, the fidelity of the location aspect in these tests is somewhat increased through the use of scenarios built with sounds and storytelling. These scenarios aim to have the users imagine that they are at other locations, including outdoors in a forest, and the approach is consistent through all iterations. When considering the remote tests, the fidelity of the evaluations with regard to location is arguably higher, as the test users are able to participate in the tests anywhere they like as long as they have a device connected to the internet. Speculation suggests that the users might still choose to remain indoors, but at least it is at a location in their everyday lives and outside of a more explicit test setting.

Closely related to location is the time aspect of the prototypes and their evaluation. Prototyping and evaluation with a low time fidelity does not allow for the variation and flexibility that real-world use means in terms of time of day and duration of use. Because of the nature of the design task, with context-awareness as a specific focus, raising the fidelity of the time aspect in some way was crucial for later evaluation rounds. The paper prototype would not allow much flexibility in this regard because of its dependency on the test leader, but this was mitigated by the move to a digital prototype, accessible online through any smartphone by invitation. As the co-located evaluations are scheduled after mutual availability, and the use of the prototype is in isolation from the activities of someone's everyday life, the fidelity of the time aspect is limited in that test format. Despite this, the co-located evaluations are kept throughout all iterations because the experience of the first evaluation round was that the valuable collection of user thoughts and reactions had been largely dependent on the adaptive probing by the test leader.

A way to increase the fidelity of the time aspect would be to split up the test to consider each scenario or task separately and to give users more freedom of choice as to when they choose to perform the evaluation. This freedom of choice is fully implemented in the remote testing as the users can participate at their leisure, which makes for a high time fidelity. Theoretically, users can even split up the test into isolated parts, as the online questionnaire and prototype used for remote testing allows them to leave, return and complete it at any point. However, they cannot be expected to do so as the questionnaire does not suggest such a conduct. At any rate, the time fidelity of the remote testing is higher thanks to it being conducted at times chosen by the users themselves.

Moving on to the PLACE framework's aspect of social context, only the initial stage of one social function is simulated in the first prototype, instead of fully implementing it and actually involving other users. The amount of information seen about other users is also limited throughout the screens of this prototype. More social features are implemented and prominently visual in the second prototype. Some examples of such features are project forums, a local feed with other users' reports, a news feed, and top lists of users. All of these contribute to a higher fidelity within the social context aspect. An interesting consideration for future evaluations is if it would be possible to make more realistic simulations of other users and/or even have test users see each other's "real" activity.

Lastly, while the evaluation of the first prototype considers a range of activities from casual exploration to post-use feedback, the feature richness implemented in this prototype was deliberately limited to lower the fidelity of the activity aspect. This was also motivated to speed up the design process at an early stage where the design was not informed by any user input. The move from physical paper prototypes to an interactive digital prototype represent a major increase in the overall fidelity of the prototype. In contrast to the first round of evaluation, the prototype and interaction now exists in the same medium as the design is meant for. Hopefully, this should lead to a greater familiarity for test users and more constructive feedback. The higher fidelity prototype also enables users to explore it more freely as its navigation is automated and the feature richness is greater. This represents a greater activity fidelity than before, as a less guided approach is closer to how real-world usage would look. To exploit this, the tasks given to users in later evaluation rounds are more open and can be solved in multiple ways. The intention is that this test approach will make further clues of users' mental models and their preferred courses of action visible.

In the remote testing, the open tasks were again made more focused. This can partly be justified by the lack of a test leader to support the user in cases where limitations of the prototype could become an obstacle to their solving of a task. Furthermore, the lack of observation makes it difficult to reason about user choices and mental models, thus defeating the purpose of having more open tasks. Lastly, with the focus of the remote testing being more summative in its intention to validate the design, the exploration of these aspects also becomes less relevant.

The PLACE framework emphasizes the re-use of as much as possible between design iterations [89]. In the case of this project, the same overall usability test structure with scenarios, sound effects and note-taking to keep track of user actions and reactions was kept intact through all iterations. While the individual tasks were not re-used directly, some of them remained in a similar form across iterations, and especially between co-located and remote tests. Furthermore, the demographic questionnaire filled out by users pre-test is re-used through all iterations, as are the explanatory texts about citizen science and the context of this project. The description of the test procedure was merely edited to account for the differences between digital and physical prototypes, and the post-test questionnaire remains largely unchanged across all iterations.

In terms of the prototypes the re-use between iterations is mainly evident in the information content, where made-up project names and descriptions saw plenty re-use.

Between the digital prototypes of the second and third iterations, which were both created using the same software tools, some images, graphical elements and interaction behaviors could be re-used.

Data analysis

The data output of the evaluative studies consisted of written notes and questionnaire answers in multiple forms. At each iteration of the design process this data had to be analyzed to advance the problem understanding and provide a clear and structured foundation for further idea refinement and concept improvement. The notes from each co-located test contained both descriptions of what actions the test user had taken to solve the tasks given to them during the evaluation, and their reactions along with any expressed thoughts. To process these notes they were read through, focusing both on problems and negative reactions but also positive remarks. All significant comments were noted down so that when similar problems or reactions appeared later in the notes, the initially noted remark could be modified, extended or split up to include the new data. In this way a growing set of problems were allowed to arise from the data. When all material had been processed, the set of problems was sorted using affinity grouping. This process was iterated until a final structure which covered the entire spectrum of findings while maintaining effective internal consistencies was found. The approach to analyzing and grouping data was identical through each overall design iteration, but since the underlying data varied, each analysis and affinity grouping settled on different data structures.

The results from the demographic questionnaire filled in by test users prior to their participation in a usability test was quantitative and could be readily summarized in tables. Answers to the open questions about overall experience and how the application could fit into their everyday life, asked in the post-test questionnaire, were also analyzed. The users' remarks about overall experience were included into the affinity grouping described above, alongside the other test notes. The users' reflections on how they would use the application in their daily lives were treated separately, and instead analyzed collectively across all evaluation rounds by reading them through to seek for statements about motivations and contexts of use. Such remarks could be aggregated into two separate lists and the most commonly occurring answers then highlighted.

Part of the post-test questionnaire used in the first round of evaluations revolved around test users' reactions to the design's use of different contextual elements to inform its context-aware behaviors. This data was collected quantitatively, as the users were asked to respond within a Likert-type response scale [101] from 1 to 5, were 1 corresponded to a severe dislike and 5 to a strong like. When processing this data, the responses were shifted to values on a scale from -2 to +2, to correctly consider responses of 1 or 2 as negative. Lastly, the distribution of user responses was multiplied by the corresponding values and summarized into a single score for each contextual element. Through this translation the data can be presented in a table where each contextual element has a single score that can be negative, neutral or positive.

For the second round of evaluations the inquisition into using different contextual elements was replaced with a mutual ranking between a selection of eight of the design's features. This data, being quantitatively represented with ranks from 1 to 8, could be analyzed by summarizing each feature's rank through addition across all users' responses. In this process a single score for each feature is reached, but since the rank is descending with increasing importance a low score is preferable to a high.

Results

With the design process of this project and its implementation of methods established, the resulting knowledge and final design proposal can be presented in its appropriate context. This chapter represents the contribution of this thesis, which lies both in the proposed design of a citizen science platform application but more importantly in the knowledge of user experiences, behaviors, and opinions in relation to it. This knowledge stems from the literature review, stakeholder interviews, and user evaluations conducted throughout the design process, is manifested in the proposed design and finally summarized in a list of design guidelines. As the body of knowledge grew during the process and early evaluations informed later designs, this chapter is structured chronologically and begins with the resulting insights, "care-abouts", that emerged during interviews with stakeholders. Following this is a synthesis of the most important findings from formative evaluations of early design iterations. Both of these sections lead up to and justify the final design proposal, whose detailed description along with an associated information flow mapping serves as a manifestation of the aggregated knowledge and conjecture of important considerations for the design problem. Subsequently, the chapter presents the results of the summative evaluations, which sought to examine the design proposal's, and by extension the underlying knowledge's, applicability and validity to the research question. With these final observations and insights in place the chapter concludes by listing a set of design guidelines summarizing the knowledge and understanding of the design problem attained in this project.

Stakeholder care-abouts

Talking with various stakeholders underlines the great potential of citizen science and how it can be applied to solve different problems in research. The problem that citizen science traditionally has been implemented to solve is collection or analysis of data of vast spread or quantity. But stakeholders also bring up its potential to effectively advance areas that have had trouble creating systematic and effective ways of building knowledge from the ground up. Examples of this are healthcare and other collective systems for public service.

One of the discussion points were how to find and recruit the "right" people to participate in projects. There was some concern about prerequisite knowledge, and in those cases finding participants could become a primary problem. This raises interesting questions about awareness and getting attention from people, how big of a concern should that be for the design? A solution to the problem, for a limited domain, is leveraging nature reserves' or national parks' facilities and visitor contact to promote citizen science efforts. In this domain such applications and their results could be used to give visitors recent and local information as well as activities to do during their visit.

Another expected concern that stakeholders indeed raised was that of data quality. Some agencies are already dealing with too much data of questionable quality, even if it is generated by their own sensory equipment or staff. For them, getting involved in citizen science cannot mean devoting more resources to data validation. However, opposite perspectives were also encountered, where stakeholders see the potential of citizen science to correct faulty or outdated data in existing datasets. One of the stakeholders interviewed had first-hand experience of implementing a citizen science scheme. This talk covered some of their decision-making in terms of motivating volunteers using gamification, what types of data that untrained volunteers can contribute, and data validation. This strengthened the background findings that all of these areas require deliberate consideration and has consequences for the outcome of a project. The stakeholder interviews also introduced some perspectives that has been slightly neglected in previous research. In some domains the primary value of citizen science can be empowerment and the strengthening of civil society. This highlights the question of exclusion, which is something that should not be taken lightly for any future development within citizen science.

Formative evaluations

In addition to the concerns that stakeholders brought up in interviews, this project's formative evaluations of early design iterations also resulted in a contribution of insights relevant for citizen science in general and this project in particular. In this section the most prominent results from these evaluations of the initial two design iterations will be presented. Since the recruitment of test users for the different iterations was separate, the respective sample distributions differ somewhat. As *table 1* demonstrates, there is an exactly even balance between gender identities of male and female for the first round, and only a slight overrepresentation of males for the second round. However, as expected because of the test user recruitment being largely based on convenience throughout both these rounds, there is a lack of balance and diversity in the test users' ages. Throughout the evaluations a clear majority of the test users had no previous experience of citizen science, most of them had not even heard of the practice before. This was expected and in line with what previous research has found. Finally, it should be noted that almost half the test users who participated in the second round previously had been involved in the initial evaluations.

Table 1. Formative evaluation test user distribution

	Round 1	Round 2
Number of users	8	11
Recurring users	-	45,5%
Gender identity		
Female	50%	45,5%
Male	50%	54,5%
Age		
18-25	62,5%	63,6%
26-35	25%	9,1%
36-50	0%	0%
51-65	12,5%	27,3%
>65	0%	0%
Previous experience of citizen science		
Never heard of it	62,5%	63,6%
Heard of it	25%	27,3%
Some experience	12,5%	9,1%
Much experience	0%	0%

The problem areas that emerged from affinity grouping of the data collected during evaluations of the first prototype were: *overall features, mental/system model, searching for activities, project support and output, data reporting, events, and profile presentation* and *content*. Perhaps the most prominent issue with this design was the lack of intuitiveness of swipe navigation without any supporting hints.

Other salient problems that users experienced were a lack of community-enabling features and ways to observe and meaningfully engage with their local area. It appears as an important part of users' situated use is their geographical location, and that data and other volunteers are much more interesting in local contexts. Additionally, as users form an understanding of their relation to the larger community around citizen science practice, they express concern about how to assess the collective activity. It appears important to visualize an active community in order to foster participation.

An email containing feedback on test users' submitted reports was included as part of the first prototype, and this was generally received well. This was expected and in line with what previous research has found regarding specific and constructive feedback. When considering information and functionality to support users both prior to and during their reporting, users were more questioning to the design. Users want accessible and concise information about project protocols, data validation, and research objects.

After evaluating the second prototype other problems came to the fore. During data analysis from this round of tests the affinity grouping process settled on a different set of problem areas. What was previously accommodated in the rather large group called *overall features* can now be seen as having been divided up between the areas of *feature priority, feedback features, social,* and *rewards*. Emerging areas like *project communication* and *support* can be related back to the previously considered problem area called *project support and output*. Furthermore, *mental/system model* is again identified as a salient problem area but is now complemented with the related *UI feedback* and *interface intuitiveness*. Finally, *visuals* and *language* emerged as new areas to consider.

Also for the second design iteration test users had major complaints regarding the system model and navigational structure. This time the design had a wide but shallow model, with navigation facilitated by a drawer containing the main sections, each of which had a number of subsections accessible via a tab bar. Users found the drawer difficult to find and the tab bar unreliable as it changed throughout the app, depending on which main section the user had navigated to. A common mental model among test users seemed to be that of a homepage, which since it did not match the application's system model made navigation problematic.

Previous evaluations revealed the importance of locally situating users in their interaction. This insight was further substantiated as the design measures addressing this in the second iteration were received well. The most notable such measure is a local map and data feed that enabled users to explore each other's contributions. Combined with temporal information it also helped users to assess how active the overall community was.

Thanks to the increased complexity and feature-richness of the second design iteration and the mediating effect that it provides, users are able to consider and reflect on more aspects of the design in the second evaluation round than in the first. An example of this is how discussions around social functions like events could emerge. The evaluations uncovered that most users are used to, and might prefer, handling such things through established social media networks. Another example of a more complex matter that emerged in the second evaluation round is the accessibility and organization of data in different places of the design. As data can live in multiple places, for example both in relation to a specific project, aggregated across projects, or in relation to an individual user, it can be confusing to users if datasets or organizational functions differs between instances. While some discrepancy in data presentation and visualization can be expected to maintain effectiveness in different contexts, it should be implemented deliberately and carefully. Evaluation results indicate that users expect redundancy in data across related contexts and presentations, rather than isolation to one place.

It should be noted that users again desired situated support in reporting, just as in the previous evaluative round. Additionally, several users remarked on the importance of clearly communicating the goals, purposes, and outcomes of projects. Furthermore, users had more specific remarks on the aesthetics and phrasing of the button used to initiate new reports. Some users remarked that its distinct color, while eye-catching, is slightly irksome and too attention-seeking. Additionally, the word report has quite serious connotations and can be deterring to some users. And its association to some of the data collection and analysis practices in citizen science is weak. An example of this is when participation involves transcribing pictures of texts.

The reactions to using different context sources for context-aware adaptation was quite coherent among users and subsequent data analysis produced some quite clear judgements in this regard. The results, which can be seen in *table 2*, indicates that it is perfectly fine, or even preferable, for an application like this to use self-reported interests, society needs, season, research needs, current time and location, previous activity in the app, weather, and self-reported health goals as a basis for its context-aware adaptation. However, it is not acceptable to use movement patterns, phone usage history, private calendar, health suggestions, or web history. Emerging discussions with test users while this data was collected hinted that many of the low scores were related to privacy concerns. Context-aware adaptation based on others' activity in the app, and to the user's social relations could be acceptable in some instances. Some users questioned the effectiveness of adapting based on other users. And despite its low score, adaptation based on social relations was included in this borderline category because remarks during the evaluations made it clear that how those relations were inferred was of utmost importance.

