Everyone counts? Design considerations in online citizen science

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ABSTRACT:
Effective classification of large datasets is a ubiquitous challenge across multiple knowledge domains. One solution gaining in popularity is to perform distributed data analysis via online citizen science platforms, such as the Zooniverse. The resulting growth in project number is increasing the need to improve understanding of the volunteer experience; as the sustainability of citizen science is dependent on our ability to design for engagement and usability. Here, we examine volunteer interaction with 63 projects, representing the most comprehensive collection of online citizen science project data gathered to date. Together, this analysis demonstrates how subtle project design changes can influence many facets of volunteer interaction, including when and how much volunteers interact, and, importantly, who participates. Our findings highlight the tension between designing for social good and broad community engagement, versus optimizing for scientific and analytical efficiency.

Keywords: Citizen Science | Public engagement with science and technology | Social inclusion

Context

During the last decade, an increasing number of research teams have deployed online citizen science projects to aid with data analysis [Brabham, 2008]. Typically, these projects invite volunteers to complete a classification task associated with a single element of data, such as an image, graph or video clip, with multiple volunteers examining each separate data point. The growth of this mode of distributed data analysis is being driven by the increased availability of datasets in many research disciplines, coupled with the concurrent broad establishment and use of web-connected computer and mobile technology. In addition to being motivated by the need to produce annotated datasets for research purposes, project owners are frequently passionate about the potential of citizen science to engage the public in authentic research. This raises a range of interesting challenges and questions for those studying, designing and implementing citizen science projects, such as how to effectively satisfy the dual aims of citizen science of scientific efficiency and social inclusivity. Here, we use a large dataset of more than 60 online citizen science projects, representing the most comprehensive collection of online citizen science project data gathered to date, to study how project design affects volunteer behaviour, and ultimately the success of the project.

We focus on a well-established platform for online citizen science, the Zooniverse. The Zooniverse is the largest and most popular citizen science platform for data interpretation [Woodcock et al., 2017] (**Figure 1** and **Figure 2**). It has provided a space for volunteers to contribute to more than 100 distinct research projects across multiple domains, including astronomy, ecology, medicine and the humanities. Although diverse in subject matter, Zooniverse projects are unified by a common theme of asking volunteers to perform simple tasks such as image classification and text transcription, and the aggregation of these projects onto one platform confers a unique opportunity to examine volunteer behaviour across projects.

Citizen science involves the collaboration of the general public with professional scientists to conduct research. The principal benefit of applying this method is that it enables research that would not otherwise be possible; although computer-based analysis can address many research questions, it is yet to surpass human ability in a number of areas, including recognition of the often complex patterns that occur within data [Cooper et al., 2010; Kawrykow et al., 2012]. Other potential benefits to online citizen science based research include a reduction in data processing time and cost [Sauermann and Franzoni, 2015], and the engagement of a more diverse crowd that may include typically underrepresented skills or demographic features [Jeppesen and Lakhani, 2010; Pimm et al., 2014]. Online citizen science projects are an effective form of public engagement, providing volunteers with an opportunity to learn more about science [Masters et al., 2016] and with an easily accessible means to make an authentic contribution to a research project, which can improve public engagement with, and advocacy of, scientific material [Forrester et al., 2017; Straub, 2016].

Despite the relative infancy of online citizen science, it has already contributed many noteworthy discoveries across diverse research domains, including the identification of new types of galaxies [Cardamone et al., 2009], models of large carnivore coexistence in Africa [Swanson et al., 2016], elucidation of protein structures relevant to HIV transmission [Cooper et al., 2010; Khatib et al., 2011], classification of cancer pathology [Candido Dos Reis et al., 2015] and mouse retinal connectome maps [Kim et al., 2014]. The growing success of citizen science, in conjunction with significant reductions in the barriers to developing online citizen science projects, has led to an exponential growth in the number and diversity of projects. This is creating both an opportunity, and a need, to further study and understand the volunteer experience [Cox et al., 2015; Sauermann and Franzoni, 2015], as the sustainability of citizen science is dependent on our ability to design for volunteer engagement while optimising for scientific efficiency.

There has already been much work to examine project design in the Zooniverse, though typically by researchers studying a small number of projects. For example, Jackson *et al*., investigated the effect of novelty on user motivation, showing that for one project (*Higgs Hunters*) a message informing volunteers when they were the first to see a particular data object increased participation [Jackson et al., 2016]. Lee *et al*., found that messages which refer to learning, contribution and social engagement were more effective than direct appeals to altruism [Lee et al., 2017]. Segal *et al*., used active messaging about 'helpfulness' in the longest running Zooniverse project, *Galaxy Zoo*, to further increase engagement [Lintott et al., 2008; Segal et al., 2016]. Sprinks *et al*., recently found that participants prefer task designs with greater variety and autonomy, however fulfilling this preference did not improve performance [Sprinks et al., 2017]. Together, these studies reveal that user motivations, as discerned by studies of behaviour, are predictably complex. The effect of participation on volunteers may be assumed as similarly complicated, though work by Masters *et al*., has shown that volunteers self-report learning both about the scientific topics with which they are engaged, and about the process of science itself [Masters et al., 2016]. This work also shows that learning about scientific topics occurs, and is correlated with further engagement in the project.

None of these studies has taken advantage of the large number of projects now available on the Zooniverse platform; completing such a survey would allow us to identify aspects of project design which have significant effects. Because Zooniverse projects use a common codebase they share many similar features (e.g. the flow from the landing page to the classification interface, the presence of discussion forums etc.), therefore, differences will be due to fundamental design choices, such as the difficulty of the task set, the choice of dataset and the amount of data available. In this study, we employ the Zooniverse online citizen science platform as a 'web observatory ecosystem' to study volunteer behaviour across n = 63 projects. This work extends preliminary analyses previously presented as a poster at The Web Conference 2018 [Spiers et al., 2018] through quantifying and comparing additional project measures, utilizing the similar number of astronomy and ecology projects to assess the academic domain specificity of our observations, and closely examining unique findings associated with an individual Zooniverse project, *Supernova Hunters*. The analyses presented here provide quantitative evidence and insight relevant to researchers designing and developing online citizen science projects, and are informative to researchers studying the crowd-based production of knowledge.

Methods

To conduct the data analysis performed in this study, we first assembled the most comprehensive collection of Zooniverse classification data to date; including data from n = 63

Zooniverse projects (**Figure 1**, **Table 1**). Although these projects are all hosted on the same platform, these projects differ in domain (**Figure 2**), launch date (**Figure 1**) and task, amongst other variables such as level of social media engagement and level of press attention. An overview of project characteristics is provided in **Table 1**.

Data for the n = 63 projects were obtained from Zooniverse databases. Projects were selected for inclusion in this analysis based on data availability. Project characteristics, including domain and launch date are summarized in **Table 1**. Projects that have been rebuilt and relaunched were treated as separate projects for the purpose of this analysis (see *Notes from Nature*, *Milky Way Project* and *Chicago Wildlife Watch* in **Table 1**). Zooniverse projects can be highly variable in duration, from weeks to years, therefore, for ease of comparison across projects a consistent observation window of 100 days post-launch day was applied across all analyses. For logged-in, registered volunteers it is possible to describe volunteer-specific classification activity.

Throughout this paper, the term 'classification' is used to denote a single unit of analysis on a project by a volunteer, such as the tagging of an image or a video, whereas the term 'subject' refers to a single data object such as an image, video or graph. Different classification types can vary significantly in the amount of effort they demand. For a detailed glossary of Zooniverse terms, see Simpson *et al*., [Simpson et al., 2014]. For further information about the Zooniverse platform please see www.zooniverse.org.

To examine volunteer demographic features, data were extracted from Google Analytics (GA) (https://analytics.google.com/) for five astronomy and five ecology projects. To improve comparability between the projects examined and create a more uniform sample, we analysed the five most recently launched projects built using the project builder (https://www.zooniverse.org/lab) for both the astronomy (*Gravity Spy*, *Milky Way* (2016), *Radio Meteor Zoo*, *Supernova Hunters* and *Poppin' Galaxy*) and ecology (*Chicago Wildlife Watch* (2016), *Arizona Batwatch*, *Mapping Change*, *Camera CATalogue*, *Snapshot Wisconsin*) domains, from our cohort of n = 63 projects. For each project examined, several variables were extracted from GA for the classify page of each project for the first quarter of 2017 (January 1st 2017 to March 31st 2017; data obtained May 9th 2017). These included the number of 'Page views' ('Page views is the total number of pages viewed. Repeated views of a single page are counted') subset by the secondary variables of age and sex.

