Designing with and for the Crowd: A Cognitive Study of Design Processes in NatureNet

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NatureNet is a citizen science project that, in addition to collecting biodiversity data, invites end-users to contribute design ideas to guide the its future design and development. This paper presents the NatureNet model of crowdsourcing design, then compares an analysis of the design process to published analyses of traditional face to face design processes. The protocol analysis approach is used to segment and code the design ideas submitted to NatureNet. We use the Function-Behavior-Structure ontology as a basis for comparison across the crowdsourced design data and design data collected in face-face sessions. The primary finding of this paper is that crowdsourced design results in a different distribution of cognitive effort when compared to traditional design processes.

Introduction

NatureNet is a citizen science project that encourages non-designers to contribute to its continual re-design. Society is now facing design challenges on a much larger scale as we become increasingly global and technological. Design solutions must not only respond to the needs and desires of their users, but must also be environmentally sustainable, attractive to multiple cultures, adaptable as technology changes, and intuitive to potential users. Tim Brown from IDEO proposes that designers cannot meet all of these challenges alone. The amount of problems to which design might contribute far exceeds the number of designers in the world, despite the continued best efforts of design schools. There is a need

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to rethink design, and one avenue is democratization: extending the capability and responsibility of design to all [1].

Crowdsourcing is a term used to describe situations where an open-call is made to a large number of self-selected individuals to provide input to a process [2, 1]. Often associated with micro-tasks, such as labeling images or transcribing audio recordings, crowdsourcing may also help designers leverage greater cognitive diversity, among other potential benefits for the design process [3]. For instance, crowd-collaborative innovation platforms such as Quirky.com and OpenIDEO.com provide opportunities for expert and non-expert designers to contribute to design.

These crowd-collaborative innovation platforms and crowdsourced design in general have received more attention over the past years [4], but the majority of this work has focused on integrating the crowd into existing design processes or on modifying the design process and its organizational structures to improve the quality or heterogeneity of the design artifacts [5, 6, 7, 8, 9]. This has resulted in a variety of crowdsourced design models which often rely on either selecting the best design out of many competing designs or iterating between phases of design generation and design evaluation [10]. Consequently, few of the crowdsourcing design models afford opportunities for individual crowd members to be involved in all aspects of a single design.

This prior work provides a strong practical foundation for accomplishing crowdsourced design; however, they do not include cognitive studies of how the crowd designs. The design process that arises from the crowd is surely different from that of traditional design teams, but exactly how has yet to be explored. The question of how best to utilize and optimize crowdsourced design can benefit from an evidence-based understanding of it. In this paper, we describe the NatureNet model for crowdsourced design, present a protocol analysis of the design process followed by NatureNet's users, and compare that process to cognitive studies of small, co-located design teams.

NatureNet: Crowdsourcing science and design contributions

NatureNet is a citizen science system designed for collecting biodiversity data from parks, creeks, backyards, and other natural settings. (https://www.nature-net.org). Users are encouraged to participate in the design of the system in addition to collecting data about the environment at the park [11]. NatureNet is developed as a platform spanning both desktop and mobile devices, including a website, iOS app, and an Android app.

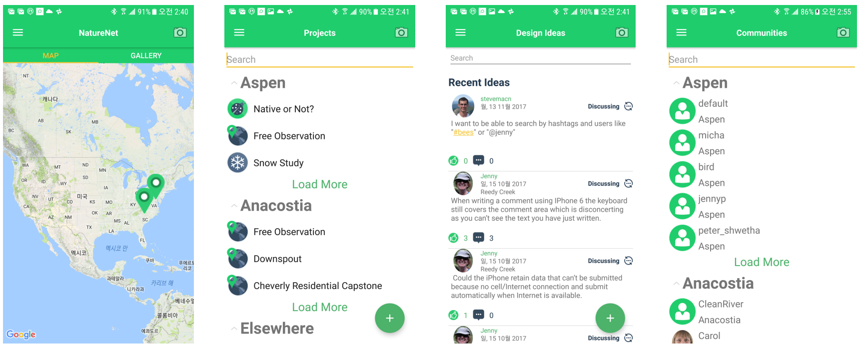
Supporting these systems allows people to contribute regardless of the devices that they have available. The website and mobile apps provide four major functions (see Figure 1):

Explore: map based observations, this screen displays observations posted by users (e.g. a mushroom photo).

Projects: project list, this screen provides a project list and each project displays the project description with observations (e.g. pond water project).

Design Ideas: design idea list, this screen display design ideas posted by users (e.g. an idea about adding hashtags).

Communities: user and group lists, this screen provides a list of users and groups with their contributions (e.g. “Reedy Creek”, a local nature center).



(a) Explore (b) Projects (c) Design Ideas (d) Communities

Fig. 1 The four major functions of NatureNet as shown on the android mobile app

NatureNet as a Citizen Science Platform

As a citizen science platform, NatureNet allows users to contribute to ongoing environmental projects. To contribute to the projects, users take a mobile device into a park or other natural environment to gather photographs and notes. A submission or observation can include a photo, location, project, and comments with information such as water temperature, air temperature, and water pH. Alternatively, the user can submit a pdf with more detailed project information.