Table 2. Context source evaluation results

Score	Context source
+12	Self-reported interests
+10	Society needs
+10	Season
+8	Research needs
+7	Current time
+7	Current location
+6	Previous activity in app
+6	Current weather
+4	Self-reported health goals
+2	Others' activity in app
-5	Social relations
-5	Movement patterns
-7	Phone usage history
-8	Private calendar
-9	Health suggestions
-12	Web history

Analyzing the test users' importance ranking of features represented in the second prototype painted a clear picture of which parts of the design should be considered important and not. Whether using median, mean, type, or additive values to summarize the results, the same final hierarchy emerged. Interestingly, this ranking, presented in *table 3*, showed a clear segmentation in prominence among the different features. The context-aware suggestions of projects (called *Spotlight* in the prototype) comes out clearly on top. It is followed by two features equally important, namely the *local data feed* and *project finder*. After these features there is a distinct jump down to a cluster of less important features followed by the clearly least important, the *contribution calendar*.

Table 3. Feature priority ranking results

Additive rank	Application feature
27	Spotlight (exploration and context-aware suggestions of projects)
37	Local map & data feed
37	Project finder (characteristics-based search)
49	Pinning projects (creating shortcuts)
53	News feed
58	Events
62	Project forums
73	Calendar (showing contribution history and streaks)

Prompting test users to reflect on their possible real-world usage of the design gave clues about potentially important motivations and contexts of use. Test user responses indicate that the most prominent motivations behind use could be that it presents a meaningful way to pass time, a possibility to make a positive difference in the world, and a way to find new interests. Potential demotivating factors are the obscurity of citizen science, lack of users, unclear purposes of projects, and lack of valuable rewards for engagement. Additionally, test users anticipated that the most common context of use would be contributing to projects outdoors, on excursions planned beforehand with the support of the application. This represents valuable insights to design for situated use and starts to answer some questions of interest for a project placed in the third paradigm in HCI. Test users' reflections on potential real-world usage are appropriately situated in users' contexts, and relates the use to established situated activities, technology appropriations, and individuals' construction of meaning in the interaction. The following section will describe the final design proposal, which is heavily influenced by these resulting insights of the formative evaluations.

Design proposal

Proposing a design of a citizen science platform application serves to apply the knowledge gained through this project and exemplify what is relevant to address in an answer to the research question:

What should be considered when designing a context-aware smartphone application intending to engage the general public in citizen science practice?

The design proposal reached through the conscientious design process described in earlier chapters, will be presented and followed by an evaluation of its merits. The presentation will consist of explanatory text that serves to describe functionality and justify design decisions, complemented with screenshots of the design's prototypical representation. As the design process was carried out in Sweden, with Swedish stakeholders and Swedish test users, the prototypical representation of the design uses the Swedish language for its elements and descriptions. Direct translations throughout this text will serve to identify and explain each function or element that appears on the screenshots.

In addition to the research question it is also relevant to relate back to the initial idea that staged the design challenge. That is, designing a digital platform application for smartphones that through smart use of metadata, available open data and context-awareness attempts to increase the reach of citizen science projects while providing users with engaging user experiences. Referring to it as a platform application entails that the application should seek to aggregate citizen science projects from different authorities or organizations and facilitate engagement and participation in them through a common interface.

These preconditions have implications for the designed solution. Notably, it needs to accommodate and manage a wide and multidimensional set of projects. These can vary in subject area of study, demands on volunteers, context of participation, and more. In the final design proposal this is manifested in a number of features that enable users to explore the collective project space both freely and purposefully. Accommodating various projects also means accommodating their respective datasets. Based on the background research within citizen science and the design guidelines proposed in the theory chapter of this thesis, showcasing this data is beneficial for volunteer participation and engagement. One such benefit comes from the way it can visualize the activity of volunteers so that they see themselves as parts of a community that is alive. This is something that both background research and the formative evaluations of this design process identifies as important. To gain these benefits, the final design proposal leverages visualization and exploration of datasets in a few salient ways to be described in detail at each such instance.

A recurring theme in research and models of participation within citizen science, for example the aforementioned MLC model [41], is sense of community. This is often seen in relation to locality and the volunteers' identification to places in their lives. The design attempts to enable communities to grow within each respective project, but as the special importance of community-building in the local sense was a noticeable take-away from formative evaluations in this design process, measures to facilitate this are also seen prominently in the design.

After these overarching themes have been introduced, considerations on the overall user experience of the final design will follow. Proceeding from this is an increasingly detailed description of the design starting with its system model, consistent interface patterns, and choice of phrasing. The description goes on to cover the design's approach to the more specific concerns of independent amateur research projects, social use, and gamification, before giving a detailed rundown of each screen of the interface and its features.

Overall user experience

The fact that users are volunteering their time and effort to contribute to citizen science agendas has implications for the user experience design of an application like this. The proposed design invites users to explore the project and data spaces by readily presenting them in ways where the user is able to actively sort or adapt the display as they please. This aims to invoke curiosity which is a positive experience that can induce a will to participate.

As background research has found that anxiety over data quality and lack of self-confidence inhibit participation, the design seeks to alleviate this by incorporating welcoming and educational walkthroughs as users visit a project for the first time. Furthermore, the button to start a new contribution is given a salient placement and appearance, with carefully considered aesthetics and phrasing to make it encouraging. Getting volunteers to start participating is key and can start a self-reinforcing cycle as the one described by the MLC model [41]. Another central aspect of the MLC model is learning, and the design attempts to communicate an educational experience by repeatedly visualizing data and seeking a serious but inviting visual appearance.

A feeling of control over integrity and participation in the application is sought by clearly and consistently highlighting the individual user's contributions in a personally customizable color and by providing a collective place for everything of their direct concern, called *My page (Min sida)*, as one of the main screens in the application. This intends to build trust and give the user an experience of being in control.

As the extrinsic motivation of doing something good by contributing to science has been identified as one of the major motivations for participation, both in literature and formative evaluations, it is important to consider what user experience fortifies that motivation. In this design proposal there are a few things to note in that regard. As users submit contributions, an animated screen that explicitly thank them is shown automatically. More elaborate feedback on the scientific results of a project cannot be automated, but the design incorporates functionality to enable project initiators to communicate such feedback. Additionally, users are given titles as if they were scientists, based on what subjects they contribute in. For example, someone mostly volunteering in biology projects would see the title "Biologist" under their name on their page. This appropriately pays attribution to their efforts and could also increase individuals' identification with the cause. In a more abstract sense, these considerations are relevant for the user's ability to find or construct meanings with their use.

System model

The design is comprised of four main screens arranged spatially in a horizontal manner. Complementing the already introduced *My page (Min sida)*, is *Projects (Projekt)*, *Search (Sök)*, and *Explore (Utforska)*. The navigation between each main screen is facilitated and grounded by a persistent tab bar at the bottom of the screen. In an abstract model, this represents the width of the design. Consequently, exploring each main screen allows venturing deeper into the design. All main screens are made up of sections with different informational and navigational content, so called stacks. Generally, these sections or the content within them can be expanded to make up a new screen on top of the origin, thus utilizing the depth of the design for spatial arrangement.

This model is justified by findings from the project's formative evaluations. It pays resemblance with the first design iteration but abandons the problematic reliance on swipe navigation and lack of visual support to aid the user in navigation. The wide system model utilized in the second design iteration and its stacked navigational conventions motivated a more narrow and deep approach when designing the final proposal. Furthermore, those evaluations highlighted the potential strength and established understanding of a consistent tab bar, as users were provoked and confused by the faulty implementation.

Consistency

By leveraging consistency in interface elements and colors, the design attempts to be intuitive and efficient in use. The color blue is used consistently throughout the design to indicate pliancy, this should enable users to quickly identify interactive elements without further visual clues. Another less prevalent but equally consistent color is a personal color, customizable by each individual user. The design uses this color to distinguish data or elements originating from the user. This has the benefit of making datasets easier to navigate but should also increase the user's identification with the design and its use. In the representational prototypes shown below, this personal color is salmon.

To provide a consistent means of navigation across the width of the design and provide a basis for the user's formation of a correct mental model, there is a permanent tab bar at the bottom of the screen. As previously described, each main screen has expandable sections that are spatially organized by depth. Depending on the section they might include interactive and expandable sub-elements. And in all cases the pliant text *Show all (Visa alla)* is shown in the upper right corner of the section as a consistent means of expansion. Whenever the user moves deeper into the application, a back button appears at the top left of the screen along with a description of where the button leads. This can be likened with a one-step breadcrumb and seeks to provide consistent support to the user in strengthening their mental model and enable them to confidently know where they are. Additionally, in line with current interface conventions, double-tapping any icon in the tab bar brings the user back to the corresponding main screen no matter how deeply they had navigated.

Lastly, an interesting problem within the design challenge at hand is maintaining consistency while accommodating a variety of citizen science projects with different characteristics. The design attempts to solve this by presenting projects using pre-defined sections of content that each project can prioritize according to their needs. In doing so, it is possible to ensure consistency in the use of interaction design conventions, colors, and graphical elements, while allowing projects enough customization to make the interface effective for their case. This design approach is explained in greater detail in the sections concerning individual project pages and reporting.

Phrasings

A recurring question during the iterations of the design has been terminology and phrasing of the different aspects of citizen science. Some notable examples are questioning what words to use for projects, feedback messages, reports, submission of reports, and achievements. Justified by previous research and formative evaluations, the design proposal uses the word *project (projekt)* to describe a citizen science research project, simply *messages (meddelanden)* both for feedback and newsletter-style messages from project administrators, *contribution (insats)* for reports, *submit (skicka)* to send those contributions, and *achievements (bedrifter)* for describing the gamified badges volunteers can strive to unlock.

Perhaps the most interesting word among these is *contribution*. It was chosen because of its positive connotations and the fact that it is universally applicable both across observational and analytical projects, as well as for committing new data and doing data validation efforts.

Personal projects

While it is not visible in the representational prototype, the design proposal features *personal projects*. *Personal projects* are user-initiated research efforts, a way to facilitate for intrinsically motivated individuals to bring their ideas and data collection practices into the organized structure of the application. A motivation for including this feature lies in the potential for visualizing and accessing datasets that traditionally might have lived in notebooks or spreadsheets, never to be aggregated or analyzed in larger contexts. It also serves to motivate hobby citizen scientists to become users of the application by designing to support existing situated activities. Even if such users' initial motivations might simply be to make their own data collection easier or more accessible, recurring use could open their eyes for established citizen science projects that they take interest in.

However, it is important to note the limited role personal projects are allowed to take in the overall design. Because of the ethical obligations concerning initiating and administering a citizen science project, personal projects are not open for contribution by the public. Furthermore, they are not displayed among other projects on the projects main page, unless an exceptional personal project is manually curated in. Personal projects can be made open for public display and found using the search functionality of the application. Even so, they are to be clearly distinguished from "official" projects visually and explicitly in text.

The public visibility of personal projects is motivated by the potentially interesting creativity of users, and the sense of local community is important to volunteers. As the design in general has a limited social functionality, personal projects represent a potential outlet for creative research and expression that might interest and inspire other users. As such, the projects need to be visible for users to have a way of finding them and following their progression. However, the openness of the functionality represents an avenue for freer technology appropriation and meaning creation among users, which is in line with what is to be considered important for third paradigm HCI. But consequently, it is difficult to anticipate how the functionality will be used and manifest itself.

Context-awareness

With the initial motivation behind the formulation of the project's research question being the identified need of fitting citizen science practice into the daily lives of volunteers, context-awareness has been considered a potentially important mechanic for the design from the outset of the process. While formative evaluations served to extend the notion of what fitting citizen science into everyday lives entails, most notably in the way that test users liked to plan excursions ahead of time, they also substantiated the effectiveness of context-awareness for other uses cases. With this background, the final design includes several important implementations of context-awareness. Interestingly, few of them are prominently visible and obvious, a characteristic which will be elaborated on in the discussion chapter of this thesis.

While the respective features will be described in detail in subsequent sections, it can be said collectively that their design is motivated as a way to improve user experiences and support situated use. This is achieved by intelligent and careful consideration of relevant contextual factors, informed by the formative evaluation's inquiries into test users' reactions to the use of different context sources.

Sociality

Considering the prevalent role community building has been given in previous research within citizen science, it is important to discuss how this is expressed in the design proposal. Visualizing the community's data is an important trait of the design and serves to place everyone's data in a context and to give the impression of a living community. Furthermore, the design includes project specific forums to enable users to interact with each other and strengthen the community around a cause. It is also a way to open up for creativity and ideas for improvement that might emerge organically among engaged volunteers. This functionality is motivated by findings in previous research, especially the mechanics of the self-reinforcing MLC model presented in the theory chapter of this thesis.

Ideas of further social functionality, such as the creation of events and following of friends, was entertained during the design process. These ideas were ultimately excluded as formative evaluations pointed to the fact that such functions already exist on established social media platforms and could appropriately be outsourced that way. This is an example of how users consider appropriation of technology, and what it means to be responsive to this as an interaction designer in the third paradigm of HCI. From the users' point of view, having comparable functionality on different platforms is not necessarily useful, and might even be troublesome if it imposes on users' free appropriation of technology.

Gamification

As was pointed out in the background of this thesis, gamification is a trend both in interaction design and citizen science. The difficulty of gamifying citizen science tasks without jeopardizing the data quality or demotivate intrinsically motivated volunteers, even when only considering individual projects, eventually led to it taking a relatively minor role in the design. Nonetheless, the final design allows users to strive for unlocking *achievements (bedrifter)* as a reward for contributing to projects. This mechanism is implemented in an unobtrusive way by being present in the application without prompting for attention. Users who are curious will be able to find and explore what achievements there are, whereas others can simply ignore them. This type of non-diegetic reward system and its restrained implementation is primarily motivated by findings in the literature study. Previous research has suggested that non-diegetic rewards, like achievements, can hold some value both to intrinsically and extrinsically motivated volunteers.

The achievements are mainly project specific, and each project is given 100 *achievement points* to distribute between multiple achievements. The points are merely a means to enable progress bars to be displayed to users as they progress through their use, and the total points available are capped to limit excessive competitiveness. All of these design choices follow from the balanced and more unobtrusive approach to gamification that the application takes, with the hope of increasing some users' motivation to participate while avoiding demotivating others.

Apart from the motivational aspect of achieving goals and filling progress bars, the achievements also intend to serve a secondary purpose in nudging volunteers to contribute in new ways or make longer-lasting commitments to projects. A project could for example implement achievements for data validation efforts, creative contributions, or contributing from different locations. That would not only nudge volunteers to increase their involvement with the project, and potentially create a stronger identification with it, but increasing diverse contribution in this manner could also be beneficial for the research agenda and data. It is also a mechanism that attempts to motivate some dabblers, the most common type of citizen science volunteer, to greater commitment in projects.

A final remark regarding the achievement mechanisms of the design is the potential it opens up to combine goals of different projects and let volunteers explore the project space through global, non-project specific, achievements. Such achievements could for example concern different projects that share the same subject area or are applicable in the same contexts.