The breadth and depth of the data collected by GA, in addition to it being a free and easily accessible service, has led to GA becoming an accepted research tool and one of the most frequently used methods to measure website performance [D.J. et al., 2014]. GA has been successfully used to examine user behaviour [Crutzen et al., 2013; Song et al., 2018] website effectiveness [Plaza, 2011; Turner, 2010] and web traffic [Plaza, 2009]. However, it should be noted that it does have a number of constraints. For example, although GA uses multiple sources (third-party DoubleClick cookies, Android advertising ID and iOS identifier for advertisers [Google]) to extract user demographic information (age, gender and interests), these data may not be available for all users. In the analyses presented here, demographic data was available for 49.83% of total users for the variable of age, and for 53.41% of total users for the variable of gender. A further limitation is that occassionally the demographic data reported by GA may reflect a sample of website visitors, and hence may not be representative of overall site composition. Although the data presented in this study represents a sample of website visitors, for each page examined this sample was large (representing hundreds to thousands of page views) therefore the impact of missing demographic information from individual users or mis-sampled data will be minimal. The possibility of 'referrer spam' and 'fake traffic' pose further limitations to the accuracy of reports from GA, however these issues are less likely to influence non-commercial sites such as The Zooniverse.

Results

How heterogeneous is classification and volunteer activity across projects and academic domain?

A large amount of heterogeneity is found between the n = 63 Zooniverse projects for the total number of classifications received within the first 100 days post-launch (**Figure 3a**, **Table 1**). Notably, three orders of magnitude difference is observed between the project with the most classifications (*Space Warps*; total classifications n = 8,011,730) compared to the project with the fewest (*Microplants;* total classifications n = 8,577) (**Table 1**)[*]. This suggests that the inclusion of a citizen science project on a successful citizen science platform website such as the Zooniverse does not guarantee high levels of engagement alone, as measured by number of classifications, and that some projects are far more successful at attracting classifications than others. Although initial inspection revealed a large difference between the number of classifications (within the first 100 days post-launch) for the n = 26 ecology projects (median = 224,054; interquartile range (IQR) = 78,928 – 758,447) compared to the n = 22 astronomy projects (median = 666,099; IQR = 150,642 – 1,178,327) (**Table 2**), this difference was not significant (*P*-value = 0.07, Mann-Whitney-Wilcoxon Test), indicating that other variables likely play an important role in the value of project metrics such as classification count.

The absolute number of classifications received by each project may be influenced by factors such as how popular the project is or how much publicity it has received. Therefore, to examine whether volunteers experienced projects differently once contributing, we next analysed the median number of classifications made by registered volunteers within 100 days post-project launch for each of the 63 projects (**Figure 3b**, **Table 1**). Again, a large amount of heterogeneity was observed between projects, with a broad spectrum from the project with the highest median number of classifications per registered volunteer (*Pulsar Hunters*; n = 100), to the projects with the lowest (*Orchid Observers*, *Mapping Change* and *Decoding the Civil War*; n = 3), and this difference was highly statistically significant in each case (*P*-value = < 2.2e-16, Mann-Whitney-Wilcoxon Test). This indicates that once volunteers are participating in a project, a variety of engagement levels are observed. However, no significant difference was found (*P*-value = 0.47, Mann-Whitney-Wilcoxon Test) when comparing the median number of classifications per registered volunteer within the first 100 days post-launch for the n = 26

[*] The few classifications received by the Microplants project are likely due to this project being promoted primarily in a museum setting, as opposed to the broader Zooniverse community.

ecology projects (median = 15; IQR = 9 – 32) to the n = 22 astronomy projects (median = 17, IQR = 11 – 26).

The majority of Zooniverse projects show similar temporal trends in classification activity – most projects possess a classification curve characterized by a high level of activity upon project launch (due to the sending of an e-newsletter to the Zooniverse volunteer community) that rapidly declines (**Figure 4a**), with intermittent spikes of activity, which can be the result of further project promotion, press coverage or the release of new data, amongst other factors. Of the 63 projects assessed, the *Supernova Hunters* project showed striking exception to this trend and instead had a classification curve displaying a recurring peak of activity each week (**Figure 4b**). This pattern of classification activity has arisen from *Supernova Hunters'* regular release of new project data and concurrent e-newsletter notification sent to project volunteers [Wright et al., 2017]. Notably, volunteer activity on the *Supernova Hunters* project has begun to precede the sending of e-newsletter notifications, suggesting that volunteers anticipate the release of new project data, and are therefore deeply engaged.

The number of unique volunteers contributing to each project within the first 100 days post-launch, and its link to domain, was examined (**Figure 3c**). As with the number of classifications, the number of unique volunteers contributing to each project is highly heterogeneous (**Table 3**) and does not show any clear domain specificity; no significant difference (*P*-value = 0.07, Mann-Whitney-Wilcoxon Test) is observed between astronomy (median = 3863; IQR = 1760 – 5906) and ecology (median = 1975; IQR = 1289 – 3273) projects. As expected, the number of volunteers contributing to a project within the first 100 days post-launch is positively correlated with the number of classifications received by that project (R = 0.64, *P*-value = 2.30e-08). However, this correlation is not perfect, suggesting varying levels of volunteer contribution dependent on project. Rather than being stochastic, these differing volunteer contributions to individual projects are likely due to project specific variables. The heterogeneous contributions of volunteers to specific projects is also illustrated by the variable median number of classifications per project per day (**Figure 5**).

How skewed are volunteer contributions in Zooniverse projects?

Prior work has identified skewed volunteer contribution distributions in similar settings such as Wikipedia and OSS development [Franke and von Hippel, 2003; Ortega et al., 2008; Panciera et al., 2009; Wilkinson, 2008] as well as Zooniverse projects [Cox et al., 2015; Sauermann and Franzoni, 2015]. We sought to extend previous analyses of Zooniverse projects by examining volunteer classification contribution inequality across a larger number of projects, which also enables assessment of our findings for domain specific trends. Applying an approach frequently used to examine income inequality [Gastwirth, 1972], we plotted the Lorenz curve for the distribution of volunteers' total classifications for each project (**Figure 6a**), and calculated corresponding Gini coefficients (**Table 4**).

Across all n = 63 projects a large area is observed between the Lorenz curve and the 45° line (perfect equality). This indicates that a large fraction of classifications are provided by a relatively small number of volunteers across all projects. However, heterogeneous volunteer contribution equality was identified between Zooniverse projects – the Gini coefficients varied from 0.54 for *Microscopy Masters* (**Figure 6b, c**), to 0.94 for *Supernova Hunters* (**Figure 6d, e**). Examining the mean Gini coefficient for each domain revealed similar Gini coefficients for ecology (0.80), astronomy (0.82), other (0.80) and transcription (0.81) projects, suggesting similar patterns of volunteer contribution across these domains.

Biomedical projects displayed a notably different average Gini coefficient of 0.67. This was significantly less than the Gini coefficient observed for astronomy projects (P-value = 0.046, Mann-Whitney-Wilcoxon Test), indicating a more unequal distribution of volunteer effort in astronomy projects compared to biomedical projects, suggesting that astronomy projects may attract a contingent of more prolific classifiers than biomedical projects. Notably, a comparably low Gini coefficient (0.72) has been reported elsewhere for the online biomedical citizen science project *Mark2Cure* [Tsueng et al., 2016]. This raises an interesting line of enquiry for future analyses – is there something about biomedical projects that disincentivises return volunteers, hindering the development of prolific classifiers, or are biomedical projects more successful in attracting a large number of casual contributors? Could this be related to perceived difficulty, or importance, of biomedical tasks? Further understanding patterns in volunteer contribution equality to different projects may provide insight regarding how to better design for the many or for the few, dependent on the particular project task.

Are Astronomy and Ecology projects associated with different volunteer demographics?

We next sought to describe basic demographic features of volunteers contributing to projects from differing domains. To perform these analyses, data were extracted from GA (https://analytics.google.com/) for the classification pages of five astronomy and five ecology projects (for a full description of approach, see the **Methods** section).

First, we examined the number of times the classification page was viewed for each project, subset by age of visitor for both astronomy (**Figure 7a**) and ecology projects (**Figure 7b**). No consistent trend was observed across the five astronomy projects examined (**Figure 7a**): for example, *Poppin' Galaxy* was more popular amongst the youngest age group (18 – 24) whereas *Supernova Hunters* is more popular amongst the oldest age group (65+), and other projects show no clear age bias in classification page views.

We see more uniformity in percentage page views by age group for the five ecology projects examined (**Figure 7b**). Although there is no striking overall trend, the peaks appear bimodal for the majority of projects examined, with peaks in percentage page views for 25 – 34 year olds and 55 – 64 year olds. The consistency in these peaks between the projects examined, particularly for the 55 – 64 year olds, indicates that ecology projects are more popular within these age groups. Such observations could be utilized to inform project promotion strategies.