As an example of a NatureNet citizen science usage, a user may find the project “Planting for Pollinators” in the app, as shown in Figure 2. The description of this project asks contributors to take a photo of a plant or pollinator. They then take a photo of a flower with a hummingbird pollinating it, add a description and then submit it. Their observation is shown on a map of submissions to the project, with the location detected automatically from the mobile device. Other users can engage with this new observation from their own apps or on a desktop by commenting on or liking it. Over time the project will elicit many contributions, allowing the scientists to get a better sense of the distribution of pollinators and plants.

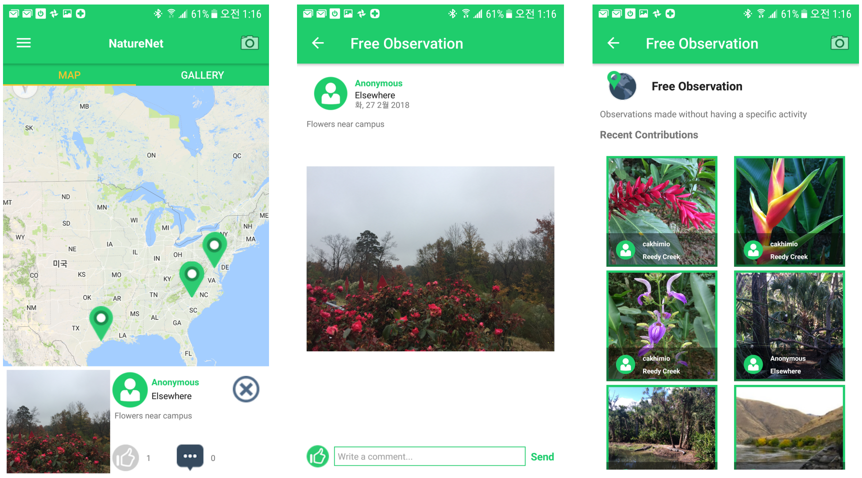


Fig. 2 Observations displayed on the android mobile app: explore (left), a single observation (middle), and a project (right)

NatureNet as a Crowdsourced Design Platform

As a crowdsourced innovation platform, NatureNet allows end-users to shape the design and development of NatureNet. End-users contribute through "design ideas", which they can submit when they identify an issue with the existing design, have suggestions for a new feature, or want to do something new that is currently not supported. Users can also contribute by commenting and voting on existing design ideas. While these ideas can include new workflows and ways of using the platform, many contributions are based on the users' direct experience with the visual design, information design, and/or interaction design of the platform.

To draw an example from our data, one user submitted the idea "I suggest allowing users to upload data from low-cost environmental sensors (Water quality, air quality)." This idea was submitted to the Design Ideas page as a "new feature." This idea might require a significant change to the platform but also changes the types of projects that can be carried out. Other ideas, such as "Can I take a picture of a plant from multiple angles [as] part of one single observation", might make the user experience more seamless but not fundamentally change what NatureNet does. Once these ideas are submitted, users can comment or vote on the idea. NatureNet team members can also comment on the idea. The interface for submitting and reviewing design ideas can be seen in Figure 3.

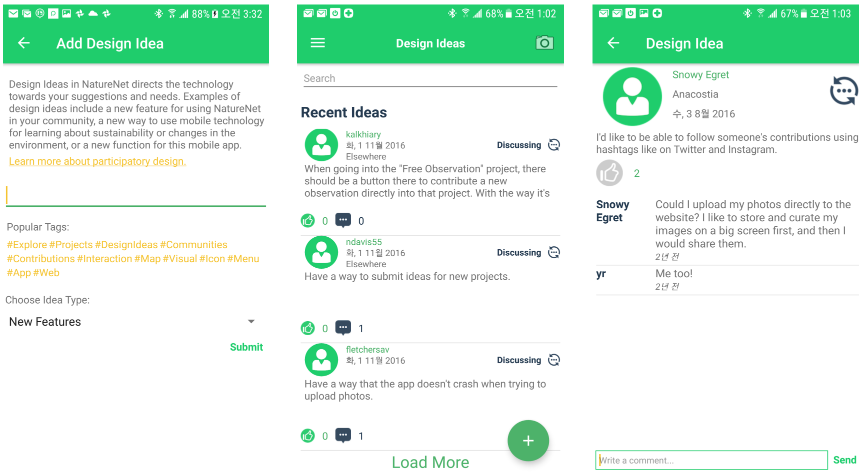


Fig. 3 Design ideas as shown on the NatureNet Android app: Adding a design idea (left), listing existing design ideas (middle), and viewing details of an existing design idea (right).

Crowdsourced Design in NatureNet

Crowdsourcing design is a way to quickly get a variety of design ideas. This process has been used with varying success. For instance, there are examples of the crowd outperforming experts [12], and examples of the crowd proposing obvious and redundant ideas [13]. Consequently, there are many techniques for boosting the creativity of the crowd such as combining crowd ideas [14]. Another technique for improving the quality of crowdsourced ideas is to guide design ideas by giving the crowd feedback about their contributions or explicit training [15]. Crowds generate many ideas, and given their potential for similarity [13], many crowdsourcing ideation platforms implement affordances for voting and for filtering ideas [16]. Through these many techniques, crowdsourced ideas can provide companies with many designs that have reasonable quality at relatively cheap prices. This balance between cost and quality is often made as an argument for and against crowdsourcing. In NatureNet, the crowd isn't compensated monetarily but instead through the satisfaction of seeing their ideas implemented, through community reputation, and a voting system. This lessens the need for quality control mechanisms that are typically associated with crowd-work such as test questions.