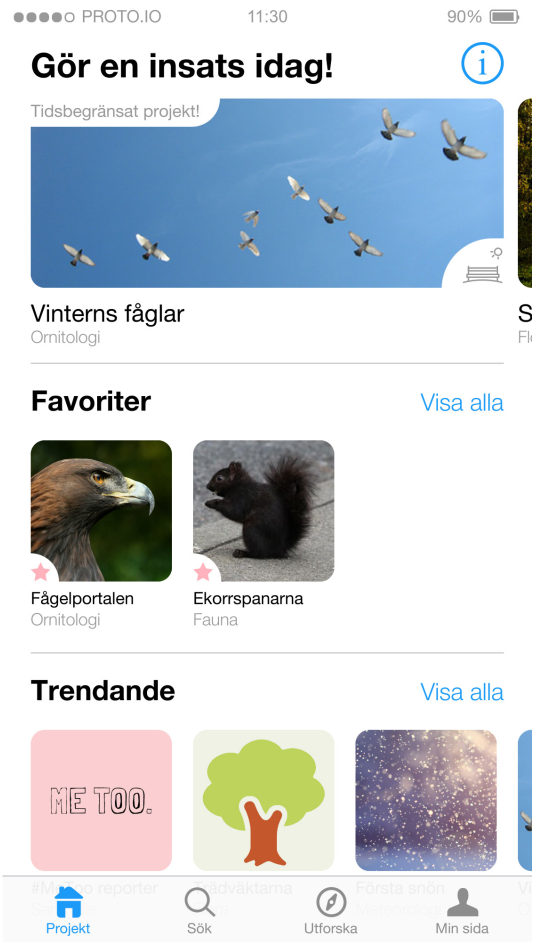

Figure 11. The prototypical representation of the Projects page.

Projects page

The *Projects* (*Projekt*) page (see *figure 11*) primarily consists of swimlanes containing different projects that the user can explore and to engage in. The swimlane is a well-established and understood user interface convention that is commonly used, specifically for exploration of content spaces. At the top of the page there is a more prominent swimlane with context-aware suggestions that represent ways for the user to engage in their present context. These suggestions adapt to external contextual factors such as temperature, precipitation, date, time, user location, other users' activity, and current needs of science and society. Internal factors like previous activity in the app and interests (self-reported by the user) also influence the results. This behavior is justified by the findings about users' reactions to different context sources from the project's formative evaluations. The context-aware suggestion function can also leverage open data, for example the terrain type around the user's location, and further improve suggestions of activities based on logically deduced higher-level context. An additional consideration for the function's adaptation is to combine suggestions familiar to the user with other of less familiarity, to pique the user's interest and promote an experience of curiosity. To make the suggested activities more actionable there are informational icons in the lower right corner of the projects' pictures that gives the user more information about what participating in each project entails. These icons can represent the activity level of the project, for example if it is suitably carried out stationary or while walking, or other relevant characteristics, like if it involves photography or is temporally limited. As the icons might be difficult to understand at first use, they offer a tooltip if tapped. Additionally, there is a standardized info button at the top right corner of the swimlane that explains the context-aware behavior, to aid the user's understanding of what the suggestions are based on. The inclusion and prominence of this feature is motivated by one of the primary background findings that originated the research question of this project; how to fit citizen science practice into the daily life of volunteers. Additionally, it attempts to fully embrace the importance of situated use by adapting based on its best approximation of an individual user's context. While the formative evaluations hinted that premediated use might be more common, it also uncovered the important motivation of use as a meaningful way to pass time. The context-aware suggestion feature is potentially effective for such use cases.

The other swimlanes intend to entice curious exploration and contain different categorizations of projects, for example the user's favorites, trending projects, projects that are new to the platform, and previously visited projects. There is also a swimlane dedicated to projects within specific research areas. Which research area to display is controlled by the user through a dropdown-like list. Lastly, there is a swimlane for project mixes, where the user is able to start predefined mixes that combine contribution to different projects based on their themes or characteristics. Mixes line up contribution requests and can encompass a defined number of contributions or perpetuate until the user explicitly cancels them. The duality of this feature is that it can both serve as an easily initiated and lax leisure task to pass time doing something benevolent, or as a challenge that sets a goal of the use and frames an engaging user experience. For example, it could engage a user in identifying stellar phenomenon for several projects from the couch on a rainy day, or be a fun activity for the family excursion, giving tasks to find and photograph trees, flowers and acorns for different projects. While this function is primarily focused on projects where the citizen scientist analyses data, and not on data gatherings, it can be used for gathering data as well in cases where objects of study are plentiful and easily accessible, so as not to bore the user with tedious search quests. The project mixing functionality can be justified by considering how mixes can be used to support users' established situated activities in the world. For example, mixes could be tailored to coffee breaks or daily commuting. Additionally, project mixes represent a design measure targeting dabblers in the way that they mix projects up to avoid tediousness and use perpetuation in contribution to increase data returns.

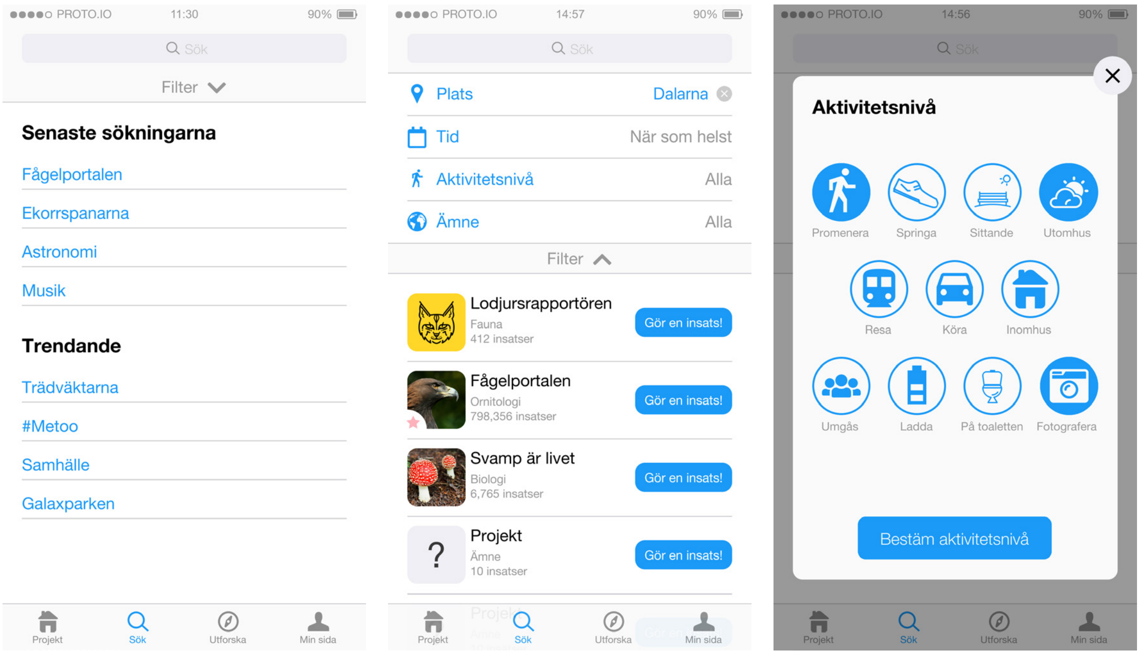

Figure 12. The prototypical representation of the Search page.

Search page

The second main page and tab (see *figure 12*), titled *Search* (*Sök*) page, is dedicated to searching for projects. When entering this page, the application will propose quick searches based on the user's search history and generally trending search terms. Keeping in line with user interface conventions, this list disappears as the user interacts with any other element on the page. The other interactive elements available to the user are the search field at the top of the screen, and the filter drawer positioned just underneath.

When entering a free text query into the search field, the application will process the text to give smart suggestions based on project title as well as identified search tags. These tags can relate to geographic areas, the date and time, the initiating organizations, and much more. For example, if the user searches for a specific city by name, potential projects whose name include the city's name will be complemented by projects available there, with prioritization given to projects limited to that geographic area.

The filter function is contained within a small downwards opening drawer positioned just underneath the search field. Through this functionality the user can filter the results with aspect to location, time, activity level and subject. When selecting a filter, a popup window will appear where the user selects how to apply that filter. Upon confirmation, the popup disappears, feedback on the filter setting is shown in the filtering drawer, and the filter is applied to the results of the search. If no search word is entered previous to filtering, the application will apply the filter to the entire project space. To sort the results aware of context, the application will weigh in several factors, among them the user's favorite projects, self-reported interests, other users' activity, and the current time and location of the user.

The projects in the result list are presented with picture, name, research area, and total number of contributions. Additionally, each project has a shortcut to its contribution interface represented by a distinct button. This is included in the design to improve efficiency of use in cases where users look to quickly report a sighting they unexpectedly have encountered. While this use case might be rare, it is most effectively supported through the *Search* page. A side effect of this contribution shortcut is how it lowers the threshold of contribution for all, which is positive as continual engagement in a project is heavily dependent on getting started.

What contexts of use that users envisioned during formative evaluations were influential in the design of the *Search* page. The design specifically aims to address the most prominently expressed use context, planning future excursions. The advanced filtering functions facilitate the need to specify future contexts, and look to make sure that users find interesting and applicable activities to engage in. The importance to consider such expected appropriations and meaning creations motivates the prominence and design of the *Search* page.

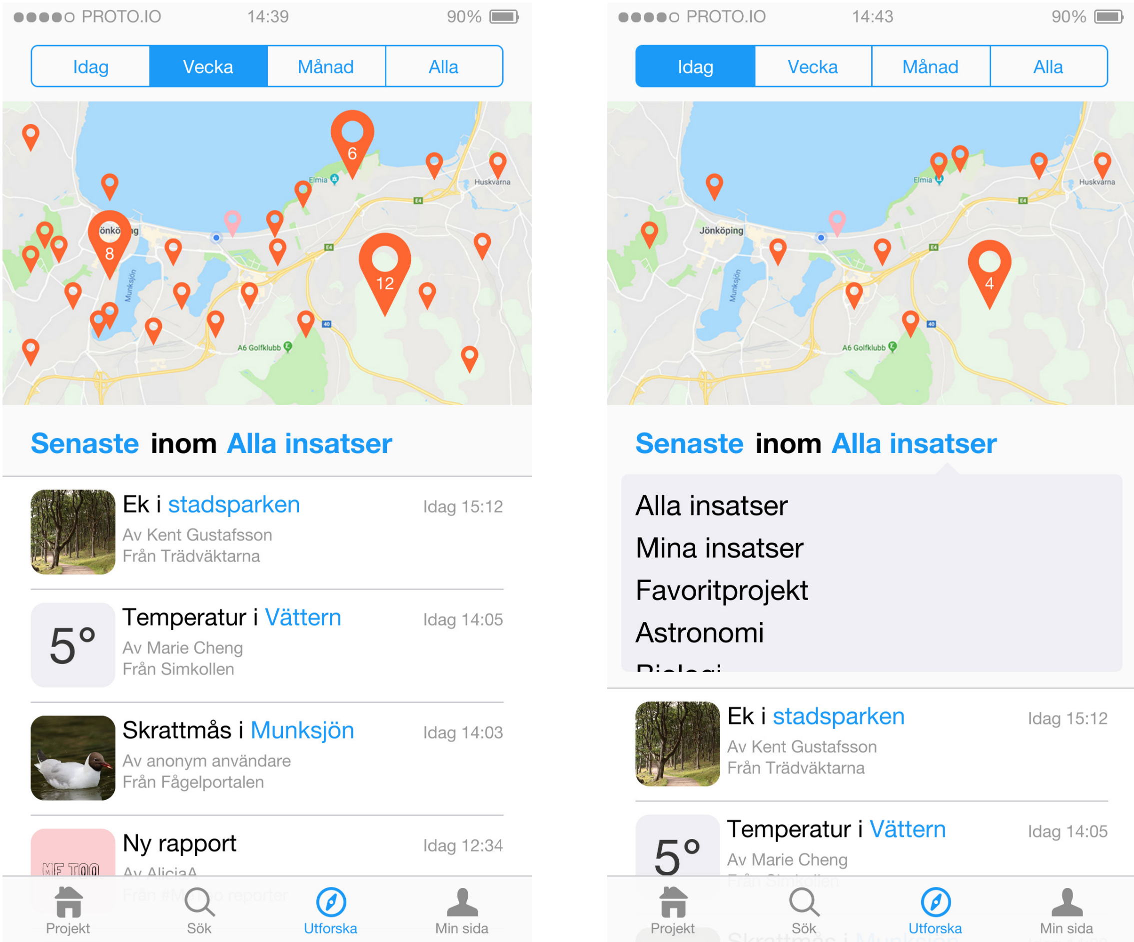

Figure 13. The prototypical representation of the Explore page.

Explore page

The *Explore* (*Utforska*) page (see *figure 13*) allows the user to explore all datasets that are accommodated in the application. The map is central to this page as the main means of visualization. Contributions are marked and aggregated into orange pins, and all data entries that correlate to the pins visible at a given moment are displayed in a list below the map. In line with current conventions users are able to adjust the map through pinch-to-zoom and panning gestures. Including contributions not bound to a geographic location in this interface is desirable but not straight-forward, how to approach this is elaborated on in the discussion of this thesis. The default state of the map is based on the user's location and adjusted to include a significant enough number of contributions. In this situating manner the *Explore* page serves to provide users with the local connection and feeling of an active community that both previous research and formative studies have identified as crucial for users' engagement.

There are two ways for the user to control what will be shown in the map besides manipulating the map itself. The user can specify how old the contributions shown in the map are allowed to be. This is controlled using a segmented controller, a common user interface element for mutually exclusive settings, at the top of the page. The other option is the sort and filter function placed directly underneath the map. The default setting for this function is to display all available data on the map sorted chronologically. This setting is communicated to users as a text string “Senaste inom Alla insatser” (“Newest among All contributions”), where “Newest” and “All contributions” are displayed with blue text to convey pliancy. If the user taps on any of those terms the list of contributions will move down to make room for a dropdown-like popup where the user can change the sorting and filtering settings independently by selecting terms from predefined lists.

In addition to time, sorting can also be done based on popularity (number of views) or controversy. Contribution controversy is based on how other users have flagged the entry. This sorting mechanism prioritizes contributions that have exceptional numbers of positive flaggings, an interesting combination of positive and questioning flaggings, or a limited number of questioning flaggings without any positive ones. In this way it serves to highlight exceptional contributions (for example rare sightings) along with contributions that need further validation or discussion, while avoiding to bring too much attention to questionable contributions by hiding them after enough questioning flaggings have been submitted. The inclusion and design of this functionality intends to maintain a positive and safe user experience that plays on curiosity and learning.

Additionally, the contribution space can be narrowed down by applying different filters. This functionality is represented by the second pliant term in the aforementioned text string. The filters available to users are both project-based, limiting the data based on research areas, and user-based, allowing them to display only their own contributions or data from their favorited projects. This way the user can decide what kinds of data is interesting and can easily explore larger geographical areas when hunting for something special. Including this exploratory functionality represents an additional potential for users to find or construct meanings with their interaction, based on knowledge gain or specific interests. By making contributions public and visible, even if it is limited to this specific community, it is also a mechanism to promote volunteer attribution and community feedback. Both of which previous research has identified as potentially important factors driving motivations to participate.