Comparing the average page views count per age group for the five ecology projects to the five astronomy projects revealed a greater proportion of page views for astronomy projects relative to ecology projects for 18 – 24 year olds (Fisher's Exact Test, odds ratio = 1.89, P-value = 8.86E-62) and 65+ year olds (Fisher's Exact Test, odds ratio = 2.89, P-value = 4.16E-134). A smaller proportion of page views in astronomy projects relative to ecology projects was observed for the 25 – 34 year olds (Fisher's Exact Test, odds ratio = 0.77, *P*-value = 5.67E-13), 45 – 54 year olds (Fisher's Exact Test, odds ratio = 0.88, *P*-value = 5.11E-03), and a striking under enrichment in the 55 – 64 year olds (Fisher's Exact Test, odds ratio = 0.39, *P*-value = 4.77E-156) (**Table 5**). These findings reflect the observations in **Figure 7a** and **Figure 7b**.

Next, we compared classification page views subset by sex for the five astronomy and five ecology projects, with data extracted from GA (see **Methods** section). A clear male bias can be observed in percentage classification page views across the five astronomy projects examined (**Figure 7c**), whereas ecology projects see more equality in percentage classification page views between the sexes (**Figure 7d**). Comparing the average page view counts by sex for the five ecology projects to the five astronomy projects revealed a highly significant greater proportion of males in astronomy projects compared to ecology projects (Fisher's Exact Test, odds ratio = 3.92, *P*-value = 0), and a smaller proportion of females (Fisher's Exact Test, odds ratio = 0.25, *P*-value = 0) (**Table 6**).

Discussion

To ensure the sustainability of distributed data analysis via online citizen science, we must further understand the volunteer experience. In the analysis presented here we utilize a well-established online citizen science platform, the Zooniverse, as a 'web observatory ecosystem' to examine multiple project measures from the most comprehensive collection of online citizen science project data gathered to date.

Key findings include observation of a high level of heterogeneity, and little domain specificity, in the absolute number of classifications, number of unique volunteers and the median number of classifications per volunteer per project in the 100 days following project launch. These observations indicate that variables beyond the host citizen science platform and academic domain likely play an important role in project success. Such variables may include task difficulty, level of project promotion, quality of researcher engagement with volunteers or even the inclusion of 'charismatic' features or species (consider penguins vs. wildebeest). Quantifying these variables and relating them to project measures represents a worthwhile future direction to this work. Although highly variable in the total number of classifications received, the classification curves of individual projects were highly comparable, with all but one project, *Supernova Hunters*, displaying a characteristic peak of activity upon launch followed by a rapid decline in classification activity. Supporting previous studies, when examining volunteer classification contribution inequality we found a large fraction of classifications are provided by a relatively small number of volunteers across all projects. Finally, demographic analysis of astronomy versus ecology projects indicated that projects appeal to a broad age-range regardless of academic domain. In contrast, examining gender differences revealed a clear male bias amongst astronomy projects, whereas ecology projects showed greater variability in their gender balance.

In addition to these central findings, we identified a number of exceptional features associated with a single project: *Supernova Hunters*. Beyond possessing a notably unusual classification curve that displayed weekly peaks of activity, reflecting the scheduled release of new data to this project concurrent with the sending of a newsletter to project volunteers, the *Supernova Hunters* project also displayed the highest level of classification contribution inequality amongst its volunteers. In the context of other findings here, it is also worth noting that the *Supernova Hunters* project displayed both an age and gender bias, with volunteers primarily males over the age of 65.

Our observation of frequent, weekly spikes of classification activity concurrent with the release of small sets of data in the *Supernova Hunters* project indicate that a scarcity of data is associated with sustained volunteer engagement with a project. For the *Supernova Hunters* project, this model of activity has arisen organically due to the incremental production of subject data, therefore, the pattern of volunteer engagement observed for this project is serendipitous rather than deliberately designed. Other researchers planning citizen science projects may wish to consider intentionally adopting a similar approach of incremental data release to encourage volunteer engagement. For example, a project with a large, pre-existing data set could partition their subjects for gradual release, generating an artificial scarcity to encourage more frequent volunteer interaction.

Adopting a model of generating artificial data scarcity within a project design may encourage increased volunteer interaction through creating a heightened sense of competition to interact with a limited data set. A similar device of generating artificial scarcity is frequently applied in game or game-like design to drive further engagement [Deterding et al., 2011; Seaborn and Fels, 2015]. The motivation of competition is particularly relevant to a project such as *Supernova Hunters* where there is the legitimate possibility of being the first person to discover a supernova in the relatively small amount of new data released each week. It is understandable that engaged volunteers would be highly motivated to return to a project upon release of new data to have the opportunity of being the first to discover a supernova, or, as observed by Jackson *et al*., volunteers may just be motivated by being the first to see novel data [Jackson et al., 2016].

However, our analyses indicate that perceived scarcity has effects beyond motivating volunteers to interact with a project more frequently. *Supernova Hunters* was identified as the most unequal project for volunteer classification contributions, therefore a small cohort of highly dedicated volunteers submit the majority of classifications in this project. The scarcity of data in this project, consequential competition to classify, and rapid processing of project subjects is causing the volunteer community of the *Supernova Hunters* project to be limited to a smaller group of highly dedicated individuals who are willing and able to return to the project upon data release.

There are a number of advantages to cultivating a community of dedicated and experienced volunteers who consistently return to a project upon data release, as this would enable quicker, and potentially more accurate, data processing. However, doing so may generate unexpected effects - our analyses indicate that this may be associated with a less diverse community of volunteers. We found the *Supernova Hunters* community to be demographically biased towards men of retirement age. It is possible that individuals who are unable to offer a regular, weekly time-commitment during the working day have been excluded from contributing to this project. Additionally, the increased competition to classify or higher science capital perceived to be required to contribute may make this project more appealing to older males, or, conversely, less appealing to other demographics. As shall be discussed, the impact of group diversity on project success remains to be fully delineated, particularly in online environments such as the Zooniverse where, although the majority of contributions are made independently and individually, there remains significant opportunity for group interaction and discovery through online fora [Boyajian et al., 2016]. Group diversity is commonly defined as differences in attributes between individuals resulting in the perception that others are different from oneself [Van Knippenberg et al., 2004]. Although positive, negative or no relationships have been found between a group's diversity and its performance, the literature is in agreement that there are two primary mechanisms through which diversity can impact group performance; the 'informational' or 'decision-making perspective', or the 'social categorization perspective' [Chen et al., 2010; Van Knippenberg et al., 2004; Van Knippenberg and Schippers, 2007; Williams and O'Reilly III, 1998].

As increased project participation has been found to develop the scientific knowledge of volunteers [Masters et al., 2016], cultivating the selection of a highly dedicated small community of volunteers through gamification may benefit a more challenging project that requires a higher level of skill, such as Foldit [Cooper et al., 2010]. Although we do not examine the impact of sustained volunteer engagement on data quality in the *Supernova Hunters* project in the analyses presented here, this represents an interesting direction for future research. Further, sustained engagement may result in changed modes of volunteer participation over time, generating higher proportion of more experienced volunteers able to contribute to important community functions such as helping to onboard newcomers, answering questions and moderating discussions [Jackson et al., 2015; Mugar et al., 2014; Østerlund et al., 2014].

However, as we have seen here, cultivating a small, highly dedicated volunteer community can be associated with less diversity. As described in the social categorization perspective of the impact of group diversity on performance, smaller and more homogenous groups may outperform heterogeneous groups because people categorize themselves and others into social groups based on differences in social attributes, and as a result have a more positive experience when working with others they consider similar [Chen et al., 2010]. Therefore, a more homogenous community has the potential to positively benefit a project. However, there are circumstances when a less-diverse community may have a negative impact on project success. For example, a cross-section of volunteers representative of the broader population may be essential for the validity of results in a health-related data collection project. Further, as stated in the 'informational' or 'decision-making perspective' of the impact of diversity on group performance, heterogeneous groups can outperform homogenous groups due to their broader range of skills, knowledge and opinions. Beyond research objectives, lack of group diversity may also curtail the potential of a citizen science project to achieve other aims, such as fostering scientific education within typically underserved communities. However, the effect of group diversity on the success of a citizen science project will be influenced by many factors, including the type and complexity of the task involved, task interdependency and the group type and size [Horwitz and Horwitz, 2007; Van Knippenberg and Schippers, 2007]. Further, the importance of these variables will have differing importance dependent on whether a project is online or offline [Martins et al., 2004].