In NatureNet, users can post ideas, comment on ideas to improve them or modify them, and vote. Throughout this process, the design and development team (referenced from here on as the NatureNet team) tracks new ideas, discusses the ideas, provides feedback about feasibility. The NatureNet team has been made up of one designer, one design idea moderator, and one to three developers. As the NatureNet team integrates users' ideas they often combine multiple related ideas or create features that solve more than one problem, to address more design ideas, and save time. This creative combination may lead to new and interesting solutions that are different but related to the individual ideas proposed by end-users.

The role of the NatureNet team is to manage the process, evaluate comments and contributions, and then implement the crowd's designs. We conceptualize this as a cyclical process of ideation, discussion and implementation, one cycle of which leads to a new version of the design. This process allows for the synthesis of crowdsourced perspectives and the selection of strong ideas by the NatureNet team for integration into the next version [17]. A design idea can have any of the following status labels, indicating its progress:

- *Discussing*: submitted ideas (this is the initial status of each idea)
- *Developing*: selected ideas for the implementation
- *Testing*: implemented ideas before release
- *Done*: implemented and released ideas

Figure 4 illustrates the transition from submitting a design idea to implementing a design idea in NatureNet. The crowd generates and contributes new design ideas in the current iteration of the design. The new design ideas can be tagged by the crowd or the NatureNet team for categorization using hashtags. In addition, the crowd can choose from a dropdown of the following idea categories when submitting their idea: *new feature*, *project idea, community idea*, and *improvement*. Design ideas are searchable by content and tag, which helps the NatureNet team track categories of design ideas over time.

The NatureNet team oversees the progression of these ideas through the process, communicating with the crowd throughout. To select an idea, the NatureNet team considers several aspects such as the idea type, number of likes, number of comments, difficulty of implementation, and priority. Once a design idea is selected for implementation, the NatureNet team develops prototypes, and evaluates them by communicating with the crowd. Once a prototype is implemented, the new version gets feedback from the crowd and this process iterates to create subsequent versions.

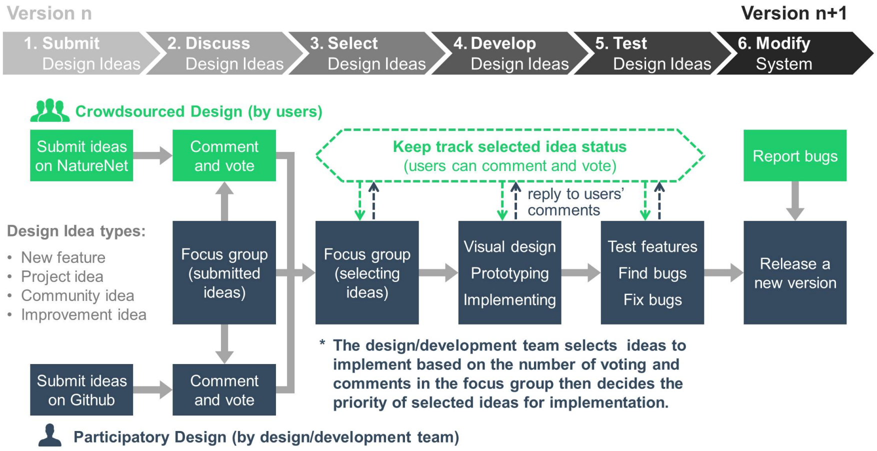


Fig. 4 Design process model shows how designs are contributed and implemented.

This process leads to a model of design that is very different from traditional co-located small-team design. The crowdsourced design model adopted by NatureNet is different from traditional design methods in the following four ways:

Communication (direct, indirect): In a traditional design meeting, designers communicate with each other directly. In crowdsourced design, participants communicate indirectly, typically through a discussion forum.

Synchronicity (synchronous, asynchronous): The discussions in a traditional design meeting occur at the same time. Contributing design ideas in a crowdsourced design is asynchronous: they occur at any time.

Proficiency (qualified, unqualified): In a traditional design session, the participants are selected based on their qualifications for the design problem. In crowdsourced design, the participants need not be and typically are not qualified in the area of the design problem.

Optionality (required, volunteer): In a traditional design session, the participants are required to contribute to the design process. In crowdsourced design, the participants volunteer to participate.

A Protocol Study of Crowdsourced Design in NatureNet

In this section, we describe a protocol study of the NatureNet crowdsourced design process. This study investigates the cognitive processes adopted by the crowd designers, and explores how the four differences above impacted the distribution of cognitive activities in the design process. Protocols are records of designers' communications, usually verbal but increasingly text-based where online technology is involved. Protocols can be segmented to enable analysis, and this segmentation is based on a coding scheme. Function-Behavior-Structure (FBS) [19] and Level of Abstraction [18] are examples of coding schemes for design protocol analysis.

The FBS ontology provides a set of categories of cognitive issues that can be used to characterize what designers are thinking about during the design process [19]. In a typical design process, designing an artifact involves a series of elementary steps which transform, first, the desired 'function' of the artifact into its 'expected behavior'; then the expected behavior into a 'structure' intended to enable the artifact to exhibit the expected behavior. After further steps of analyzing the structure for its 'actual behavior' the structure is finally transformed into a design description from which an artifact may be produced. Reasoning about the function (F) refers to the manner in which the design object fulfills its purpose, i.e., the designer is working with the functional aspects of the problem domain. Reasoning about the behavior (B) concerns the description of the object's action or process in given circumstances and often deals with a response to some user action. i.e., the designer is concerned with the behavioral aspects of the problem domain. Behavior is either derived (Bs) or expected (Be) from the structure. Reasoning about structure (S) involves the consideration of visual and conceptual elements, such as "Pond water", search-bar, or mobile app. In addition to these main categories, requirements (R) represent intentions from the client that come from outside the designer. The FBS coding scheme categorizes the designer's behavior based on his/her concentration of Function, Structure or Behavior at each stage of the design [19].