There are some notable design choices to remark on when examining the contribution list. Here, contributions are presented with a picture or icon, depending on the characteristics of each project, a heading based on the most significant data, volunteer name, and associated project. Additionally, information related to the currently active sorting mechanism is shown to make those mechanisms more transparent to users. This means that each contribution is complemented by a timestamp, its number of views, or flaggings, depending on current settings. Furthermore, the application utilizes open data to find geographical classifications and boundaries based on terrain or societal constructs, for example lakes or parks. If the application is able classify a contribution as such, that classification will be included in that contribution's heading as a pliant text term. Tapping the term will adjust the map to filter contributions based on this classification. Again, this design is justified by its potential to invoke curiosity and a user experience imbued with learning.

Finally, enabling users to explore the contributions of others have to be done with respect to privacy and security concerns. Sensitive data will be published with a delay and can be given a fuzzy location, a randomized position in a predefined area around the user, when appropriate. Exceptionally sensitive data will not be displayed on the map at all.

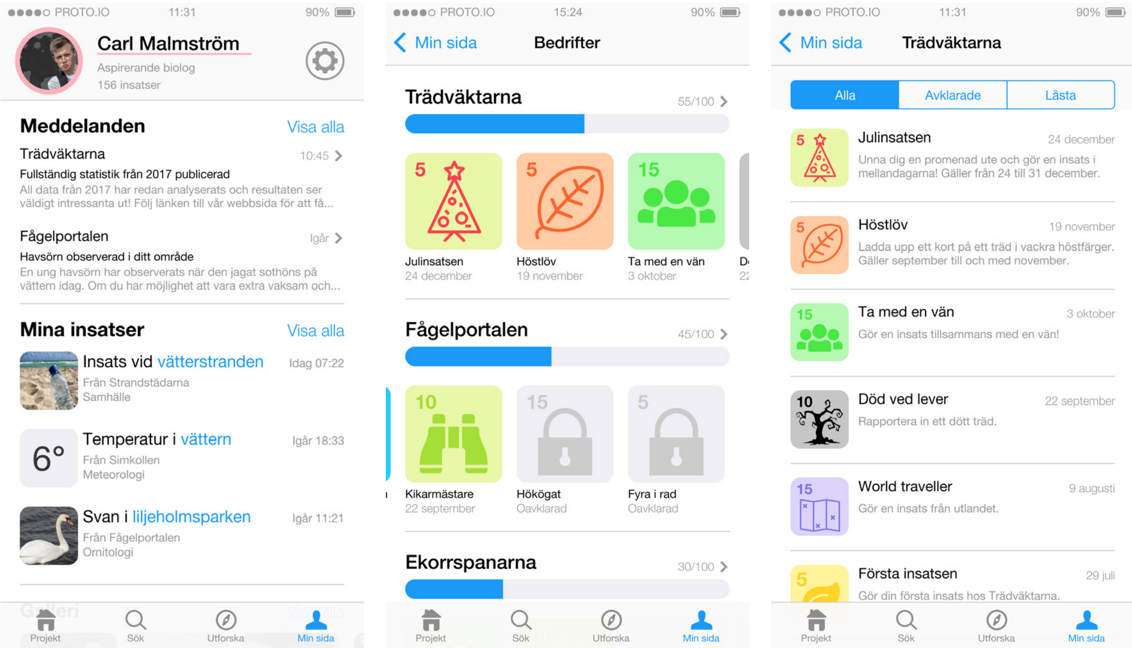

Figure 14. The prototypical representation of My page to the left, underlying achievements pages to the middle and right.

My page

The focus of *My page* (*Min sida*, see *figure 14*) is to aggregate the user's activity with the application into an overview. Consequently, this means that most of the content included on this page is not unique to it, but can also be found on the pages of individual projects. For example, the *messages (meddelanden)* section on a user's *My page* gathers all messages from different project involvements in one place, making it easy to access and overview for the user, while the same messages are also available separately on the respective projects' pages. The other sections of the page are dedicated to the user's contributions, pictures and achievements, and work in the same way. While it represents significant redundancy, formative evaluations indicated that such a design was expected by users and desirable to invoke an experience of being in control.

The user's name, title and total number of contributions are displayed at the top of this page. The title is supposed to be a motivating factor and feedback mechanism, as it is playful and adapts based on the user's activity. The title will depend on what field the user engages in the most, if the user starts to classify galaxies she could be titled "Amateur astronomer". With increasing engagement and contribution the title advances, so after many contributions the same user could for example be titled "Proprietor of the Hubble telescope". If the same user engages in several scientific fields there can be hybrid titles or a rotation between different titles. In addition to appropriately situate and attribute the user as a scientist, which should encourage desired user experiences and learning, it also serves to strengthen the volunteer's identification with project causes and thus promote engagement.

As previously described, *achievements (bedrifter)* are non-diegetic rewards included as a way to promote extrinsic motivations and to inspire users to try out different means of contribution. The achievements are represented as badges that can be unlocked and collected. When an achievement is locked the badge is grey with a padlock icon, but the user can see the description of what is required in order to unlock it. This way the user gets a hint of what features the project contain and is subtly nudged to try some of them out. Every project gets a maximum of 100 points to distribute on achievements, in five-point increments. Consequently, the max number of achievements are 20 per project. Progress bars that are filled up as users unlock achievements and collect their points are shown on the *My page* for all projects that the user engages in. Representing this using progress bars intends to motivate the user to collect more achievements in those projects, if nothing else because it can be satisfactory to see the bar fill up.

My page also includes a button for the user to access their settings, represented by the common cog icon. While there is no prototypical representation of the settings page itself, it should be of little concern for the design as there are particularly well-established user interface conventions in this regard. In addition to controlling sensor permissions and notifications, the page also features settings regarding the user's name, anonymity, personal color, subject interests, and contribution data control.

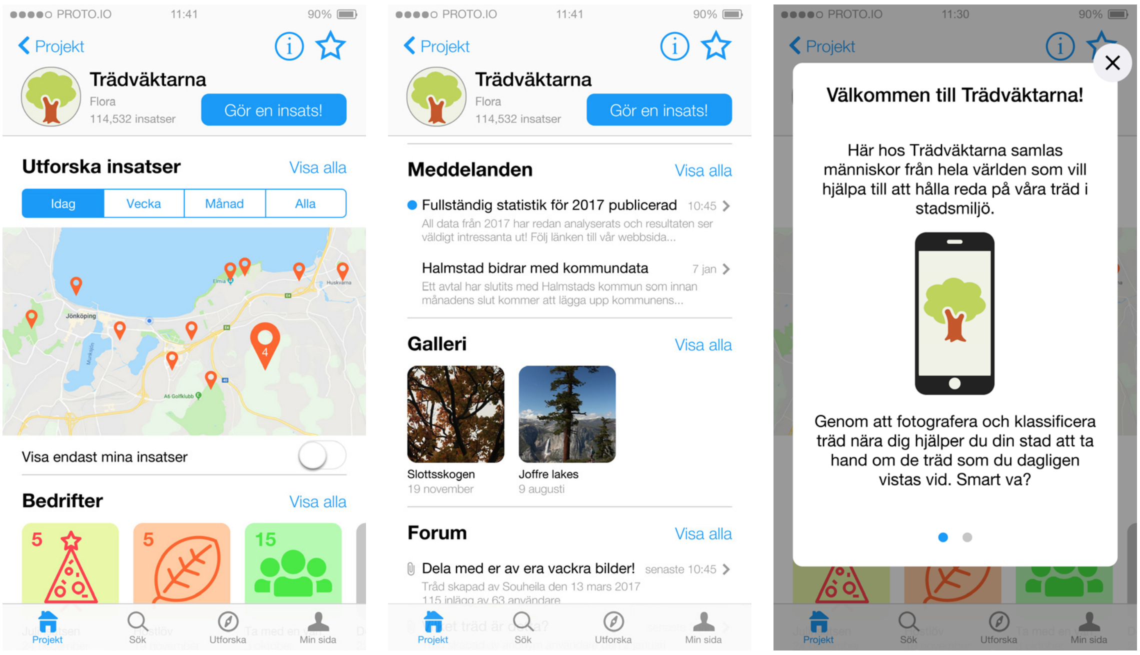

Figure 15. The prototypical representation of a page for an example project called Trädväktar-na, with the welcoming popup to the right.

Individual project page

Every project gets an individual page (see *figure 15* for an example) as a sort of project homepage. When a user opens such a project page for the first time a welcome message is displayed in a popup to help the user understand the purpose and protocols of that project. This message also seeks to motivate why the user should donate their time to make contributions to this specific project. The popup can be closed as the user desire, so that users already familiar with the project can skip ahead. The prominence of this communication is motivated by users' remarks about project purposes during formative evaluations. It can also serve to provide some basic training in a project's collection protocols, which is highly regarded in previous research.

The administrators of a project get to choose a thumbnail picture and place the project into a predefined category based on its research subject. This information is displayed at the top of the page along with the total number of contributions made to the project so far and a button to start a new contribution. In this area of the screen there is also a pliant star that users can tap to mark the project as a favorite and an info button that brings back the welcome message. Marking a project as a favorite makes it more accessible, as it creates a shortcut to it on the *Projects (Projekt)* page and includes it in the corresponding filter on the *Explore (Utforska)* page. Additionally, the user receives updates on the project through messages, available both on the individual project's page and on the user's *My page (Min sida)*. Having the ability to mark projects as favorites can increase the volunteer's identification with projects, but mostly it is a way to improve efficiency of use for recurring participation.

The main interaction area of a project page is made up of a stack composed of standardized content sections. Among these sections are *explore contributions (utforska insatser), messages (meddelanden), achievements (bedrifter), gallery (galleri), events (evenemang),* and *forum*. Each section displays their content in different forms, like lists (*messages, events,* and *forum*) or swimlanes (*achievements* and *gallery*). The sections can be prioritized differently or be excluded based on the needs of different projects. Most of the information in the project feed is available to users in other places of the app, summarized with content from other projects. *Forums* and *events* are the only sections that exclusively live isolated on the individual project pages.

Most projects will want to offer a way to explore what has been contributed by its users to show that a project is active and has a living community. Just as for the *Explore* page, such publicizing of contributions also serves to increase volunteer attribution. In projects where location is not registered the contributions will be shown as a gallery or a list, but in most cases they will be shown on a map to situate them in relation to the user geographically. This map works the same way as on the *Explore* page, with the exception that the contributions will not be displayed on a list below the map unless the user expands this section. No matter the mode of presentation or if the section is expanded or not, the design includes a switch that allows users to change the display between including all contributions or just the individual user's.

The *messages* section follows conventions on email and messaging inboxes, and allows project administrators to communicate the progress of the research along with other information that might be interesting to volunteers. Based on findings from literature, this kind of feedback is critical for users to be able to find meaning in their engagement, especially as the motivation to contribute to science is prevalent. The messaging feature also enables administrators to contact specific volunteers to give personal feedback or point out something interesting or plausibly wrong in a contribution. Apart from what this means to scientists for their understanding of potentially critical data contributions, such personal feedback has been shown to be highly motivating to volunteers both in previous research and the formative evaluations of this project. It also represents a potentially powerful mechanism for learning and development of scientific skills, which should further reinforce volunteers' motivation to participate.

The user's latest *achievements* in a project are summed up in a swimlane on its page. The colorful badges are supposed be visually interesting and invoke a feeling of curiosity. As has been described earlier, their purpose is to subtly remind and motive users to collect more of them and extend their engagement in the project.

The *gallery* section consists of a swimlane that displays the user's pictures from previously submitted contributions. In some projects, where pictures are fundamental to data contribution, it might be valuable to present the user's activity in this format. In other projects this might only serve its secondary purposes as a reminder of previous activity or a way to inspire creativity and personalization of the project page.

Formative evaluations motivated the outsourcing of *events* to established social media networks, but in order to support existing situated activities, projects still have the option to include a list of links to upcoming gatherings or happenings on their page. The list entries only include essentials such as time, place, and title, along with a link to the hosting social media website where volunteers can find more elaborate information. Project administrators will be given instructions on how to create an event that is publicly open, even to those that are not registered to the specific social media network used.

The project *forum* is a place where users can discuss and share freely in relation to the project. This is an important function as it serves multiple purposes. Firstly, forum threads can be used as a supporting mechanism where volunteers can seek answers to any questions regarding the project, its protocols, or specific contributions. This way it can lower thresholds to participate, increase self-confidence in volunteers, and help alleviate anxieties related to this. Secondly, in seeking this support from the community other users' engagement and identification with the project are also strengthened, and implicit roles that users can aspire to is allowed to emerge. As previous research has found, helping others with identification of species and phenomena can be a primary way of contribution for some volunteers. Thirdly, discussion is an important part of learning, and as the MLC model introduced in the theory chapter of this thesis established, learning is in consequence an important part of citizen science. Having forums to enable meaningful discussion can advance both the research agenda and individual volunteers' knowledge. Lastly, forums represent a potential outlet for volunteers' creativity. This could for example manifest itself as users sharing their best pictures taken during engagement with a project or expressing ideas about improving the project's research practices. In any and all cases, the freedom to appropriate forums as volunteers see fit should help them find and construct meaning with the interaction and strengthen the community around projects.

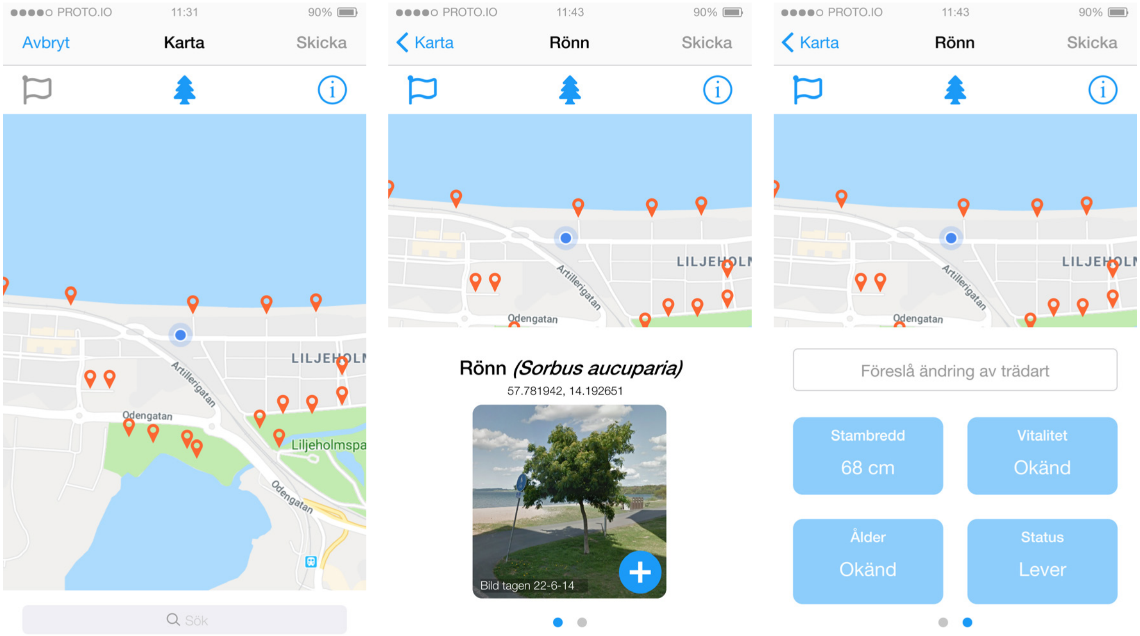

Figure 16. Prototypical representation of a report page for an example project.