It should also be considered whether 'designing for exclusivity' is acceptable to the broader ethos of citizen science, and human-computer interaction more generally. Frequently citizen science projects have the twin goals of contributing to both scientific productivity as well as 'social good', e.g. encouraging learning about and participation in science [Woodcock et al., 2017]. Those designing and implementing online citizen science projects should also consider whether it is acceptable to the practice of citizen science to cultivate scenarios that intentionally restrict the opportunity of the full volunteer community to access a project, or whether they should be implementing inclusive design approaches and 'designing for all'. Beyond the goal of encouraging diversity, researchers should consider the extent to which they can and should facilitate the accessibility of their project to underserved online communities, which may include people with low ICT skills, the elderly or individuals with reading difficulties, through the implementation of relevant inclusive design approaches such as universal usability

[Shneiderman, 2000; Vanderheiden, 2000], user-sensitive inclusive design [Newell, 2011], designing for accessibility [Keates, 2006] and ability-based design [Wobbrock et al., 2011], and these factors should be examined closely in future work.

When considering the consequences of implementing design changes modelled on the observations made here, project owners must be cognisant of the dual aims of citizen science; to perform authentic research in the most efficient manner possible (scientific efficiency) and to allow a broad community to engage with real research (social inclusivity). The relationship between these two aims, social inclusivity and scientific efficiency, is nuanced. There may be instances where a project is more scientifically efficient if it is more exclusive, therefore, the scientific efficiency of a citizen science project may occasionally directly conflict with the aim of social inclusivity. Although designing projects for efficiency via exclusivity is not ideal, it is not clear whether the alternative, of reducing scientific efficiency in the name of inclusivity, is preferable. For example, in the *Supernova Hunters* project, social inclusivity may have been enhanced through providing greater opportunity to classify through increasing the number of classifications required to more than necessary for each image. However, this would not only represent a wasteful application of volunteer time and enthusiasm, but may undermine one of the most commons motivations of volunteers – to make an authentic contribution [Raddick et al., 2010].

In conclusion, we present here quantitative evidence demonstrating how subtle changes to online citizen science project design can influence many facets of the nature of volunteer interaction, including who participates, when and how much. Through analysing the most comprehensive collection of citizen science project data gathered to date, we observe sustained volunteer engagement emerging from the incremental release of small amounts of data in a single Zooniverse project, *Supernova Hunters*. However, this increased interaction was observed in conjunction with high levels of classification contribution inequality, and a demographically biased community of volunteers. This model of incremental data release has cultivated a scenario where a large number of classifications are provided by a small community of volunteers, contrary to the typical Zooniverse project in which a small number of classifications are provided by a large community. These observations illustrate the tension that can exist between designing a citizen science project for scientific efficiency versus designing for social inclusivity, that stems from the liminal nature of citizen science between research and public engagement.

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Tables

Table 1. Project characteristics

This table details multiple measurements associated with the 63 projects examined in this study, with all variables calculated for 100 days post-launch of each individual project. 'N_all_classifications' – total number of classifications; 'N_all_volunteers' – total number of unique, registered, volunteers; 'N_classifications_100_days' – number of classifications made within 100 days post-project launch; 'Classifications_not_logged_in' – number of classifications made by volunteers who weren't logged into the Zooniverse during 100 days post-project-launch; 'Classifications_registered_users' – number of classifications made to logged-in registered volunteers within 100 days post-project launch; 'N_unique_users" – number of unique volunteers who classified during 100 days post-project launch; 'Least_classifications_single_user' – least classifications made by a single registered volunteer during 100 days post-project launch; 'Most_classifications_single_user' – most classifications made by a single registered volunteer during 100 days post-project launch; 'Mean_classifications_per_user' – mean classifications made by registered volunteers during 100 days post-project launch; 'SD_classifications_per_user' – standard deviation of the classifications made by registered volunteers during 100 days post-project launch; 'Mode_classifications' – mode classifications made by registered volunteers during 100 days post-project launch; 'Median_classifications' – median classifications made by registered volunteers during 100 days post-project launch.

Project_ name	**Domain**	**Launch_ date**	**Launch_ date_ +_100_ days**	**N_all_ classifi- cations**	**N_all_ volun- teers**	**N_ classifi- cations_ 100_days**	**Classifi- cations_ not_ logged_in**	**Classifi- cations_ registered_ users**	**N_ unique_ users**	**Least_ classifi- cations_ single_user**	**Most_ classifications_ single_user**	**Mean_ classifi- cations_ per_user**	**SD_classifi- cations_ per_user**	**Mode_ classifi- cations**	**Median_ classifi- cations**
Microplants	Ecology	30/06/2013	08/10/2013	42720	226	8577	1626	6951	17	2	4408	408.882353	1115.01939	2	6
Microscopy Masters	Biomedical	31/03/2016	09/07/2016	42070	2583	23404	9164	14240	1343	1	280	10.6031273	17.1262835	1	7
Orchid Observers	Ecology	23/04/2015	01/08/2015	53531	1769	23529	2712	20817	838	1	4012	24.8412888	175.466219	1	3
Planet Four: Craters	Astronomy	31/03/2015	09/07/2015	32957	702	23702	12889	10813	546	1	226	19.8040293	32.5124121	1	7
Arizona BatWatch	Ecology	19/10/2016	27/01/2017	25702	1433	24389	5560	18829	1322	1	2646	14.2428139	86.0015451	1	4
Season Spotter Image Marking	Ecology	21/07/2015	29/10/2015	78849	3762	25102	9346	15756	1199	1	388	13.1409508	23.6041927	1	6
Mapping Change	Ecology	20/09/2016	29/12/2016	26769	1500	25218	2570	22648	1375	1	2197	16.4712727	89.6967421	1	3
Shakespeare's World	Transcription	08/12/2015	17/03/2016	96670	2153	41931	19517	22414	1147	1	1872	19.5414124	81.5271065	1	4
Decoding the Civil War	Transcription	21/06/2016	29/09/2016	70763	3104	45096	12740	32356	2300	1	1265	14.0678261	57.0036568	1	3
AnnoTate	Transcription	01/09/2015	10/12/2015	126321	1443	47088	31475	15613	724	1	2145	21.5649171	94.7890425	1	5
Wildebeest Watch	Ecology	30/06/2015	08/10/2015	109700	2846	50230	13378	36852	1399	1	2426	26.3416726	86.089079	2	9
Stardate M83	Astronomy	13/01/2014	23/04/2014	52258	1193	52246	12693	39553	1193	1	5200	33.154233	209.926085	1	7
Poppin' Galaxy	Astronomy	23/03/2016	01/07/2016	111102	2601	54337	11590	42747	1255	1	3561	34.0613546	142.486409	1	9

Pattern Perception	Other	23/05/2016	31/08/2016	80187	2409	63246	17755	45491	1726	1	2661	26.3563152	102.757725	1	7
Notes from Nature Launch 2016	Transcription	16/06/2016	24/09/2016	145534	2333	63640	5100	58540	1280	1	5733	45.734375	275.474369	1	5
Season Spotter Questions	Ecology	21/07/2015	29/10/2015	193992	4988	73247	25098	48149	2062	1	1372	23.3506305	61.9102569	1	10
Whales as Individuals	Ecology	30/06/2015	08/10/2015	271610	6902	95971	14804	81167	1861	1	4799	43.6147233	196.176428	1	11
Computer Vision: Serengeti	Ecology	10/05/2016	18/08/2016	114647	3145	100248	17628	82620	2425	1	8394	34.0701031	200.708284	1	10
Understanding Animal Faces	Other	21/07/2016	29/10/2016	136636	2290	110051	30627	79424	1999	1	3806	39.7318659	133.916421	1	11
Galaxy Zoo: Bar Lengths	Astronomy	30/06/2015	08/10/2015	319528	5307	118236	17244	100992	1972	1	8642	51.2129817	302.231117	1	11
Radio Meteor Zoo	Astronomy	12/08/2016	20/11/2016	159700	3194	122688	21010	101678	2769	1	4358	36.7201156	178.498579	1	8
Worm Watch Lab	Biomedical	03/07/2013	11/10/2013	711111	13348	123236	34163	89073	4177	1	2901	21.3246349	75.8444223	2	8
Cyclone Center	Other	27/09/2012	05/01/2013	645686	13758	135832	36188	99644	3016	1	9987	33.0384615	215.729955	6	9
Comet Hunters	Astronomy	16/12/2015	25/03/2016	760203	7157	138741	7020	131721	1458	1	7062	90.3436214	403.741767	1	14
Jungle Rhythms	Ecology	13/12/2015	22/03/2016	280240	2871	141972	16629	125343	1278	1	15311	98.0774648	699.461606	1	12
Bat Detective	Ecology	02/10/2012	10/01/2013	587871	5501	174490	31600	142890	1183	1	20036	120.786137	843.983672	1	10
Planet Four: Terrains	Astronomy	30/06/2015	08/10/2015	905464	10097	186343	44796	141547	2481	1	8636	57.0523982	324.907669	1	15
Snapshots at Sea	Ecology	22/12/2015	31/03/2016	964128	4575	193842	24230	169612	1174	1	21685	144.473595	949.192234	4	24
Condor Watch	Ecology	15/04/2014	24/07/2014	484759	5796	210787	66617	144170	3100	1	5746	46.5064516	217.480695	1	11
Science Gossip	Transcription	04/03/2015	12/06/2015	538470	7850	216012	39981	176031	4321	1	11394	40.7384865	216.152588	1	14
Notes from Nature Launch 2013	Transcription	23/04/2013	01/08/2013	1011392	9133	229983	78105	151878	3354	1	4802	45.2826476	206.476886	1	7
Western Shield - Camera Watch	Ecology	07/04/2016	16/07/2016	472255	3367	237321	24070	213251	1718	1	10178	124.127474	551.604443	1	16
Chicago Wildlife Watch Launch 2014	Ecology	11/09/2014	20/12/2014	2994189	8286	267644	70386	197258	805	1	20187	245.040994	999.527494	3	32
Chicago Wildlife Watch Launch 2016	Ecology	26/10/2016	03/02/2017	320955	2121	299342	42174	257168	1887	1	7163	136.284049	374.735564	1	34
Operation War Diary	Transcription	14/01/2014	24/04/2014	795960	14836	316246	43873	272373	8523	1	6472	31.9574094	159.743558	1	5
Sunspotter	Astronomy	27/02/2014	07/06/2014	5604299	8578	324311	81516	242795	548	1	34510	443.056569	2019.75124	5	92