The FBS coding scheme provides a standardized vocabulary which applies to design activity regardless of context. Gero states that 'foundations of designing' are independent of the designer, their situation, and what is being design. Accordingly, all designs could be represented in a comparable way, as could all records of designing [20]. The FBS framework makes these uniform representations possible. As such, FBS allows us to compare synchronous and asynchronous protocols. It allows us to analyze crowdsourced and non-crowdsourced designs using the same coding scheme.

In traditional design, there are commonalities of process that can be observed regardless of the design context. Gero et al. (2014) surveyed a set of thirteen design sessions and observed that the design issues that the designers are thinking about as they are designing, as coded by FBS had many similarities despite design contexts [21]. They also present "empirical evidence of commonalities across designing independent of the designers' geographical location, expertise, discipline, the specific design task, the size and composition of the design team, and the length of the design session" [22].

In the FBS coding scheme, issues can be categorized into problem focused and solution focused. Problem focused issues are Functions (F), Requirements (R), and Expected Behaviors (Be). Solution focused issues are coded as Structure (S) or Behavior derived from structure (Bs). P-S index is a concentration indicator defined by Gero et al. [23]. It is calculated as the ratio of number of issues in the problem space divided by the number of issues in the solution space.

$$P - S\ index = \frac{\Sigma(\mathrm{F, R, Be})}{\Sigma(S, Bs)}$$

A design session with a P-S index larger than 1 is a problem-focused designing style, and a session with a P-S index value less than or equal to 1 is a session with solution-focused style. We've used the P-S index to understand whether the crowd moves from a concentration on problem focused design to solution focused design as the usability of the NatureNet platform improves.

There have been several design studies looking at different aspects of design from creativity to technique and discipline based on FBS ontology [23, 24, 25]. Hence, basing our study on FBS in addition to providing the possibility of achieving comparable results regardless of the design topics, makes the output cognitively comparable with other more common forms of design.

Design Data Collected from NatureNet

We include 183 design ideas that were submitted to NatureNet by 74 different contributors in our analysis. These design ideas were collected from the NatureNet website, mobile apps, and the tabletop version of NatureNet. We didn't include data about voting and comments in the corpus that we analyzed. These 183 ideas were collected between April 24, 2016 and October 5, 2017. All ideas are included in the analysis, regardless of whether they were chosen for implementation.

Users could see and interact with all the ideas that were previously contributed by other users. Figure 5 shows several design ideas captured from the web interface to demonstrate what end users would see as they contribute new ideas. Ideas were often repeated because end-users didn't search through previously submitted design ideas to see if their idea had already been proposed. This is consistent with previous work; BlueSky shows that crowdsourced ideas often repeat concepts and don't typically cover the design space [13].

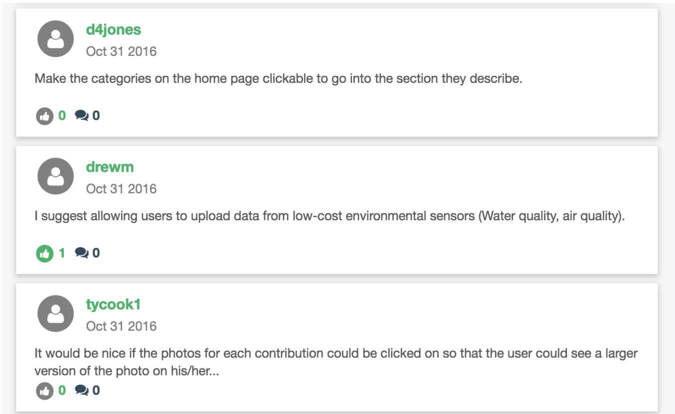


Fig. 5 A screenshot of some of the design ideas that were posted by NatureNet users (from www.nature-net.org).

Hypotheses

Considering different characteristics of NatureNet design model compared to traditional design processes, we hypothesize that the following patterns will be observed in the crowd data:

- Crowdsourced design ideas from end-users will have a stronger focus on Function than traditional design contexts because end-users have specific functional needs that are not provided in the current implementation.
- Crowdsourced design ideas will not focus as much on expected behavior because users are not experts in user experience design and lack an appreciation of expected behaviors.
- Similar to traditional design, we expect crowdsourcing design ideas to have a strong focus on structural aspects of the design. Previous studies of design activities show that design teams tend to have a

larger percentage of time or issues related to the structure of the design when compared to function or behavior of the design [23, 26, 27]

- We expect NatureNet to oscillate between focusing on the problem and on the solution. Problems inspire solutions and new solutions may lead to new problems if the solution is incomplete or ineffective. In design, it is common for the problem and solution to co-evolve [28].
- The distribution of contributions among participants will be similar to behavior in online communities. In traditional design sessions, one person can "hold the floor", thereby dominating the design session. We expect to see a small portion of the crowd exhibit similar behavior by submitting a substantial fraction of the ideas.