Reporting

The reporting pages (example shown in *figure 16*) are used to create and submit contributions. They are built on a template structure which means that there are several standardized elements that can be used to build a reporting page, making it effective for specific contexts while maintaining consistency in interaction and aesthetics between reporting pages. The need of freedom in customizing protocols for specific cases was reflected already in the stakeholder interviews conducted at the outset of this project.

The top of every reporting page is reserved for support functions, such as an information button that opens a help popup, a guide to determining species or phenomena (if applicable) and a function for flagging your own or other user's reports. These prominent supporting functions intend to alleviate volunteers' anxieties about data quality and their own abilities, which are issues highlighted both in previous research and this projects' formative evaluations. The design includes report flagging for its potential to validate data through peer-review, highlight exceptionally interesting reports, and provide a way for self-doubting volunteers to communicate their uncertainty. Flags can either be positive, if a report is exceptionally well executed or of a rare phenomenon, or questioning. A questioning flag is used to indicate that the data might not be reliable or valid. How the design uses flags to determine controversial reports is described in the section dedicated to the *Explore (Utforska)* page, and how projects choose to process reports and their flags in data validation protocols are up to each individual project.

Diversity in protocols and complexity requires that reports can consist of one or more pages. The example in *figure 16* shows a report with two pages, where the first page is used to define what object to report on. This interaction is usually carried out through a map with pins that point out available objects in the user's vicinity but could also use a gallery or list to display the objects if they are not location based. Additionally, there is a search function at the bottom of the screen that allows a user to find objects to report on using free text in cases where that is effective. Some projects might require the user to send data in order to receive instructions for the next step of the report, hence the need to support even more pages in one report. However, for many projects one report page will probably suffice. In this case, the user will either choose the object to report on, as in the case of reporting the sighting of a bird, or get an object assigned by the project, as in the case of analyzing a picture of a galaxy.

After the object of the report has been established, the next step is to add or alter information concerning it. To enable large interaction elements and avoid clutter, the report supports the use of carousels, where the user can navigate by swiping sideways through several panes of information supported by visuals clues in the form of dots at the bottom of the section. In contrast to other user interface conventions like the page scroll, the carousel has predefined snap points and can thus make sure that elements that belong together are not separated by the edges of the screen. This enables project administrators to control what content should be displayed simultaneously at any given moment based on the data collection protocol. Additionally, this design choice also intends to give the user a sense of progress by using a skeuomorphic association to turning the pages of a physical, paper-based, report.

When the user is finished with a report, it must be submitted in order to be registered in the project. If the user decides to navigate back to the previous screen instead, it will be saved locally until visited again. Similarly, the report will be saved locally also in cases where the user is offline, but then it will be uploaded automatically once internet connection is restored.

All different interface elements that can be used for data collection are not defined in this report. This is partly due to the fact that this project is independent from any citizen science stakeholders, which means that the design is not tailored to fit any specific real project. Another reason not to define the report interface in detail is to avoid the claim of having constructed an exhaustive list of all possible interface elements needed to support all imaginable future projects. There exist well-established user interface conventions for collecting data in various forms and formats, and these should be leveraged. A suggested approach if this project should be realized would be to start with a group of stakeholders and develop a set of convention heeding interface elements that would suit a wide variety of projects. This set could then be iterated and expanded as the number of projects grow.

In many cases, we believe that the reliability of a report increases if the user is aided with context-aware suggestions. For example, if the user sees a bird and want to report it to a project, it is probably helpful to see which birds that are commonly reported in the area. Also, if the user reports a bird that is very rare but has a strong resemblance to a very common relative in the specific area, the application could show the different birds, highlighting the differences, and kindly ask the user if it could be the more common bird that has been spotted. However, even if there are a number of interesting application ideas for context-awareness in this manner, it is important to note that this feature has not been thoroughly researched and would need further development and evaluation before implemented. Some of the potential upsides are how it supports users and makes contribution easier regardless of previous knowledge. It could also be used to automatically provide specific and direct feedback, which could both motivate and educate volunteers. It is however important to consider what context-aware behaviors like these could mean for data quality and reliability.

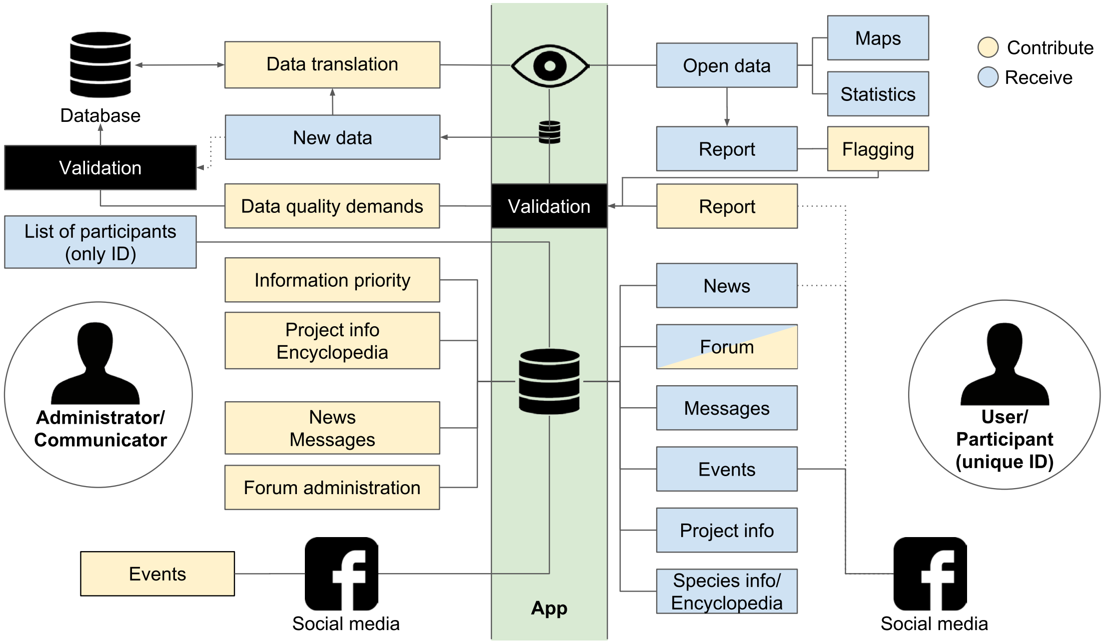

Figure 17. Information flow mapping of the proposed application.

Information flow mapping

An overview of the resulting mapping of information flows concerning the proposed design is shown in *figure 17*. The left side of the diagram concerns the infrastructure, inputs, and outputs of an administrator, or initiator, of a citizen science project. The flows pass through the application, represented by a green band in the middle, to the user, or volunteer, whose informational elements are shown on the right side of the diagram. Information that the respective stakeholder, administrator, and user is exposed to is color coded so that information contribution is represented by yellow and information receival blue.

An important care-about found among stakeholders is data validation protocols and mechanics. The information flows concerning validation should see relative diversity and complexity across different citizen projects, depending on routines and data demands. Because of this, it is important to note that there is no single validation procedure and information flow envisioned, but rather a suite of possible ones. Nonetheless, as a user submits a report it enters the application's temporary database along with any data flagging. At this stage, there is a potential for data validation using mechanisms internal to the application. These include peer-reviewing, seeking consensus across independent reports, expert user review, user trust rankings, and automatic data analysis to identify outliers. Depending on the individual project, any number of these mechanics can be active and facilitated by the application. In addition, or in place of this, the data can be sent to the project administrator for processing and validation as they see fit.

Of high technical interest is the translation and communication between the application and the various databases of each project. In order for the application to work there needs to be a translation protocol in place that ensures the correct pairing of different APIs. This is anticipated to be established as a crucial initial effort in the introduction of each project. The data translations need to consider what data to include in the communication between databases, how different data fields correspond in name and format, if there are relative hierarchies in the data, and what the relevant API commands are.

Related to this is the specification of reporting demands and how that affects the interface. While the shape and handling of data is largely described through the data translation protocols, the resulting interface implications should remain to be solved. This is conceptualized as being solved using pre-defined reporting templates that can be selected and adjusted according to the specific needs of each project. The templates should be designed using standardized UI-elements to ensure consistency and be based on the various data collection protocols that established citizen science projects utilize. As the application expands to accommodate more projects, reporting templates should be adapted to remain effective.

A large portion of the information flows visualized in the above figure concerns communication between the two primary stakeholders, the project administrator and the user. An administrator of a project in the application is expected to prioritize information in order to achieve a purposeful arrangement of content on their project page within the app. Additionally, information about the project's purpose, goals, and protocols are needed to introduce volunteers to the cause and enable them to contribute. In some cases, further support might be appropriate, for example to aid in species identification. As previous research and results from formative evaluations has shown, the importance of a continual engagement and communication between project administrator and volunteer cannot be understated. This is facilitated through a number of information channels flowing through the application. Administrators are indebted to share news of research progression and publications to the volunteers who have contributed their time and effort to the cause. This is an important feedback mechanism that increases the ownership and identification volunteers feel towards the project. More specific feedback can also be implemented by sending messages to individuals or groups of volunteers, but what form and frequency this takes will naturally vary between respective project and administrator.

A notable exception in the application's informational flows is the outsourcing of events to external social media services. This is motivated by findings and discussions emerging in the formative evaluations of this design process.

Summative evaluation

A prototypical representation of the design proposal described in the previous section was evaluated with users both in co-located and remote evaluations. As described in greater detail in the implementation chapter of this thesis, the concluding data analysis treated the respective data outputs collectively despite differences in setup and data collection protocols between the two tests. The resulting insights that make up this section attempt to evaluate and validate the design measures taken in the final design proposal and in doing so further the substantiated knowledge and problem understanding of this project. Being a summative evaluation, it also serves to test the current tacit hypotheses and their adequacy to be considered for inclusion in any answer to the research question at hand.

The resulting sample of test users participating in the final evaluation, summarized in *table 4*, is overrepresenting female and young users. Considering the generally weak awareness of, and engagement in, citizen science that was mentioned in the background of this thesis, it should also be noted that this sample has more experience of citizen science than the general public can be expected to have.

Table 4. Final evaluation test user distribution

	Round 3	Remote	Sum
Number of users	10	10	20
Recurring users	40%	20%	30%
Gender identity			
Female	70%	70%	70%
Male	30%	30%	30%
Age			
18-25	60%	10%	35%
26-35	20%	20%	20%
36-50	0%	50%	25%
51-65	10%	20%	15%
>65	10%	0%	5%
Previous experience of citizen science			
Never heard of it	60%	10%	35%
Heard of it	30%	20%	25%
Some experience	10%	30%	20%
Much experience	0%	40%	20%

When users summarize their experience and impression of the design, they tend to describe it positively. Some recurring comments are *"user-friendly"*, *"good looking"*, *"much to explore"*, and *"straight-forward"*. This implies an intuitive and interesting interface that has the potential for good usability. By looking deeper into the evaluation data, one can seek an understanding of how these impressions are substantiated. Starting with the important relationship between the system's model and each user's mental model, the evaluation hints that the design communicates a system model that enables users to form a correct mental model. This is underpinned by observation of users' generally high ability to navigate and locate their position within the application space. Users accomplish navigation into and out of individual projects efficiently and explicitly remark how the persistent tab bar allows them to understand and navigate the interface. Through probing it is established that some, but not all, users are able to identify the color-coded pliancy used throughout the interface, i.e. that blue elements are interactive. For some this seems to be merely a subconscious realization, but it should have a significant impact on the usability of the design nonetheless.

Test users' remarks make clear that it is important for the application's success to account for and cater to individual user's interests. This is to be expected considering the important role intrinsic motivations, like subject interest, play to drive participation in citizen science in general. More specifically, the evaluation underlines the effectiveness of the design proposal's contextual adaptation of suggestions and the rich filtering functionality, as both features were received well. Additionally, the gamified elements of the design shows some promise in its capacity to motivate volunteers extrinsically. Some test users expressed a curiosity to and tentative motivation from the achievement functionality and the associated progress bars. This tentative motivation to participate seems to be only partly extrinsic, as a clear appeal to test users is the potential of achievements to introduce new perspectives and different ways of participation. This should be taken into account when considering the precise implementation of achievements in each citizen science project to be included in the application. A final remark in this regard is that the progress bars and points mechanics are not without confusion, for example it seems to be advisable to be consistent and explicit with units to numerical values like the achievement points.

Achievements have a prominent position on the user's *My page*. Judging by observation of test users during co-located evaluations, the existence of this page seems to be an assurance to users as they expect it to aggregate everything (favorite projects, contribution history, achievements, pictures, et cetera) that they have been involved in. While this is mostly true in the design proposal, there is a clear disconnect in that favorite projects are not listed on this page, but only on the *Projects* page.

Changing the focus to the *Projects* page, users are generally able to identify and explore the content within each swimlane on that screen. They also understand that the top-most heading and associated swimlane concerns curated suggestions, but some remarks suggest that this section could be made clearer or more interesting with different language. The symbols that are used to explain contextual elements of the contextually suggested projects are not straight-forward to users, but most are able to reason about their meaning. Some remarks suggest that the symbols could be improved by increasing the consistency of their presentation. One way to do this would be defining some structure to the low-level context, so that the same contextual elements and their respective states are always communicated regardless of their specificity and importance for higher-level context.

Seeing how repetitive the design of the *Projects* page is, basically being made up of a long list of swimlanes, it is interesting to consider how this is perceived by users. As previously mentioned, users understand this interface convention well and as such, the repetitiveness should improve the efficiency of use. However, it is also clear that some users consider this aspect of the design boring, which implies that there could be too many swimlanes without aesthetic or functional interruption. Perhaps this represents an opening for improvement of the user experience, and that other modes of presenting projects could be both more interesting and effective in some cases. However, it should be noted that this represents a potential improvement from an already promising design, as quantitative measures from the remote tests show a clear positive opinion of the proposed design in this regard. 50% of tests users strongly agree, and an additional 30% agree, that the *Projects* page is exciting and inviting.

While the *Projects* page seeks to facilitate free exploration of projects, the *Search* page is focused on aiding users in finding projects based on specific characteristics. As the main functionality closely follows interface conventions for searching, it is hardly surprising that this presents no usability problem for the test users. What is more problematic is the rather advanced filtering features. While most users intuitively understand how to apply and remove the respective filters, getting to that point of the interaction sequence is not as straightforward. It is clear that users look to search for something in the free text field before applying filters, which is not necessarily intended with the design. Considering the intended functional prominence of the filters, the results from the evaluation suggest that access to the filtering interface should be made more salient or that it perhaps should be exposed in full as a default behavior. In the current design this functionality is slightly difficult for users to find and access at first use. Finally, the evaluations show that users are comfortable with free text search and not unfamiliar with smart search functionality that analyzes free text input to identify for example geographical locations, which justifies the inclusion of this in the design.

In line with the formative evaluations, test users again express the value of relating data and activity to their local area. As this is utilized in multiple places in the design, it preconditions a positive user experience and also facilitates users' identification with the application and its purpose. Promoting user identification and learning by putting data and activity in the context of users' local areas is the primary purpose of the *Explore* page included in the design proposal. The evaluations validated that users like to see their local area in this manner. The design includes filtering mechanisms in three data dimensions, and while they seem quite intuitive to test users, they are far from perfect. The temporal filtering function uses a prevalent interface convention, the segmented controller. This convention and its implementation seems well-established and effective. The design of the other filtering functions relies only on color coded pliancy hinting, they are simply words written in blue, but that does not seem to hurt usability much even in the evaluation case that considers guessability. This is a positive result, considering that users have no previous experience of graphical interfaces to leverage in order to understand this convention-free design. It is however not intuitively understood by all test users, and further testing might be needed to settle the question of possibly including further visual clues to this functionality. A general remark to the *Explore* page is whether it is appropriately titled. Users might relate the term explore to exclusively new or unfamiliar data, which introduces a slight disconnect from the functionality of looking at the user's own contributions, popular (not necessarily new) data, and data from favorite projects.