Plankton Portal	Ecology	17/09/2013	26/12/2013	1378040	11607	341568	75560	266008	3331	1	51345	79.8583008	1211.46367	1	8
Fossil Finder	Other	15/08/2015	23/11/2015	681833	6499	383920	88358	295562	2730	1	38717	108.264469	934.9718	1	7
Snapshot Wisconsin	Ecology	17/05/2016	25/08/2016	730164	3489	397765	83724	314041	2566	1	8381	122.385425	374.365367	1	26
Wisconsin Wildlife Watch	Ecology	08/01/2016	17/04/2016	751528	3641	561024	53264	507760	2572	1	29181	197.418352	828.169459	1	37
Cell Slider	Biomedical	24/10/2012	01/02/2013	2757067	25688	565328	284985	280343	5110	1	13051	54.8616438	328.833481	5	14
Milky Way Project Launch 2016	Astronomy	15/09/2016	24/12/2016	629595	2992	570611	36206	534405	2821	1	32577	189.438143	1494.35326	1	17
Radio Galaxy Zoo	Astronomy	17/12/2013	27/03/2014	1956630	12179	597090	166055	431035	4173	1	35564	103.291397	770.051029	1	13
Disk Detective	Astronomy	30/01/2014	10/05/2014	2222273	12122	616142	198983	417159	4600	1	32183	90.6867391	980.951206	1	11
Higgs Hunters	Other	26/11/2014	06/03/2015	1375450	10643	654836	96728	558108	5239	1	18013	106.52949	585.468487	1	18
Supernova Hunters	Astronomy	12/07/2016	20/10/2016	1121725	2866	716055	18500	697555	1689	1	103069	412.998816	3722.1181	1	17
Penguin Watch	Ecology	17/09/2014	26/12/2014	4660524	39145	824254	163634	660620	9117	1	10059	72.4602391	321.696003	1	16
Gravity Spy	Astronomy	12/10/2016	20/01/2017	1014226	4629	872439	83287	789152	3854	1	20160	204.761806	758.005063	10	40
Milky Way Project Launch 2013	Astronomy	12/12/2013	22/03/2014	2192295	22530	944727	204365	740362	9640	1	20459	76.8010373	449.245021	1	7
Floating Forests	Ecology	07/08/2014	15/11/2014	2782903	6818	1032143	320568	711575	2810	1	79229	253.229537	2211.83415	1	36
Chimp & See	Ecology	22/04/2015	31/07/2015	2815482	7438	1076635	392514	684121	3862	1	28539	177.141637	706.935971	1	32
Andromeda Project	Astronomy	05/12/2012	15/03/2013	1958717	11255	1078393	153592	924801	5302	1	11183	174.424934	550.617197	1	27
Planet Hunters Launch 2014	Astronomy	18/09/2014	27/12/2014	8829803	43264	1085355	124803	960552	6017	1	47715	159.639688	1068.50854	1	23
Seafloor Explorer	Ecology	13/09/2012	22/12/2012	2662916	25356	1159534	174013	985521	9147	1	10586	107.742539	373.868647	3	23
Asteroid Zoo	Astronomy	24/06/2014	02/10/2014	2664806	12322	1209318	375562	833756	5571	1	35678	149.660025	726.731708	1	23
Snapshot Supernova	Astronomy	19/03/2015	27/06/2015	2021281	4906	1461538	905348	556190	3871	1	44609	143.681219	882.991824	1	36
WildCam Gorongosa	Ecology	10/09/2015	19/12/2015	4085550	15663	1797998	610319	1187679	4657	1	26477	255.030921	1218.70167	1	30
Camera CATalogue	Ecology	04/08/2016	12/11/2016	2563684	5854	1855799	162096	1693703	4759	1	40619	355.894726	1321.27837	1	48
Pulsar Hunters	Astronomy	12/01/2016	21/04/2016	3210326	10643	3049023	323717	2725306	10272	1	9318	265.314058	492.951307	1	100
Galaxy Zoo - CANDELS	Astronomy	11/09/2012	20/12/2012	25335564	153129	3699564	572620	3126944	21353	1	58637	146.4405	926.965247	1	22
Planet Four	Astronomy	08/01/2013	18/04/2013	5263065	59534	3742864	1116670	2626194	34936	1	37461	75.1715709	466.730007	2	17
Snapshot Serengeti	Ecology	11/12/2012	21/03/2013	22634263	50968	6402357	903166	5499191	18543	1	22378	296.564256	862.542229	1	58
Space Warps	Astronomy	08/05/2013	16/08/2013	18596661	30116	8011730	492064	7519666	9631	1	250190	780.777282	6271.03758	1	63

Table 2. Classifications during the first 100 days post-launch, by domain
Median, first and third quartile of number of classifications received by project subset by academic domain, for the first 100 days post-launch.

Domain	N projects	Median	First quartile	Third quartile
Astronomy	22	666099	150642	1178327
Ecology	26	224054	78928	758447
Biomedical	3	123236	73320	344282
Transcription	7	63640	46092	222998
Other	5	135832	110051	383920

Table 3. Unique volunteers during the first 100 days post-launch, by domain
Median, first and third quartile of number of unique registered volunteers by project subset by academic domain, for the first 100 days post-launch.

Domain	N projects	Median	First quartile	Third quartile
Astronomy	22	3863	1760	5906
Ecology	26	1975	1289	3273
Biomedical	3	4177	2760	4644
Transcription	7	2300	1214	3838
Other	5	2730	1999	3016

Table 4. Project gini coefficients
Volunteer classification contribution inequality was assessed by calculating Gini coefficients for each project.

Project_name	Domain	Gini
Microscopy Masters	Biomedical	0.54
Season Spotter Image Marking	Ecology	0.62
Season Spotter Questions	Ecology	0.65
Planet Four: Craters	Astronomy	0.65
Pulsar Hunters	Astronomy	0.68
Worm Watch Lab	Biomedical	0.68
Wildebeest Watch	Ecology	0.7
Science Gossip	Transcription	0.72
Understanding Animal Faces	Other	0.75
Computer Vision: Serengeti	Ecology	0.75
Pattern Perception	Other	0.75
Arizona BatWatch	Ecology	0.75
Chicago Wildlife Watch Launch 2016	Ecology	0.75
Cyclone Center	Other	0.76
Poppin' Galaxy	Astronomy	0.76

Whales as Individuals	Ecology	0.77
Snapshot Supernova	Astronomy	0.77
AnnoTate	Transcription	0.77
Snapshot Wisconsin	Ecology	0.78
Radio Meteor Zoo	Astronomy	0.78
Snapshot Serengeti	Ecology	0.78
Condor Watch	Ecology	0.78
Planet Four: Terrains	Astronomy	0.78
Seafloor Explorer	Ecology	0.78
Planet Four	Astronomy	0.79
Cell Slider	Biomedical	0.79
Gravity Spy	Astronomy	0.79
Penguin Watch	Ecology	0.79
Decoding the Civil War	Transcription	0.8
Galaxy Zoo: Bar Lengths	Astronomy	0.8
Stardate M83	Astronomy	0.8
Chimp & See	Ecology	0.8
Shakespeare's World	Transcription	0.8
Wisconsin Wildlife Watch	Ecology	0.81
Andromeda Project	Astronomy	0.81
Asteroid Zoo	Astronomy	0.82
Sunspotter	Astronomy	0.82
Notes from Nature Launch 2013	Transcription	0.83
Higgs Hunters	Other	0.83
Camera CATalogue	Ecology	0.83
Mapping Change	Ecology	0.83
Snapshots at Sea	Ecology	0.84
Operation War Diary	Transcription	0.84
Galaxy Zoo - CANDELS	Astronomy	0.84
Western Shield - Camera Watch	Ecology	0.84
Chicago Wildlife Watch Launch 2014	Ecology	0.84
Comet Hunters	Astronomy	0.84
Planet Hunters Launch 2014	Astronomy	0.86
Floating Forests	Ecology	0.86
Radio Galaxy Zoo	Astronomy	0.86
WildCam Gorongosa	Ecology	0.86
Orchid Observers	Ecology	0.86
Milky Way Project Launch 2013	Astronomy	0.87
Microplants	Ecology	0.87
Notes from Nature Launch 2016	Transcription	0.88

Jungle Rhythms	Ecology	0.88
Disk Detective	Astronomy	0.89
Plankton Portal	Ecology	0.89
Bat Detective	Ecology	0.89
Milky Way Project Launch 2016	Astronomy	0.9
Space Warps	Astronomy	0.9
Fossil Finder	Other	0.91
Supernova Hunters	Astronomy	0.94

Table 5. Page views by age group for ecology compared to astronomy projects

Average page views for ecology compared to astronomy projects, subset by the demographic feature of age. Data were extracted from GA (see **Methods**).