Analysis

To analyze the results, we used three coders in a group coding session. Before group coding, two coders coded independently to calibrate their codes. Their agreement as measured by Cohen's Kappa was strong (0.62). An analysis of these codes show aspects of the crowd design data that was not present in traditional synchronous verbal protocols of designers and design teams. The crowd participants were often unaware of design ideas that preceded their own. This lead to a lot of repetition and re-hashing of the most common design suggestions. We even observed users repeating their own ideas in cases where some time had passed. This informed the way that we coded segments in design ideas, leading us to treat each design idea as being independent of all other design ideas. This is different from traditional design contexts where each team-member can be considered to be aware of what other team members or doing and saying.

Results

To provide context for our results, we compare them with empirical results [22, 23] and a review of prior studies that have analyzed traditional design sessions [21]. To do this, we explored our results in three different ways: 1) the distribution of FBS codes, 2) patterns in how users contributed ideas, and 3) temporal trends in the problem solution index. We compared crowdsourced design to traditional design sessions in each of these aspects, providing insight into the differences and similarities between the two design contexts.

Distribution of FBS Codes in Design Ideas

The distribution of design issues is shown in Figure 6. This distribution appears to largely replicate the results of [22], in which three design sessions each employing a different concept generation technique were coded, shown in Figure 7. As shown in Figure 7, Structure (S) is most common, followed by Analyzed Behavior (Bs), Expected Behavior (Be), and Function (F); in that order. Our data contains didn't contain any requirements (R) or descriptions (D), so we omit those from our comparison.

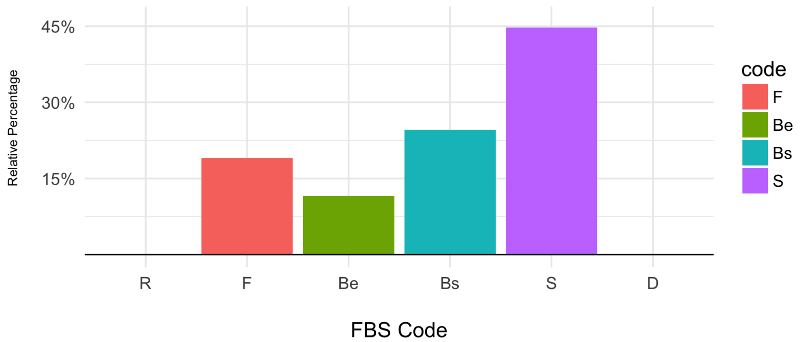


Fig. 6 The distribution of FBS codes across all of the design ideas received in the NatureNet platform. See Figure 7 for a comparison with traditional design.

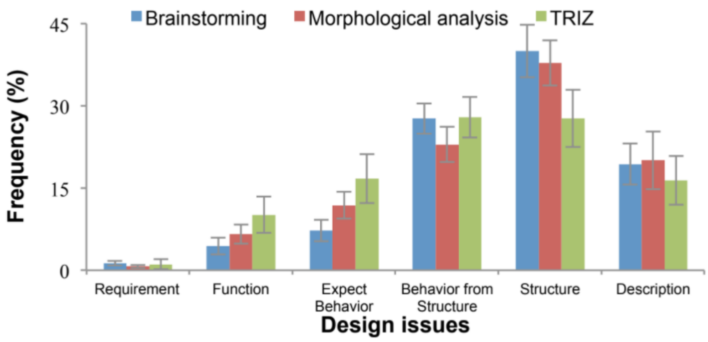


Fig. 7 The distribution of design issues (FBS codes) using three different concept generation techniques [22]. Error bars indicate the variation along each aspect between multiple design sessions in the review.

The major difference between the crowd and the traditional design contexts is the frequency of Function (F), which was more common than Be and almost as common as Bs. We might expect that the lack of D in our dataset would cause all the other codes to increase proportionately, but the increase has gone almost entirely to the S and F categories. The higher occurrence of F is mostly likely either related to the way design ideas were obtained, or the fact that the data is from end-users rather than designers and therefore tend towards suggestions for new functions.

Obtaining design ideas asynchronously means that each idea occurs independently of the ideas that appear before it. As a result, there may be less shared context to reference when suggesting new ideas, and thus less "progress" from F to B to S. Instead we found that the crowd's new ideas do not directly reference previously posted ideas. Since our crowd consists of primarily end-users, who may be motivated to submit design ideas based on immediate problems stemming from their use of the platform. Unlike traditional design processes where new ideas are considered within the broader scope of the design, end-users often suggest ideas independently. This might reflect a focus on immediate need with little additional context and without considering the larger scope of NatureNet.

We also explored potential relationships between the design issues that appear in each design idea. Correlations were computed using Pearson's Chi Squared Test. Significance was determined by applying a t-test to the individual correlations and Holm correction was used to correct for multiple comparisons. Three correlations were minor but significant: F-S (-0.21), F-Bs (-0.17), and S-Bs (.31). F likely has a negative correlation with other design issues because it regularly appears alone in short design ideas, often those that describe a desired feature in a single sentence. Some of these ideas didn't provide sufficient detail for the NatureNet team to understand the user's intent. This may stem from the fact that end-users are not designers. In contrast, ideas that discussed both Bs and S tended to be analyses of current features. For example, one idea described a new feature but did not indicate whether it corresponded to the mobile or web version of NatureNet. More scaffolding could help non-expert designers be aware of what context is relevant, but this presents a difficult interaction design problem: users often don't notice or ignore scaffolding. For example, most contributors didn't use the provided dropdown list to indicate if the idea was a new feature, an improvement, a new community, or a new project.