How individual projects are presented and introduced to volunteers is of utmost importance, and the related design measures of the final proposal was generally received well by test users. The introductory pop-up that is shown as the user first navigates to an individual project page was appreciated, but its extent too great in some users' view. In line with formative evaluations, test users still value that the design makes project purposes explicit along with explanations of what a contribution means and how it is validated. For some users this information cannot come early enough, and they would even prefer if the design could incorporate this communication to some extent at first glance on the *Projects* page. The design uses the rather common interface element of an information button represented by a lower-case i inside a circle in a number of places, and test users have no problems understanding and approaching it in the intended manner.

One use of such an information button is on the individual project page, where it is used to bring the introductory pop-up back up. Regarding the content and design of this page, test users are generally positive. The design is in line with their expectation to be able to find everything (contributions, achievements, pictures, et cetera) related to the individual project in the different sections of the page's stacked layout. As contributing to a project was deemed a prioritized functionality of the individual project page, the corresponding button has a prominent position and aesthetic as part of the page header. Despite its prominence, test users did not find this button as quickly as expected, but once they did they generally did not hesitate to tap it. Interestingly, one test user was able to consciously recount for why they had not seen this button initially. The placement and aesthetic of the page header with its white background, icon to the left of some text, and a prominent button, closely resembles how many app download prompts and advertisements look. This negatively affects the usability, or at least the guessability, of the individual project page as some users will have a slight inclination to ignore the project header because of this resemblance.

Once identified the contribution button is considered approachable. The term contribution (roughly equivalent to the design's Swedish term "insats") which is used consistently throughout the design is received well by users and seems understandable and approachable. Overall, test users do not show much hesitation to start a contribution, but this might also be conditional to the test setting. Once a contribution, or report, has been initiated and the option to close it appears, users seem to think that the term cancel (translates to the design's Swedish term "avbryt") is too severe, especially in the initial stage of a multi-stage report. Another related remark is that the physical distance between the reporting interface (bottom of the screen) and submit button (top right of the screen) could introduce an improper disconnect between the two. Another important usability problem exposed by the evaluations was that swiping between pages on a section of a screen is not always intuitive. The design uses this to allow the user to move between the stages of a multi-stage report, and hints at the interactivity through page identification dots similar to the ones commonly used in multi-page pop-ups. The intuitiveness of this convention seems to depend on where it is implemented; while no test users had problems swiping between pages in a pop-up, some hesitated to do the same between pages on a section of a screen like in the case of a multi-stage report. A final remark in relation to the reporting interface concerns the "thank you" screen that is shown for a short period of time after a user submits a contribution. While this positive feedback mechanism was generally appreciated by test users, some users foresaw how this design implementation has the potential to be tedious for experienced and frequent users in its time-demands and obtrusiveness.

Considering previous iterations

While the preceding section included some retrospection to the formative evaluations of prototypical representations of previous design iterations, it might be worthwhile to consider how the results of those evaluations relate to the final in a more deliberate manner. Such a remark concerns the final design's adaptation to the feature importance ranking from the evaluation of the feature-rich second design iteration. Test users considered explorable project displays and smart suggestions of projects to be the most important feature, and as such it is the primary main page of the final design. Actually, the top three most important features, as ranked by test users, are basically represented by three of the four main screens of the design. The fourth most important feature in the ranking was having shortcuts to favorite projects, and while this is not given a dedicated screen or menu within the interface, it has a prominent place as the second swimlane from the top on the *Projects* page.

An exposed shortcoming of the initial design was how it precluded the growth of communities with a lack of locality and sociality. Users' desire to relate citizen science practice to their local community has been consistently evident throughout evaluations, and both the second and final designs were valued in this regard. It seems that seeing other users' activity is reassuring and crucial to many volunteers' participation, both initially and continually. As this remark persists even in the final evaluation, it is important to remain open and attentive to whether the design fulfills this need in a deployed scenario.

The design has been somewhat consistent in its distancing from social network features and conventions throughout the three iterations. Because of this, there are limited clues to users' reactions and opinions of this from the evaluations. While it has been remarked on and discussed with test users, these discussions are constrained to a more abstract level as the designs lacked specific implementations. Test users seem to like the option for anonymity that has been persistent in the designs, but some also express a desire to relate their activity and use with their friends to be inspired and possibly compete. If such functionality can be implemented in an effective manner to strengthen a design in this case, the final design proposal is lacking answers in that regard.

An important design consideration in citizen science, notably underpinned by the evaluations of the second design iteration, is how to communicate and visualize project outputs. As such, the purpose of a project has been given an increasingly prominent position in the design through the iterations. The final design proposal even adapts what content to display depending on first or recurring participation in a project, an idea which stemmed from formative evaluations. Additionally, it is both interesting and unfortunate that the individual project page header's problematic resemblance to an app advertisement or download prompt actually was exposed, although not as succinctly as in the final evaluation, already in the evaluation of the second design iteration, but was not properly addressed.

By retrospectively examining reactions and opinions on the project search functionality, the opposite problem, overcompensation, in design can be seen. While it has had different names and shapes, the functionality of searching for projects by specifying advanced characteristics such as geographic location, subject area, and activity level, has been present through all design iterations. In the initial design proposal, the implementation was over-guided, which strained and confused users with unnecessary complexity for most use cases. In the second design, this problem was remedied. Instead users saw and requested the possibility to combine this advanced searching functionality based on project characteristics with the more basic text-based search. These two formative insights were significant in the design of the final proposal but evoked some unfortunate effects of combining conventions. This led to the characteristics-based search functionality, that at first was too prominent and guided, instead becoming slightly obscured and difficult to access.

When reviewing how the discrepancy between users' mental models and the system models of the different design proposals has evolved, it appears to be the smallest for the final design. While the initial design had a rather simple structure, its mode of navigation of swiping between screens without visual hints or supports made it unintuitive. The more complex second design seemed to communicate a system model of a homepage, and users had difficulties navigating using both a drawer and a tab-bar. The evaluation of the final design proposal showed no major issues in this regard, and it seemed that users were mostly able to construct a mental model that closely resembled the system model. It appears that the final design's deeper system model is easier to predict and communicated clearly enough to allow users to locate themselves spatially in the model. A final remark to consider is how swiping between pages re-appeared as a problem, though in a quite limited scope, for the final design after its omission in the second design iteration, despite it now being implemented using conventional visual clues.

Usability measures

As the conditions of the remote test prompted a more quantitative approach to data collection, some of the results from this evaluation are quantifiable metrics that can be used to reason about and justify claims about the proposed design's potential for good usability. Considering that the evaluations by design covers the first use of the application, it should be noted that these results mostly relates to the guessability of the design. With that in mind, it is clear to see that the design shows promising potential for good usability in that regard, as most test users are able to complete the test tasks without any guidance.

On the *Projects* page, 75% of test users were able to correctly identify their favorite projects, and 67% successfully found and understood the context-aware suggestions. Furthermore, 60% of test users strongly agree, and an additional 30% agree, with the statement that the *Projects* page is clear and intuitive to use.

Looking at the *Search* page, test users were able to achieve quite advanced searching tasks through the app at first use. 60% felt confident that they had successfully completed the search task, along with an additional 30% who thought they might have succeeded. However, as might be expected considering some of the previously described problems with this page, it can only be considered somewhat clear and intuitive to use. 30% of test users are neutral to that statement, 20% agree, and an additional 30% strongly agree. The usefulness of the search functionality is however unquestionable, as 90% of tests users strongly agree, and an additional 10% agree, that it is useful.

Moving on to the *Explore* page, the usability can again be considered good, as 70% of test users were confident that they succeeded in quite specific data exploration tasks through the interface at first use. An additional 10% might have succeeded but were not confident in their results. Also when interacting with their *My page*, test users were mostly successful. Two thirds of test users were able to find and correctly interpret the state of their fictitious achievements at first use.

In conclusion, the results show potential for decent usability, with a rather high guessability and promising learnability. The rather unique context of a remote usability evaluation with no intrinsic motivations behind the use or formation of tasks, and no access to additional support if test tasks are unclear, makes solving the use cases more difficult. These difficulties were evident in comments left by test users on their evaluation questionnaires. However, despite this it seems that test users were able to complete the test rather quickly. 22,2% of test users estimated that they completed the tasks in under 5 minutes, an additional 55,6% said they needed 5-10 minutes. What's even more positive and hints at a promising learnability, is that 77,8% of test users think they could redo the same tasks in under 5 minutes. The learning aspect is further underpinned by remarks made by test users during co-located evaluations.

Considering the research question

As the evaluation serves to provide a basis to judge and advance the current problem understanding and tacit hypotheses manifested in the proposed design in relation to the research question of the project, it is appropriate to again cite this question:

What should be considered when designing a context-aware smartphone application intending to engage the general public in citizen science practice?

At the conclusion of the evaluative tests performed with the prototypical representation of the final design proposal, users were asked whether they could see themselves engaging in citizen science through the application they had tested. Summarizing these answers across both co-located and remote tests show that 75% of tests users can see themselves engaging in citizen science through this application. An additional 15% are not sure, and only 10% cannot see themselves engaging. This distinctive result helps to justify that the underlying knowledge and insights eliciting the design addresses the research question and seem to do so effectively. However, it should be noted that some users had conditions to their positive answers, that also happen to neatly consolidate some central issues of the design problem. One user said they could see themselves engaging only if they saw that the community was alive, so that they would not feel like they are the only one contributing. Another user was uncertain about their capacity as a citizen scientist but said that if they would engage, this would be the way.

Design guidelines

While the design proposal demonstrates and manifests important design considerations for the design problem at hand, and as such begin to answer the research question, it is perhaps more relevant and effective to seek a more succinct presentation of this knowledge. In doing so, it is interesting to reconsider the eight design implications that concluded the theory chapter and their capacity as an answer. By estimating those implications as prescribing guidelines for design in citizen science, they can hold value in understanding how to successfully design in this case. The presented design implications were cumulatively substantiated and summarized from the body of previous research and theory that this project's literature review covered. As they were then applied in the iterative process of design which yielded considerable insights from the evaluative tests with users, it is relevant to re-assess the implications' merits based on these additional insights.

In doing so, we find that they stand and are justified further by the findings of this project. However, we propose that a new guideline to cover technology appropriation is added and given the number four, moving the subsequent guidelines down in the order. Additionally, it might be advisable to divide the previous sixth implication, concerning locality and community building, considering their respective independence and importance. The updated implications, which can be considered ten design guidelines attempting to provide a complete answer the research question to the best of this project's knowledge and extent, are as follows.

I. "Facilitate independent working and participant choice" [35]. Volunteers are motivated by different things and prefer different types of tasks, rewards, methods, and mechanics. Some people want to be alone whereas others like being part of a community. Another example is gamification, which can be motivating to some but a hassle for others [17]. Design for the users' different outlooks on use, as the third paradigm of HCI research suggests [61].

II. Inform about the scientific outcomes of projects [35], visualize the data that can be made public [49], and highlight how the data is used and who will see it [28, 54]. This is important not only as a motivating factor but also to alleviate anxiety about privacy and promote learning.

III. Shape participation to fit into the daily lives of volunteers [35], "Sell citizen science snacks, not gourmet meals!" [35], break tasks up into smaller pieces [28]. Limited time and ability to fit citizen science practice into the lives of volunteers hinders participation. Support and consider the user's existing situated activities in the world.

IV. Be attentive to users' appropriation of technologies. Don't force users into features that has established external counterparts, and increase the chances of appropriation by including multiple means of participation and engagement when implementing guidelines I and III.

V. Simplify observing processes and provide effective support to make it easy to start participating [23, 41]. Getting started on projects is important to learn and increase identification, as the MLC model (described in previous section) makes clear [41].

VI. Provide purposeful and personal feedback to affirm data quality [35] and build self-confidence in volunteers to increase their involvement [41], as shown in the MLC model. Make sure volunteers are appropriately attributed for their efforts and contributions.

VII. Make things local [28]. Situate the user in their local context and/or area of interest. Relating their or others' data and activity to the volunteer's sense of place makes learning and participation more engaging, as they should be inherently interested in their surroundings to some extent.

VIII. Enable a community to build around the project where data and ideas can be shared and reviewed [23, 41]. Cornell's Laboratory of Ornithology saw increased contributions after implementing the ability for volunteers to relate their data to others [49]. The self-reinforcing mechanisms of the MLC model also benefit from an active project community [41] to support learning, identification, and creativity.

IX. Consider which data fields can and cannot be compromised with, both for scientific precision and public display [54]. For example, exact location might be a requirement for scientific research but can be compromised with for the data that is publicly visible. Photographs might be deemed necessary for both datasets. Based on this, it is advisable to enable users to selectively reveal or anonymize information to as great an extent as possible [23, 54]. If applicable, implement technology (for example fuzzy locations, anonymized user identities, and automatic face blurring in images) to further minimize the risk of privacy concerns and anxiety among users [54].

X. Good privacy practice is to collect a minimum of personal data about volunteers and allow them to modify or delete the data they have contributed [54].

Discussion

This discussion will consider both the result and its applicability to the research question of the thesis, and the design process to reach it. The chapter will begin with its most important section; that is whether or not the research question has been answered and how well the thesis stays true to its initial intentions. Following this initial section, the chapter moves on to discuss the design process. The overall process and its respective parts will be examined broadly before subsections dedicated to some especially relevant considerations, for example of test user samples, go into greater detail. The discussion chapter concludes by returning to the final design in a section dedicated to the design's inclusion of the potentially controversial feature of personal projects, before bringing up some unknowns and areas of improvement in order to reason about future work.

Results in relation to research question

The evaluation insights, final design proposal, and design guidelines presented in the results chapter strive to collectively contribute extensive and rich, but applicable, knowledge to answer the research question stated in the introduction of this thesis;

What should be considered when designing a context-aware smartphone application intending to engage the general public in citizen science practice?

Both the design proposal itself and the design guidelines are substantiated and justified in their attempt to help answer the question by the findings from literature and evaluative studies, as presented earlier in the thesis. As the guidelines are inherently more theoretical and abstract, the discussion will be focused on conceptualizing the applied measures implemented in the design and how they connect to the underlying theory. A starting point for this discussion can be the notion of context-awareness, which is central to the aim of the project, but is it correspondingly central to the final design?

While there are many prominent features implementing context-awareness, such as the topmost swimlane of the *Projects* page, the sorting of search results, and the map of the *Explore* page, these features are intentionally designed not to be intrusive. One might wonder if these design choices would have come natural in the design process even without explicit intention to design with context-awareness. This is of course impossible to answer in retrospect but considering the lack of context-aware behaviors in designs that previous research has examined it seems unlikely.