Age range (years)	Ecology page views	%	Astronomy page views	%	Odds ratio	Lower 95% CI	Upper 95% CI	p value
18-24	1242	13.11	2215	22.15	1.89	1.75	2.04	8.86E-62
25-34	1971	20.82	1677	16.78	0.77	0.71	0.82	5.67E-13
35-44	1504	15.89	1566	15.66	0.98	0.91	1.06	6.80E-01
45-54	1160	12.25	1096	10.96	0.88	0.81	0.96	5.11E-03
55-64	2826	29.85	1418	14.18	0.39	0.36	0.42	4.77E-156
65+	765	8.08	2025	20.26	2.89	2.64	3.16	4.16E-134

Table 6. Page views by sex for ecology compared to astronomy projects

Average page views for ecology compared to astronomy projects, subset by the demographic feature of Sex. Data were extracted from GA (see **Methods**).

Sex	Ecology project views	%	Astronomy project views	%	Odds ratio	Lower 95% CI	Upper 95% CI	p value
Male	4469	43.93	8127	75.45	3.92	3.7	4.16	0
Female	5703	56.07	2644	24.55	0.25	0.24	0.27	0

Figures

Figure 1. Accumulation of projects on the Zooniverse
The launch of the n = 63 projects included in this study are indicated by vertical lines. The line colour indicates the project domain (Ecology = green, Astronomy = blue, Transcription = yellow, Other = Grey, Biomedical = red). The black line shows the cumulative number of projects launched on the Zooniverse platform.

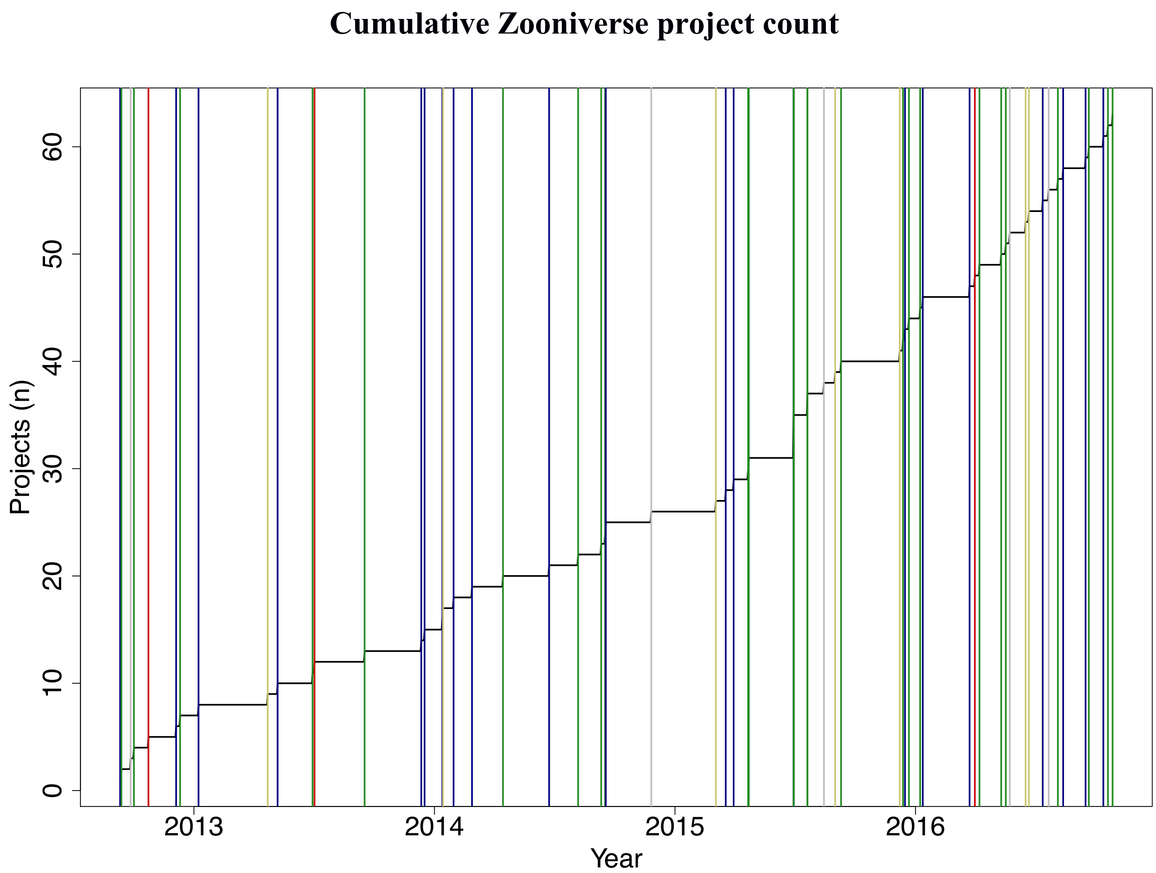


Figure 2. The Zooniverse platform supports a similar number of ecology and astronomy projects

Of the n = 63 projects included in this study; Ecology n = 26, Astronomy n = 22, Transcription n = 7, Other = 5, Biomedical = 3.