Given both observations, we can see some initial evidence that F might take on a more significant role in crowd-sourced design where end-users make up a significant portion of the crowd.

Relative user contribution frequencies

In traditional design settings, one designer can dominate a conversation by not providing opportunities for other designers to contribute. This happens when one designer talks longer and more frequently or when they interrupt others. This behavior may in turn demotivate and disincentivize participation by others. In asynchronous design contexts interruption is not possible and the conversation is parallel and distributed. Regardless, we still observed analogous conversational dominance, as some users contributed disproportionate numbers of ideas, shown in Figure 8.

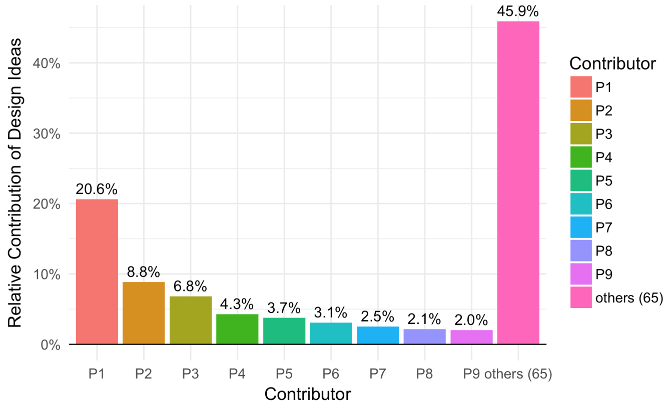


Fig. 8 Distribution of design ideas among all users. The number one contributor of design ideas accounted for 20% of the design ideas received. The top ten contributors, taken together, accounted for more than 50% of ideas.

We analyzed the sequence of submitted design ideas for "streaks": patterns of submissions by a single user with no interruptions by others. We also observed many cases where a large number of ideas were contributed by one user but with brief interjections from other users. In this analysis, we observed that there were 17 "2-streaks" (pairs of ideas submitted by a single user), 6 "3-streaks" (trios of consecutive submissions), one 4-streak, five 5-streaks, and an impressive 11-streak. Submitting as much as 6% of our data in a row with no interruptions can be considered equivalent to a designer "holding the floor". Our interface privileges recently submitted design ideas, meaning that after a long streak all immediately-visible design ideas will come from a single user.

Participation online is known to be uneven, with "superposters", users who post much more than others, often making up a substantial portion of total posts in a discussion forum [29]. We speculate that, like in discussion forum contexts, superposting and sequential posting may be discouraging for new NatureNet users who have not yet contributed. Investigating superposter behavior and how it is interpreted by other contributors is an interesting area for future research, as is designing systems to encourage equitable participation in crowdsourced design.

P-S Index and Temporal Trends

We plotted the P-S Index for the first and second halves of our “design session”, shown in Figure 10. The problem-solution index remained relatively consistent throughout the design session. This consistency is most similar to traditional brainstorming sessions which also have little variation over time, as shown in Figure 9. In comparison, the analysis of the TRIZ and Morphological sessions shows that the first half of the session is more problem focused while the second half is solution focused. NatureNet more strongly resembles unstructured brainstorming, with new problems and solutions emerging continually. This doesn’t imply that individual users of NatureNet are more balanced throughout their design sessions. We can see ideas as micro-design sessions and the unit of analysis here is the aggregate of those sessions. This analyzed macro-session was balanced over time. Ideas don’t often build on previous ideas; instead, they are generated independently, and are often not immediately evaluated.

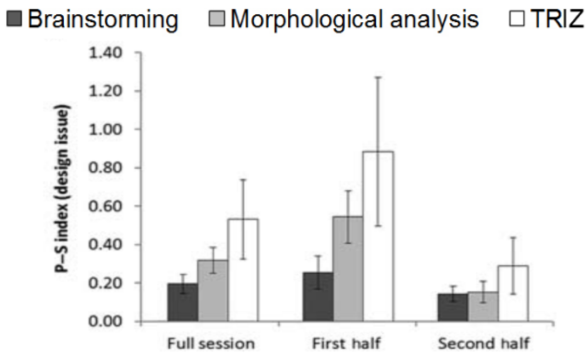


Fig. 9 An aggregated view of the design sessions from Gero et al.’s review of designing using three different concept generation techniques [23].

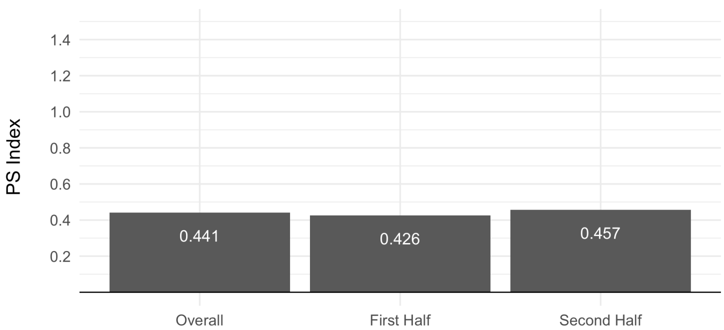


Fig. 10 First and second halves of the NatureNet “design session”. The ideas were ordered chronologically and then separated into halves to compare Fig. 9.