The reason for not making context-aware behaviors of the design more obvious is twofold. Firstly, the best practice of context-awareness is one that give accurate suggestions and aids users in prioritizing data, without being intrusive or obscuring the interface. It should anticipate the needs of the user without being seen or heard, of course always minding the integrity of the user. Secondly, the evaluations showed that most users like to plan their engagement in projects, rather than spontaneously engage based on suggestions by the application. The first prototype was designed for such spontaneous use and did little to cater for the planning of users, consequently receiving critique in this regard. This proved that the design had to allow for free exploration of the projects and for defying the context, for example by defining a future time when planning a trip or ignoring weather if rain does not bother a user. Here it is relevant to recollect the initial motivation behind this thesis, the identified need to better fit citizen science practice into the daily lives of volunteers. Context-awareness was predicted to be able to address this need, and as the thesis shows it can address it, but not completely and on its own. Instead, just as context-aware features and behaviors have their effective place in the design, so does other features, and collectively they serve the same purpose of adapting citizen science to everyday lives of users.

On a related but separate note, the implementation of context-awareness was affected by the users' attitudes towards different context sources. As the result of the evaluations showed, users are comfortable with the use of some context-aware sources, while other are deemed to be ineffective or overstep the users' boundaries for integrity. This knowledge helped shape the use of context-awareness in the design, rendering some potential use cases inappropriate as they would mostly provoke or confuse the users. However, it also showed that the most important and useful context sources for citizen science was approved by the test users. Examples of such sources are current geographical position and time. These sources are external to the user and regard the environment of the activity, which makes them highly relevant for the eligibility of some citizen science projects. It is also interesting to note that current needs of society and science are reckoned as important and relevant enough to allow for pushing the agenda of projects based on this. Some other usable context sources are self-reported interests, previous activity and the activity of others. There might well exist more context sources that are deemed allowed to use, but we argue that these provide a solid foundation when designing context-aware behaviors for citizen science. It provides the application with context considering both external environment and the interests (and thereby intrinsic motivations) of users, as well as enabling skewing to cater for the needs of society and science. Using these sources to infer higher-level contexts can not only improve user experiences, but also effectively advance research agendas.

A design proposal applying the knowledge of this project should, considering the research question, be a design that has the capability of engaging the general public in the field of citizen science. Among other things, potential for good usability in a variety of contexts is central to achieve this goal. If the design has poor usability, the average user will probably not bother to use the application. As mentioned earlier, usability can be divided into five aspects; *guessability, learnability, experienced user performance, system potential,* and *reusability* [80]. The evaluations did barely test learnability and experienced user performance, mainly for two reasons. First off, the prototypes were too narrow in their functionality as they were constructed to be used for predefined scenarios. The prototype could therefore not be tested for a longer period without boring the user with repeating the same tasks. Secondly, there is little time available to let test users become adept, as the time that they as external participants volunteer is too valuable and limited to use for familiarization with the design over extended episodes of use.

As all aspects of usability are important for a good user experience, it might be argued that it is unclear as to if the design really is able to achieve the goal of engaging the general public. However, the results of the evaluation can be said to underpin claims both for good guessability and learnability. The remote evaluation did test perceived learnability by asking how much time the test would take to complete on the second try. As argued before, the potential for good learnability is quite high, as 77,8 % of the respondents believe themselves to be able to complete the test measurably faster if charged with the same task again. Still, experienced user performance, system potential, and reusability were never tested and the design's capacity in these aspects has therefore yet to be evaluated.

Since evaluation insights to a considerable extent are made up of vague user remarks and observations, it is difficult to reason about the design's effectiveness in more definite arguments than what has already been done when presenting the evaluation results. The overall impression that emerged from observing test users was that the design, with some specific exceptions already mentioned, worked and was intuitive and easy to use. Users' comments further substantiated this impression. However, while this judgement is important in the way it represents a more complete understanding of the complexity of this human-computer interaction, it is an ambiguous claim for the design knowledge and guidelines applied in the design as assuring answers to the research question. The test users' answers to the explicit question of whether or not they could see themselves engaging in citizen science through an application of the proposed design is a more straightforward measure in this regard. And considering that 75% of users answered that question positively, and an additional 15% tentatively, an argument can be made that the insights underpinning the design addresses the research question of this thesis. And as the results of the thesis have been established and discussed, it is relevant to consider the process of reaching them.

Design process

As the chapter dedicated to the design process has established, the project utilized an iterative process divided into two phases. A possible weakness of the process is precisely in this division. There was no, or very limited, return to previous research or stakeholders for input once the human-centered design process of the second phase had commenced. While it is possible that this would have yielded a greater understanding of the design problem, the feeling was that the first phase had reached a relative saturation as it concluded. Additionally, previous research has to a large extent considered and studied active citizen science volunteers and while this background knowledge is highly relevant, the focus on uninitiated users that this project maintains is an important strength and contribution of this thesis. Because of this, the division into different phases should not be too problematic.

The overall structure and selection of methods to include in the design process was influenced by a number of factors. First, it is important to note that the project situates itself in the third paradigm of HCI research, as described by Harrison et al [61], and its associated phenomenological matrix. This emphasizes context and situated interactions. Consequently, it acknowledges the complexity of HCI and the need to accommodate rich descriptions and qualitative reasoning. It was with this in mind that stakeholder interviews with emerging questioning was chosen as a way to gain an initial understanding of the design problem.

Additionally, citizen science is relatively unknown which makes it difficult to conduct explorative and formative user research without specifically targeting already initiated and active citizen science volunteers. Because of this, the process excluded such user research in exchange for more iterations of the human-centered second phase, which served to collect user input as it included evaluations with external test users. For these evaluations, the methodological approach of usability tests was chosen as it could serve to quickly introduce uninitiated users both to citizen science and the design. By making subsequent data analysis loosely structured the process accommodated for rich data and descriptions as constructed constraints was not imposed on the dataset.

With the general process motivated, it is relevant to reason about the specific execution and results of its most crucial phase, the evaluative studies with users. The following two subsections are dedicated to this and covers both the sample of test users and the design of the evaluative tests themselves.

Test user sample

To reason about the reliability and validity of the evaluation results, one needs to consider the test user sample and how its distribution relates to the target user group. As no target user group was defined for this project, it can be considered to be the general public. The test user recruitment was largely based on convenience, which can be expected to introduce skewing of the sample distribution. The primary motivation behind implementing such a selection was the administrative difficulty in recruiting test users on short notice. The timing of evaluations in between design iterations was crucial, which combined with the fact that the pace and progress of a design process is difficult to anticipate made for a logistical problem. The process was also limited in time overall, being constrained to the extent of a thesis, which means that even small delays can have severe consequences.

The biggest skew of the test user sample distribution is towards a younger population. The age group 18-25 is clearly overrepresented, and in majority on its own, for all rounds of evaluation except the one conducted remotely. It is appropriate to take this in consideration when examining the results. One can expect that younger users in general have a higher technical literacy when it comes to smartphones and their applications. From this it can be tentatively inferred that they also have more experience and familiarity with prevalent interface conventions and guidelines in this space. It cannot be denied that this should have an effect on the evaluation results, but it is difficult to assess how severe that effect is. With the current technological evolution and its corresponding social proliferation, one might argue that a majority of the population is literate in smartphone interfaces and consequently familiar with prevailing conventions. But with that said, the test user sample distribution makes it impossible to present a more substantiated claim for the validity of the results across all age groups. An interesting point to raise in this discussion is the fact that the practice of citizen science currently sees another, older, age group overrepresented. This can partly motivate studies that target younger members of the public to increase the spread of the practice.

Moving on to review the balance between gender identities there is less of a skew within the test user sample distribution. In fact, both formative evaluation rounds had an even gender balance, which is encouraging considering their importance for the subsequent direction of the design process. However, in the final evaluation rounds, both co-located and remote, there is a clear skew towards female test users. This introduces some uncertainty about the general validity of the results from these evaluations, but again one can raise the argument that this skew is in the opposite direction of what established citizen science practice sees. If the target user group would focus on active citizen scientists, this test user distribution skew would be problematic, but as it focuses on the general public it can actually serve a compensating purpose to open up the practice for everyone.

As has been mentioned before, looking across all evaluation rounds most test users had no previous experience of citizen science, in fact they had rarely heard of the term. This was expected, and in line with what previous research into the matter has found. As such, it is an appropriate sample of the general public in this regard, but it is worthwhile to reflect on how this affects the effectiveness of the design for current practitioners. Reasonably, the design has a potentially positive effect on their practice in cases where an individual volunteer is engaged in multiple projects, in the way it converges and aggregates projects to operate within the same interface. If a volunteer is dedicated to a single project it becomes impossible to reason about this effect, as it is highly dependent on the established tools and interfaces of that specific project. However, considering that the background and theory from previous research mostly focuses on current practitioners, the design has been informed regarding their perspectives.

Another interesting discussion revolves around the discrepancy in test setup and user sample distribution between remote and co-located tests during evaluation of the final design proposal. While the test tasks were mostly identical, the characteristics of the remote test motivated the use of more quantitative data collection. The similarity in test proceedings was fundamental for attempts to infer richer understandings about problems remote test users encountered based on observations of co-located test users. However, as the sample distributions differed significantly, both in terms of age and citizen science experience, this might be an approach of questionable certitude. In hindsight, one can question why the same quantitative data was not collected during co-located tests, which would serve both to increase the validity of the resulting metrics and present a way to reason about the effects of differences in sample distributions. During the design of the tests, the quantitative line of questioning implemented in the remote test was not seen as an improvement, but rather a necessary compromise stemming for having test users fill in the questionnaires independently, and therefore wasn't considered for implementation also in co-located tests.

Additionally, it should be noted that some test users were recurring across multiple evaluation rounds. While this partly serves a purpose for the users who also participated as co-designers, it is also a result of the convenience-based user recruitment. Precisely how the inclusion of recurring users affected the evaluation results is impossible to isolate, but from observation it seems that priming with a previous design iteration affects their performance somewhat negatively in later rounds. As the design evolved significantly between each iteration, a recurring user was mostly misled by their previous experience. This was especially clear in cases where terminology had changed.

Finally, as the design process encompassed three design iterations with corresponding evaluations, it makes for a rather large user involvement overall. Summarizing the different evaluation rounds makes for a total of 39 user tests, 29 of which was co-located and involved rich data collection through observation, probing, and pre-defined questionnaires. Additionally, the process also involved users in two co-design sessions involving a total of 4 different co-designers. Such a significant user involvement is the main attestation to any validity claims about the results of this thesis.

Evaluation design

When introducing the evaluation tasks to a test user, it is important to situate the user into a context where the actions performed have a meaning. If the user is uncertain as to what the meaning of the task is, the actions taken might not be objective-based and therefore not represent a realistic situation of use. When designing the evaluations, care was taken to introduce the users to a specific scenario. This was achieved by giving short introductions of place and time as well as mission, combined with playing environment sounds to make the experience more immersive. Still, as most users had no previous experience of citizen science, it proved hard to explain the mission in a way that conveyed the overarching meaning of performing the tasks. Consequently, this made some tasks difficult to interpret and understand for users. Ideally, test users would be allowed to formulate goals of the interaction themselves, but that would render the individual tests incomparable and also put high demands on prototype fidelity and completeness.

Another factor that influenced test users' ability to successfully complete evaluative tests was that some tasks had too many steps for the user to remember. Again, this problem would probably not occur if the task was formulated by the user as part of a greater goal. But when it comes to predefined tasks, several instructions at the same time proved too much for most users. For example, when tasked with filtering contributions to only show the ones that are no more than a week old and submitted to the user's favorite projects, sorted based on how controversial they are, most users could only handle one or two of the subtasks and forgot the others. In comparison, we believe that this would not be a complicated task if the users themselves had defined the same filtering and sorting settings based on what they considered interesting to see.

To conclude, some of the assignments and tasks of the evaluative tests proved difficult to complete for several users. We believe that this is not only due to the design lacking guessability, but also to some of the tasks and their formulations being too complicated or confusing in isolation from intrinsic goals or motivations of the user.

Personal projects

The design includes the feature of allowing volunteers to create their own personal projects, even though this is not included in the prototypical representation. This inclusion is motivated in the results chapter, but it is worthwhile to discuss some related considerations going forward. The feature is expected to be controversial to some initiators, as the verification of data will be inadequate. Additionally, they might be worried that the mere presence of such projects will lessen the credibility of the application and in extension possibly even their own projects. Furthermore, there is a risk that initiators will fear that contributions to personal projects will come at a cost of engagement in established citizen science projects.

The design takes heed of these concerns. As to not get mixed up with "real" projects backed by a university, authority, or organization, and to avoid potentially problematic ethical issues, other users cannot contribute with data to personal projects, and they will not be regularly featured on the *Projects* page. All data from personal projects should be explorable, though not as a default filter view but as one that may be activated by any user. It should also be possible to include these projects in search results, if this inclusion is explicitly toggled by the user. In addition, map pins connected to data points from personal projects will be differentiated from standard projects by color.

Apart from the previously mentioned liabilities, there are a number of motivations for supporting personal projects. From the perspective of stakeholders involved in other citizen science projects, incorporating personal projects into the application means getting access to new datasets that can contain interesting data for their research. If instead considering the users, or volunteers, Harrison et al [61] list a number of questions of interest for design in the third paradigm of human-computer interaction, and some of them help motivate the inclusion of personal projects. First off, one answer to *"what existing situated activities in the world should we support?"* is believed to be these individual projects. There are people pursuing their own research in their local area, for example measuring snow depth and logging lake water temperatures. If this application can serve a purpose in their daily activities, it should be an activity to support. Not only does the application get more users and data, it creates value in the lives of people as they find meaning in its use. In addition, it will also foster sociality as users can share the research that they are pursuing, getting feedback and support by peers, who in turn can find inspiration in the creative efforts of others.

Continuing this line of reasoning, we have already started to answer the second question of interest posed by Harrison et al [61]: *"how do users appropriate technologies, and how can we support those appropriations?"*. There are a number of potential users of this application in the people engaging in individual citizen science efforts and their friends, who might want to follow their progress. Supporting and streamlining their data collection and enabling users to explore the datasets in an intuitive way might help in appropriating this new technology. Using the application often will presumably increase the probability of trying other projects that are featured, leading to more activity and a larger community overall. In a grander sense, this discussion is also a question about the general view of the scientific process of the future; should it be inclusive, or excluding? Guided by institutional agendas or accommodating of other perspectives and grassroot efforts?

Remaining design challenges

Some aspects of the design have been proven to require additional improvements in order to better satisfy the needs of users. Among them are the *Search* page, more specifically the filtering functionality. It has to be remodeled and given more prominence in order to better communicate both where it is and what it does. According to the evaluations, the users are also expecting to find more information concerning their previous activity on *My page*. Either this information has to be supplemented, or if it is not, the design should clearly guide the user to the right place.

Many projects rely on geographical data, it is for example central to reports about bird sightings or health status updates on trees. The sighting is not relevant if the scientist is not given at least an approximate position - to know *that* there are eagles in Sweden is not nearly as useful as to know *where* they are. But there are also a lot of projects where location is completely irrelevant, for example when transcribing a book or defining the form of a galaxy. On the individual project pages of such projects contributions can be displayed in appropriate formats, for example in lists or as a gallery of pictures. But these cases cause a known problem to the *Explore* page, where contribution visualization is map-based to promote local engagement. How should the contributions with no relevant geographical location be displayed here?