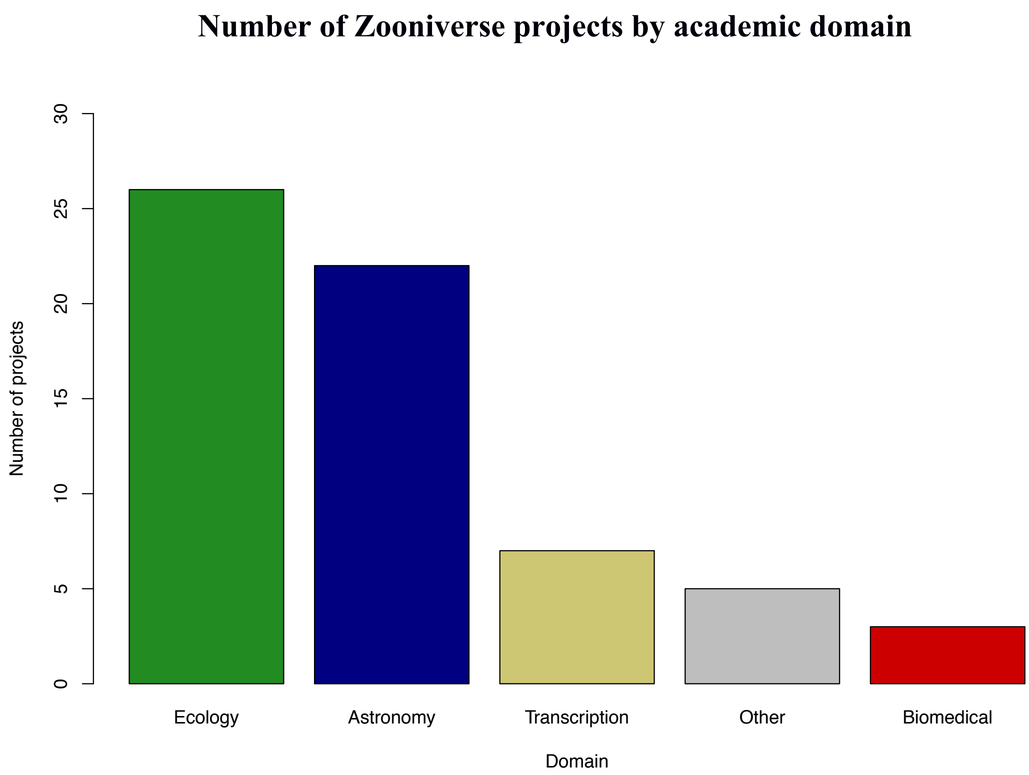
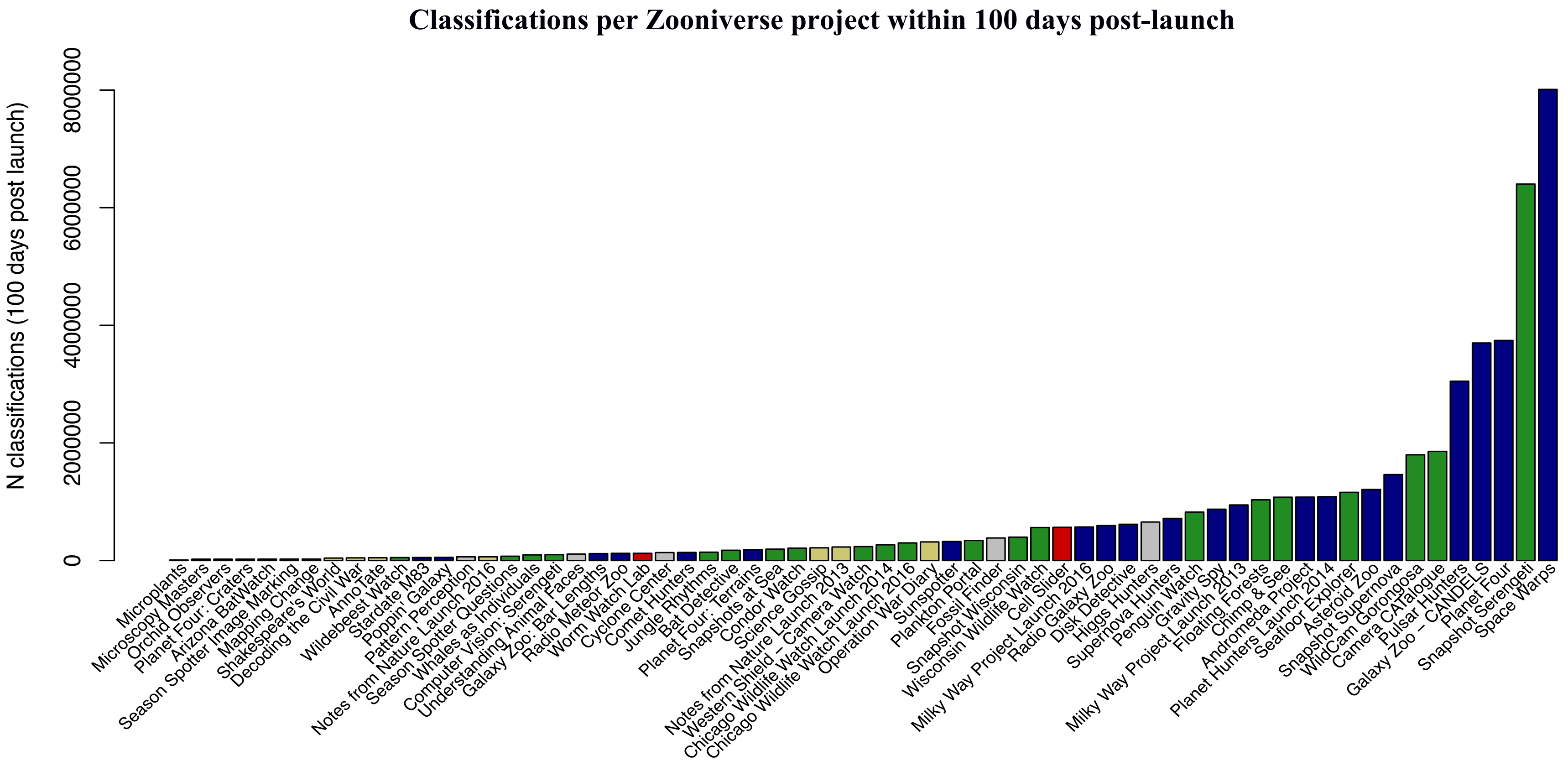
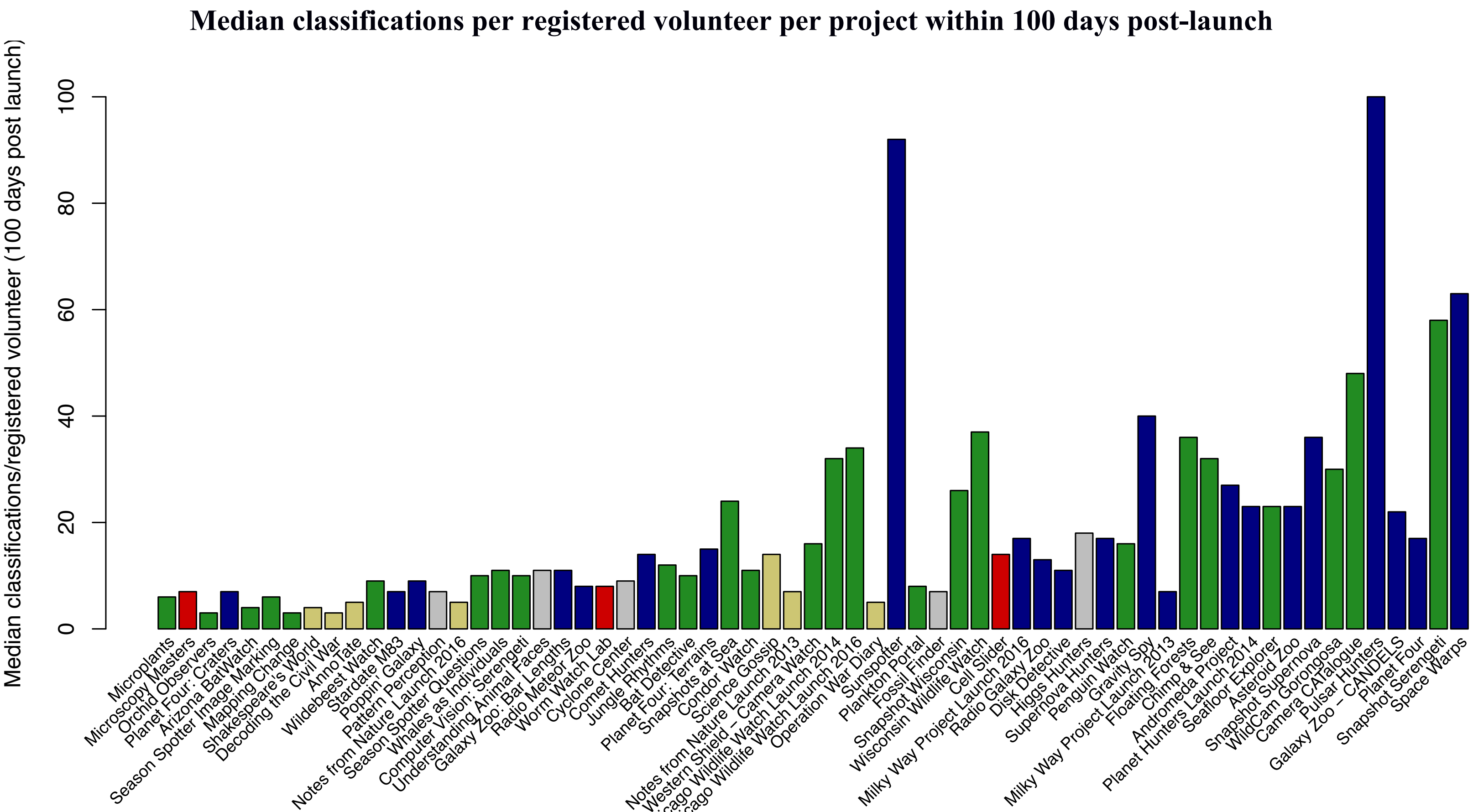


Figure 3. Project classification and volunteer activity is highly variable
Heterogeneity is observed among Zooniverse projects during the first 100 days post-launch for a) the total number of classifications received, b) the median number of classifications per volunteer and c) the number of unique volunteers contributing. Colours indicate domain; Ecology = green, Astronomy = blue, Transcription = yellow, Other = Grey, Biomedical = red.

a)