Discussion

In this paper we compare crowdsourced design and traditional design by analyzing the design ideas that were contributed to the NatureNet citizen science platform. Crowdsourced design is different to traditional design sessions in synchronicity, temporality, expertise, and communication modality. These factors affect the way that end users contribute to the design process. The analysis of the crowdsourced design ideas featured three main aspects: the FBS coding of ideas, user ideation behaviors, and temporal trends. These aspects were compared with more traditional design sessions (i.e. small, co-located design teams) based the review of design protocol studies in Gero et al. [21]. The differences between crowdsourced and traditional design include:

- Participants in crowdsourced design post more ideas that contain references to functions than participants in traditional design.
- In crowdsourced design ideas containing function are often presented without much context, instead focusing on a single new feature.
- Crowdsourced design involved end-users in the design process and end-users don't usually know what information to include in design ideas for a design team to make sense of the idea, which suggests that scaffolding to obtain context from users must be carefully designed.
- In crowdsourced design attention doesn't oscillate between problems and solutions over time, instead problems and solutions are proposed continually throughout.
- In crowdsourced design a small portion of users post disproportionately and often in rapid succession.

One possible explanation for a significant number of ideas coded as Function is that many end-users have specific things that they want to be able to do with NatureNet. This would help explain why proposed new Functions frequently appeared by themselves as short idea such as "I want to be able to post audio clips."

In another departure from traditional design, Expected Behavior (Be) appeared less frequently. We hypothesized that Be would be less frequent in crowdsourced design because new functions and structures could be explained in terms of existing behaviors, structures, and functions. On the few occasions that end-users described expected behaviors they did so from their own personal perspective, often without considering how it might affect others.

Due to these findings, future developments in crowdsourced design can include scaffolding to help users to think more broadly about their design ideas and to include more relevant information. In our current implementation, scaffolding has had mixed success. Suggesting hashtags does appear to increase their usage, but on the other hand our dropdown list of design categories was mostly ignored. It is difficult to conclude from this single study whether users' reticence to indicate the category of their submission reflects the behavior of the crowd or a usability issue.

Design ideas in NatureNet were more focused on solutions than problems. This focus didn't vary much over time, which contrasts with the transition from problem-focused to solution-focused thinking observed in most design activities. An exception to this is brainstorming, which also tends to focus on solutions throughout the design session. Our crowdsourced design appears to be similar to brainstorming in this respect, although the balance between problems and solutions is different.

We observed that a small portion of users were responsible for a large proportion of design activity. While these behaviors weren't meant to discourage others or dominate the design, their behaviors may have that effect on other users. If we refine the design of NatureNet based on the design ideas of the crowd, and 50% of the crowd's design activity is made up by just a few contributors, then we are designing NatureNet for those few people. The intent of crowdsourcing is to democratize participation, but this would more strongly resemble an oligarchy. Understanding how ideation patterns affect other contributors is an area for future research. End-users are a community and so the interactions between members and aspects such as equity and inclusion need be considered.

In summary, users' ideas are rooted in their experiences and they express solutions from their own perspective without considering the broader context in which the solution exists. This is to be expected since they are not designers. Furthermore, users didn't appear to be aware of the ideas of others, often posting duplicate or highly similar solutions. Like brainstorming, the focus on problems and solutions didn't change much over time, but with a slightly higher emphasis on solutions compared to brainstorming.

Limitations

We have presented the results from an extended crowdsourced design session; however, the results may not be representative of all crowdsourced design contexts. Crowdsourced design often integrates the crowd at discrete points in time such as during idea generation, evaluation, or modification. In those contexts, the crowd is may not be aware of the overarching design problem, goals, and solution. In our context, end-users have the option to be involved throughout most parts of the design process.

They can suggest an idea, discuss the underlying problem, and actively develop solutions with other users and the design team. Although these things are possible, we observed that users didn't always receive feedback, they often weren't aware of other similar ideas, and they may not share a collective vision for the design of NatureNet. Our notion of design is more similar to traditional design settings than discrete micro-task-based crowdsourced design. Our results compare the crowd to a design team, even though individual cognitive processes may differ. Finally, while design fixation is possible in any design setting, our crowd consists of end-users that are familiar with the existing system and its features. It is likely that this led to some amount of design fixation.

Conclusion

In this paper, we explore the design ideas that were submitted to the NatureNet apps by its end users. These crowdsourced ideas are intended to improve the NatureNet platform, and can be considered a multitude of "micro design sessions". We analyzed 183 design ideas and compared their content, distribution, and temporal trends with those of traditional design settings.

We've found that functions appear more frequently in this context, that problems and solutions appear consistently throughout the design lifecycle, and that a few users produce a large percentage of ideas. These findings have implications for crowdsourced ideation platforms and for systems that accept design ideas from their end-users. Further research includes: evaluate the quality, diversity, and creativity of the design ideas, and to develop affordances for a broader range of end-users to contribute and to consider the ideas of others on the platform.

References

1. Howe, J. (2006). The rise of crowdsourcing. Wired magazine, 14(6), 1-4.
2. Maher, M. L., Paulini, M., & Murty, P. (2011). Scaling up: From individual design to collaborative design to collective design. In Design Computing and Cognition '10 (pp. 581-599). Springer Netherlands.
3. Ponsonby, A. L., & Mattingly, K. (2015). Evaluating New Ways of Working Collectively in Science with a Focus on Crowdsourcing. EBioMedicine, 2(7), 627-628.
4. Kittur, A. (2010). Crowdsourcing, collaboration and creativity. ACM Crossroads, 17(2), 22-26.