Several solutions to this problem have been discussed. One is to anchor the contribution to the place where the user has submitted it, making it visible on the map even though the data has no direct connection to its position. The advantage to this is that other users can see which projects are popular in their vicinity and get inspired to engage in projects that might have an established local community. However, an issue with geographically situating contributions in this manner is that it can jeopardize user integrity by disclosing the locations of their home or workplace. Instead, a roughly correct randomized location might be more effective. A drawback to any solution that insists to situate contributions geographically is that it might confuse users into thinking that the data must be connected to the pin's location and draw false conclusions. This effect might be reduced by giving different colors to the map pins of geographically bound contributions and those that are not. That way the users can distinguish the difference between them.

Linguistics and exact phrasings have been identified as other remaining issues to be further specified and solved. An especially interesting part of this problem relates to the dynamic titles that the design attributes to the volunteers based on their engagement. What terms that are appropriate to use when constructing such fictitious titles is a delicate matter, as they might impose upon and de-value formal titles. Careful attention needs to be paid to properly value and attribute volunteers' efforts as scientific, while avoiding any de-valuing of formal titles and degrees among educated scientists. A general solution to this problem might be impossible or inappropriate, as some areas of research with a strong history of amateur interest, for example astronomy, already have established terminology for this, whereas other areas lack similar tradition and terms. Nonetheless, it should be possible to strike an effective balance through careful specification and adaptation based on subject area.

Another function that needs to be developed further is the reporting pages, which need a specification for their template structure. A proposed procedure for this development is described in the related section in the results chapter. Furthermore, the interface design of the application is primarily following iOS guidelines over Android ditos. In the event of further development it has to be decided if there should be one or two versions of the design, and consequences of this decision needs consideration. Lastly, the terminology and linguistics of the application would benefit from further examination to optimize clarity and invite users to engage.

Future work

As the concluding sections of the discussion chapter elaborate on, there are a number of design challenges remaining to be solved if the proposed application is to be made a reality, some of which can be addressed and improved in the process of an additional design iteration. But there are also several issues and decisions that will require collaboration with stakeholders from partnering citizen science projects. At the stage that this thesis has advanced the project to, it is advisable to start further development by establishing a closer collaboration with stakeholders of potential partner projects.

This collaboration would require a greater focus on the complexities of data collection protocols and the challenges that come from converging diverse projects into a unified interface. With the design process of this thesis being human-centered and focusing on the volunteers as users, its contributions primarily lie in the effectiveness of the design in this perspective. While it does consider what accommodating numerous and diverse projects entails and enables, further work to systematically analyze project diversity and convergence approaches is needed.

Another interesting notion worthy of further exploration in citizen science is that of locally situating users and use. It became a prominent aspect of this design process, and numerous ideas addressing it were entertained while only some could be implemented. Discussions with stakeholders inspired a suite of ideas revolving around smart, hyper-local, features to work with the experience of visiting national parks or nature reserves. Using citizen science to visualize both the human and natural activity of such areas is an enticing proposition. It could serve to both inform and activate visitors, and shape their visits in ways that not only improves their experience but also the general scientific understanding of the local biotope.

Conclusion

Citizen science has so far been kept at the periphery of the public's attention but sees some participation from volunteers primarily motivated intrinsically. An identified need to better adapt the practice to the everyday lives of volunteers to increase its reach motivated the research question of this thesis:

What should be considered when designing a context-aware smartphone application intending to engage the general public in citizen science practice?

This question is answered by the knowledge attained through user evaluations in multiple design iterations, which together with insights from previous research in citizen science forms the basis for ten design guidelines outlining what considerations has been identified as important for designing in this field. The guidelines cover things such as locally situating users, facilitate their different outlooks on use, and supporting them in their existing activities. It is difficult to anticipate what implications an application following these guidelines, like the final design proposed in this thesis, would have for the field of citizen science and its practice in Sweden. But if successful in its intentions, which evaluations indicate that it could be, it would potentially represent a significant increase in public awareness and engagement in citizen science. This would not only advance research agendas but also be beneficial for volunteers' informal science education as they can incorporate citizen science practice in their daily lives. Furthermore, once a citizen science platform like the one proposed here is established, it could open up the field to new research areas and programs as it provides a time-, attention- and cost-effective way to introduce projects and take advantage of best practices.

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Appendix A - Evaluation questionnaires

This appendix contains all questionnaires used for data collection in relation to evaluative usability tests carried out in the project. The forms collect both quantitative and qualitative data. During co-located tests the questionnaires were used as manuscripts and filled in by the test leader based on the test user's responses. In remote tests the corresponding questionnaire was filled in online by the users themselves.

Contents

Evaluation: User background

Your answers will be collected anonymously, and won't be linked to the rest of the evaluative test. Individual answers will only be visible to us (Carl & Markus). The results will be studied and presented only summatively across all users to allow us to reason about our demographic distribution of test users.

*Obligatorisk

1. **Age** *

   ____

2. **Gender** *

   What gender do you identify yourself as?
   Markera endast en oval.

   - ( ) Male
   - ( ) Female
   - ( ) Non-binary
   - ( ) Prefer not to say
   - ( ) Övrigt: ______________________

3. **Do you have any experience with citizen science?** *

   Citizen science is scientific research that members of the public contribute data or thought-power to. Some examples are: reporting what winter birds you see in your backyard, answering questions about the characteristics of galaxies on images, or measuring and reporting water quality. Research where you are a subject of study, for example answering surveys or giving ratings to products or places, is not considered citizen science.
   Markera endast en oval.

   - ( ) Yes, quite a bit
   - ( ) Yes, but only a little
   - ( ) No, but I've heard of it
   - ( ) No, and I have never heard of it
   - ( ) Prefer not to say

4. **Did you participate in one of our previous rounds of evaluation?** *

   Markera endast en oval.

   - ( ) No *Sluta fylla i det här formuläret.*
   - ( ) Yes

5. Post-test reactions EN

Your answers will be collected anonymously, and won't be linked to the rest of the evaluative test. Each individual set of answers will only be visible to us (Carl & Markus). Primarily the results will be studied and presented summatively across all users. Some of your answers might be quoted in our final thesis report, but always anonymously and separate from the rest of your answers.

1. **What did you like and dislike with the application and how it was used?**
   Everything is up for debate! Try to consider both big picture stuff and details.

2. **Can you see yourself using this application? Why/why not?**

3. **How and in what contexts do you think you would use it? Reflect on how the application could fit into your daily life.**
   Please ignore this question if you wouldn't use it at all.

4. **How did you feel about the application suggesting something for you to do?**

5. **How did you experience searching for something to do through the application?**

6.

How would you feel about the application suggesting things for you to do based on..

Markera endast en oval per rad.

	I would hate it/I would be very uncomfortable	I wouldn't like it/I would be uncomfortable	I wouldn't care that much	I would like it	I would love it	Not sure
Your interests, reported by yourself						
Your interests, based on web history						
The current time						
Your movement patterns (ie where and when you usually move around in the world)						
The season						
Your previous activity in the app						
Your phone activity (ie how much you use your phone)						
Your health, suggested by the app (ie you should probably go outside and take a walk after sitting still for so long)						
The urgent needs of scientists (ie they need data to study a phenomenon)						
Your social relations						
The urgent needs of society (ie we need data to avoid disaster or improve conditions)						
The current weather						

	I would hate it/I would be very uncomfortable	I wouldn't like it/I would be uncomfortable	I wouldn't care that much	I would like it	I would love it	Not sure
Your calendar events (for example free time between events)	◯	◯	◯	◯	◯	◯
Others' activity in the app (ie popular activities)	◯	◯	◯	◯	◯	◯
Your current location	◯	◯	◯	◯	◯	◯
Your health or fitness goals, reported by yourself	◯	◯	◯	◯	◯	◯

5. Post-test reactions EN

Your answers will be collected anonymously, and won't be linked to the rest of the evaluative test. Each individual set of answers will only be visible to us (Carl & Markus). Primarily the results will be studied and presented summatively across all users. Some of your answers might be quoted in our final thesis report, but always anonymously and separate from the rest of your answers.

1. **What did you like and dislike with the application and how it was used?**
   Everything is up for debate! Try to consider both big picture stuff and details.

2. **Can you see yourself using this application? Why/why not?**

3. **How and in what contexts do you think you would use it? Reflect on how the application could fit into your daily life.**
   Please ignore this question if you wouldn't use it at all.

Ranking of features

Please rank the features according to how important they would be for your use of the app. 1 being the most important and 8 the least important.

News feed	
Local map & feed	
Events	
Spotlight (smart suggestions of projects)	
Project finder	
Pinning projects	
Project forums	
Calendar with contributions and streaks	

Your answers will be collected anonymously, and won't be linked to the rest of the evaluative test. Each individual set of answers will only be visible to us (Carl & Markus). Primarily the results will be studied and presented summatively across all users.

5. Post-test reactions EN

1. **What did you like about the application and how it was used?**

2. **What did you dislike about the application and how it was used?**

3. **Can you see yourself engaging in citizen science through this application?**
   Markera endast en oval.

   - Yes
   - No
   - Don't know

Citizen science platform evaluation

Thank you for participating in this design evaluation. We who authors it are Carl Malmström and Markus Jarlback, and study a master in Interaction Design and Technologies on Chalmers University of Technology in Gothenburg. For our master's thesis we design a platform app for citizen science, and this evaluation is part of that project. Your answers will be collected anonymously, and individual answers will only be visible to us (Carl & Markus). The results will be studied and presented in our thesis paper only summatively across all test users. The individual answers will be deleted once our project is finished (spring term 2018). If you have any questions please don't hesitate to contact us (carlmal@student.chalmers.se, marlor@student.chalmers.se).

*Obligatorisk

1. **Age** *

____

2. **Gender** *

What gender do you identify yourself as?
Markera endast en oval.

- ◯ Female
- ◯ Male
- ◯ Non-binary
- ◯ Prefer not to say
- ◯ Övrigt: ______________________________

3. **Do you have any experience with citizen science?** *

Citizen science is scientific research that members of the public contribute data or thought-power to. Some examples are: reporting what winter birds you see in your backyard, answering questions about the characteristics of photographed galaxies, or transcribing old ship logs. Research where you are a subject of study, for example answering surveys or giving ratings to products or places, is not considered citizen science.
Markera endast en oval.

- ◯ Yes, quite a bit
- ◯ Yes, but only a little
- ◯ No, but I've heard of it
- ◯ No, and I have never heard of it
- ◯ Prefer not to say

4.
Did you participate in one of our previous rounds of evaluation? *
Markera endast en oval.

- No
- Yes

Now, you will be able to open the prototype on your phone or computer using the link below.

https://share.proto.io/HFJIGP/
(If you open it on your phone it will first ask you to download the free proto.io app, to run the prototype from)

It is only a prototype so all things won't work as intended, but for the most part you should be able to tap, scroll and swipe as you would in any app. Sometimes the content won't update exactly according to your actions, since the app isn't programmed "for real".

If there are tasks that can't be solved feel free to explain the problem in the associated questions, or just skip them.
Keep in mind that we don't evaluate you, we evaluate the app!

Here are some tasks and questions you can solve once you open the prototype

5.
Which projects seems to be your favorites?

6.
Which projects are you suggested to take part in today? What can you find out about those projects on this screen?

7.
I consider the projects page clear and intuitive to use
Markera endast en oval.

	1	2	3	4	5	
Completely disagree						Completely agree

8.
I consider the projects page exciting and inviting
Markera endast en oval.

	1	2	3	4	5	
Completely disagree	⬭	⬭	⬭	⬭	⬭	Completely agree

9.
Possible comments about the task and the projects page

____
____
____
____
____

Link to the prototype in case you've closed it: https://share.proto.io/HFJIGP/

Imagine that you're planning a hike in Dalarna county between the 5th to 9th of March. Search for things to do during the days you're there.

10.
Were you able to solve this task?
Markera endast en oval.

- ⬭ Yes
- ⬭ No
- ⬭ Maybe

11.
I consider the search function clear and intuitive to use
Markera endast en oval.

	1	2	3	4	5	
Completely disagree	⬭	⬭	⬭	⬭	⬭	Completely agree

12.
I can imagine situations when the search function would be useful
Markera endast en oval.

	1	2	3	4	5	
Completely agree	⬭	⬭	⬭	⬭	⬭	Completely disagree

13.
Possible comments about the task and the projects page

Link to the prototype in case you've closed it: https://share.proto.io/HFJIGP/

Imagine that you want to explore what has been reported to your favorite projects this past week. Try to find a way to see an overview of that.

14.
Were you able to solve this task?
Markera endast en oval.

- Yes
- No
- Maybe

15.
Possible comments on the task and the "explore" page

Imagine that you want to see what you've accomplished through your use of the app.

16.
In what project does it appear you've accomplished the most achievements?

17.
What was your latest achievement in that project?

18.

Possible comments on the task and "My page"

Now you've solved all tasks! We would be very grateful if you would like to summarize your impressions a bit. Try to consider both larger things and details.

19.

What did you like about the application and how it was used?

20.

What did you dislike about the application and how it was used?

21.

Approximately how much time was needed to solve the tasks?

Markera endast en oval.

- Less than 5 minutes
- 5-10 minutes
- 10-20 minutes
- 20-30 minutes
- More than 30 minutes

22.

Approximately how much time do you think would be needed to solve the tasks again?

Markera endast en oval.

- Less than 5 minutes
- 5-10 minutes
- 10-20 minutes
- 20-30 minutes
- More than 30 minutes

23.

Can you see yourself engaging in citizen science through this application?

Markera endast en oval.

- Yes
- No
- Not sure

Appendix B - Thematic analysis

This appendix contains an analysis of what themes emerged and persisted through the design process. The themes are outputs of affinity grouping at different stages of the overall process, and the table below shows how these themes relate to each other through the ordering and merging of cells.

<table>
<tr><th>1st idea generation</th><th>1st data analysis</th><th>2nd idea generation</th><th>2nd data analysis & 3rd idea generation</th><th>3rd data analysis</th></tr>
<tr><td>Rewards</td><td rowspan="4">Overall features</td><td>Rewards</td><td>Rewards</td><td>Rewards</td></tr>
<tr><td>Social</td><td>Social</td><td>Social</td><td rowspan="4">Feature priority</td></tr>
<tr><td>Activation</td><td>Suggestions and notifications</td><td rowspan="3">Feature priority</td></tr>
<tr><td>Context-awareness</td><td>Make it local</td></tr>
<tr><td>Activities</td><td>Searching for activities</td><td>Searching for activities</td></tr>
<tr><td>Project initiation</td><td rowspan="3">Project support and output</td><td rowspan="3">Project support and output

Visualization of activity</td><td rowspan="2">Project communication
Feedback features
UI feedback</td><td rowspan="2">Project communication</td></tr>
<tr><td>Feedback</td></tr>
<tr><td>Support</td><td>Support</td><td>Support</td></tr>
<tr><td>Data quality</td><td>Data reporting</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Mental/system model</td><td>Mental/system model</td><td>Mental/system model
Interface intuitiveness</td><td>Mental/system model</td></tr>
<tr><td></td><td>Events</td><td>Events</td><td></td><td></td></tr>
<tr><td></td><td>Profile presentation and content</td><td></td><td></td><td>Personal</td></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td>Visuals</td><td>Visuals</td></tr>
<tr><td>Language</td><td>Language</td></tr>
<tr><td></td><td>Emotion</td></tr>
</table>