5. Chan, J., Dow, S., & Schunn, C. (2014, February). Conceptual distance matters when building on others' ideas in crowd-collaborative innovation platforms. In Proceedings of the companion publication of the 17th ACM conference on Computer supported cooperative work & social computing (pp. 141-144). ACM.
6. Chan, J., Dang, S., & Dow, S. P. (2016, February). Improving crowd innovation with expert facilitation. In Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing (pp. 1223-1235). ACM.
7. Xu, A., Huang, S. W., & Bailey, B. (2014, February). Voyant: generating structured feedback on visual designs using a crowd of non-experts. In Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing (pp. 1433-1444). ACM.
8. Valentine, M. A., Retelny, D., To, A., Rahmati, N., Doshi, T., & Bernstein, M. S. (2017, May). Flash Organizations: Crowdsourcing Complex Work by Structuring Crowds As Organizations. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (pp. 3523-3537). ACM
9. Lasecki, W. S., Kim, J., Rafter, N., Sen, O., Bigham, J. P., & Bernstein, M. S. (2015). Apparition: Crowdsourced user interfaces that come to life as you sketch them. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (pp. 1925-1934). ACM.
10. Wu, H., Corney, J., & Grant, M. (2014). Crowdsourcing Measures Of Design Quality. In ASME 2014 International Design Engineering Technical Conferences and Computers and Information in Engineering. ASME
11. Maher, M. L., Preece, J., Yeh, T., Boston, C., Grace, K., Pasupuleti, A., & Stangl, A. (2014, February). NatureNet: a model for crowdsourcing the design of citizen science systems. In *Proceedings of the companion publication of the 17th ACM conference on Computer supported cooperative work & social computing* (pp. 201-204). ACM.
12. Poetz, M. K., & Schreier, M. (2012). The value of crowdsourcing: can users really compete with professionals in generating new product ideas? Journal of product innovation management, 29(2), 245-256.
13. Huang, G., & Quinn, A. J. (2017, June). BlueSky: Crowd-Powered Uniform Sampling of Idea Spaces. In Proceedings of the 2017 ACM SIGCHI Conference on Creativity and Cognition (pp. 119-130). ACM.
14. Yu, L., & Nickerson, J. V. (2011, May). Cooks or cobblers?: crowd creativity through combination. In Proceedings of the SIGCHI conference on human factors in computing systems (pp. 1393-1402). ACM.
15. Dontcheva, M., Morris, R. R., Brandt, J. R., & Gerber, E. M. (2014, April). Combining crowdsourcing and learning to improve engagement and performance. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 3379-3388). ACM.
16. Ahmed, F., & Fuge, M. (2017). Capturing winning ideas in online design communities. In Proceedings of the 17th ACM Conference on computer supported cooperative work and social computing (pp. 1675-1687). ACM.

17. Grace, K., Maher, M. L., Preece, J., Yeh, T., Stangle, A., & Boston, C. (2015). A process model for crowdsourcing design: A case study in citizen science. In Design Computing and Cognition ‘14 (pp. 245-262). Springer.
18. Purcell, T., Gero, J., Edwards, H., & McNeill, T. (1996). The data in design protocols: The issue of data coding, data analysis in the development of models of the design process. Cross et al, 153, 151-168.
19. Gero, J. S. (1990). Design prototypes: a knowledge representation schema for design. AI magazine, 11(4), 26.
20. Gero, J. S., & Kannengiesser, U. (2014). The function-behavior-structure ontology of design. In An Anthology of Theories and Models of Design (pp. 263-283). Springer London.
21. Gero, J.S., Kannengiesser, U., and Williams, C. (2014) Does designing have a common cognitive behavior independent of domain and task: A meta-analysis of design protocols, International Conference on Human Behavior in Design.
22. Gero, J. S., Kannengiesser, U., & Pourmohamadi, M. (2014). Commonalities across designing: Empirical results. In Design Computing and Cognition ‘12 (pp. 265-281). Springer, Dordrecht.
23. Gero, J. S., Jiang, H., & Williams, C. B. (2013). Design cognition differences when using unstructured, partially structured, and structured concept generation creativity techniques. International Journal of Design Creativity and Innovation, 1(4), 196-214.
24. Jiang, H., Gero, J. S., & Yen, C. C. (2014). Exploring designing styles using a problem–solution division. In Design Computing and Cognition' 12 (pp. 79-94). Springer, Dordrecht.
25. Kan, J. W., & Gero, J. S. (2009). Using the FBS ontology to capture semantic design information in design protocol studies. In About: Designing. Analysing Design Meetings (pp. 213-229). CRC Press.
26. Yu, R., Gero, J., & Gu, N. (2013, July). Impact of using rule algorithms on designers’ behavior in a parametric design environment: preliminary result from a pilot study. In International Conference on Computer-Aided Architectural Design Futures (pp. 13-22). Springer, Berlin, Heidelberg.
27. Williams, C. B., Lee, Y., Gero, J., & Paretti, M. C. (2013, August). Exploring the Effects of the Design Prompt on Students’ Design Cognition. In ASME 2013 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. ASME
28. Dorst, K., & Cross, N. (2001). Creativity in the design process: co-evolution of problem–solution. Design studies, 22(5), 425-437.
29. Huang, J., Dasgupta, A., Ghosh, A., Manning, J., & Sanders, M. (2014, March). Superposter behavior in MOOC forums. In Proceedings of the first ACM conference on Learning@ scale conference (pp. 117-126). ACM.