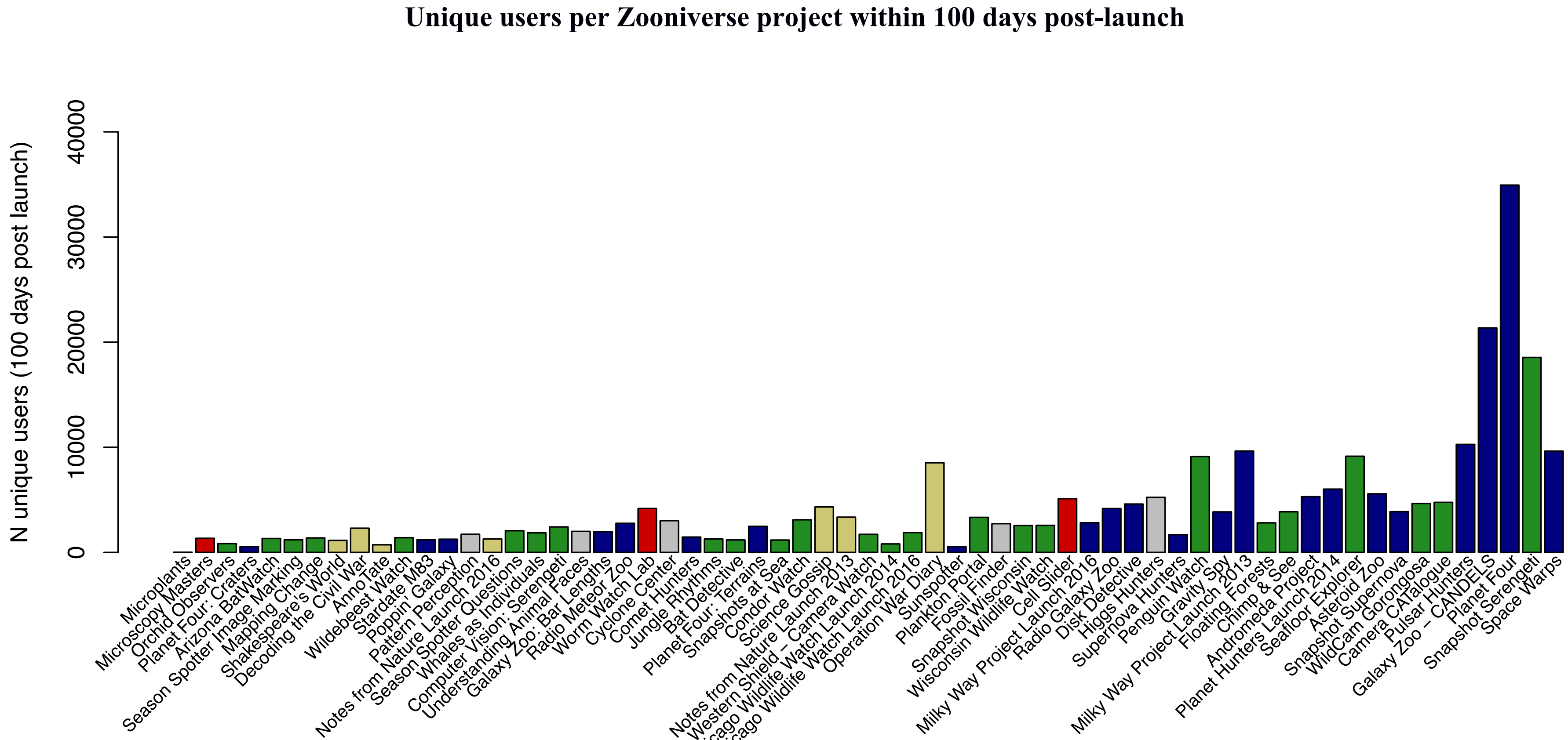


b)



Median classifications per registered volunteer per project within 100 days post-launch
Median classifications/registered volunteer (100 days post launch)
0
20
40
60
80
100
Microplants
Microscopy Masters
Orchid Observers
Planet Four: Craters
Arizona BatWatch
Season Spotter Image Marking
Mapping Change
Shakespeare's World
Decoding the Civil War
AnnoTate
Wildebeest Watch
Stardate M83
Poppin' Galaxy
Pattern Perception
Notes from Nature Launch 2016
Season Spotter Questions
Whales as Individuals
Computer Vision: Serengeti
Understanding Animal Faces
Galaxy Zoo: Bar Lengths
Radio Meteor Zoo
Worm Watch Lab
Cyclone Center
Comet Hunters
Jungle Rhythms
Bat Detective
Planet Four: Terrains
Snapshots at Sea
Condor Watch
Science Gossip
Notes from Nature Launch 2013
Western Shield – Camera Watch
Chicago Wildlife Watch Launch 2014
Chicago Wildlife Watch Launch 2016
Operation War Diary
Sunspotter
Plankton Portal
Fossil Finder
Snapshot Wisconsin
Wisconsin Wildlife Watch
Cell Slider
Milky Way Project Launch 2016
Radio Galaxy Zoo
Disk Detective
Higgs Hunters
Supernova Hunters
Penguin Watch
Gravity Spy
Milky Way Project Launch 2013
Floating Forests
Chimp & See
Andromeda Project
Planet Hunters Launch 2014
Seafloor Explorer
Asteroid Zoo
Snapshot Supernova
WildCam Gorongosa
Camera CATalogue
Pulsar Hunters
Galaxy Zoo – CANDELS
Planet Four
Snapshot Serengeti
Space Warps

c)


Unique users per Zooniverse project within 100 days post-launch
N unique users (100 days post launch)
0
10000
20000
30000
40000
Microplants
Microscopy Masters
Orchid Observers
Planet Four: Craters
Arizona BatWatch
Season Spotter Image Marking
Mapping Change
Shakespeare's World
Decoding the Civil War
AnnoTate
Wildebeest Watch
Stardate M83
Poppin' Galaxy
Pattern Perception
Notes from Nature Launch 2016
Season Spotter Questions
Whales as Individuals
Computer Vision: Serengeti
Understanding Animal Faces
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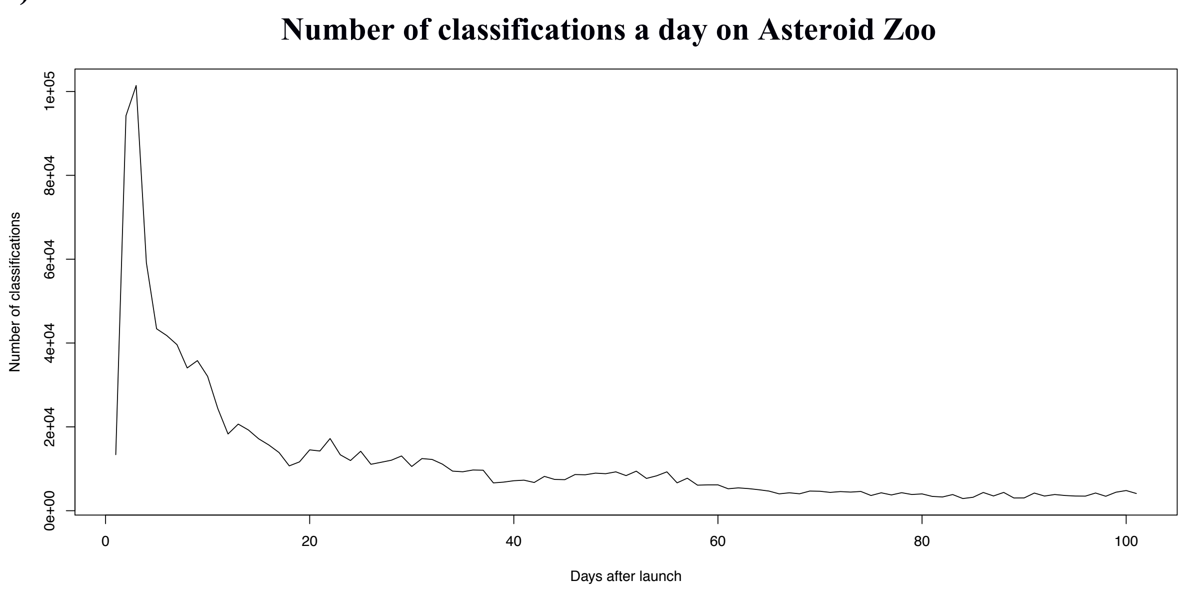
Worm Watch Lab
Cyclone Center
Comet Hunters
Jungle Rhythms
Bat Detective
Planet Four: Terrains
Snapshots at Sea
Condor Watch
Science Gossip
Notes from Nature Launch 2013
Western Shield – Camera Watch
Chicago Wildlife Watch Launch 2014
Chicago Wildlife Watch Launch 2016
Operation War Diary
Sunspotter
Plankton Portal
Fossil Finder
Snapshot Wisconsin
Wisconsin Wildlife Watch
Cell Slider
Milky Way Project Launch 2016
Radio Galaxy Zoo
Disk Detective
Higgs Hunters
Supernova Hunters
Penguin Watch
Gravity Spy
Milky Way Project Launch 2013
Floating Forests
Chimp & See
Andromeda Project
Planet Hunters Launch 2014
Seafloor Explorer
Asteroid Zoo
Snapshot Supernova
WildCam Gorongosa
Camera CATalogue
Pulsar Hunters
Galaxy Zoo – CANDELS
Planet Four
Snapshot Serengeti
Space Warps

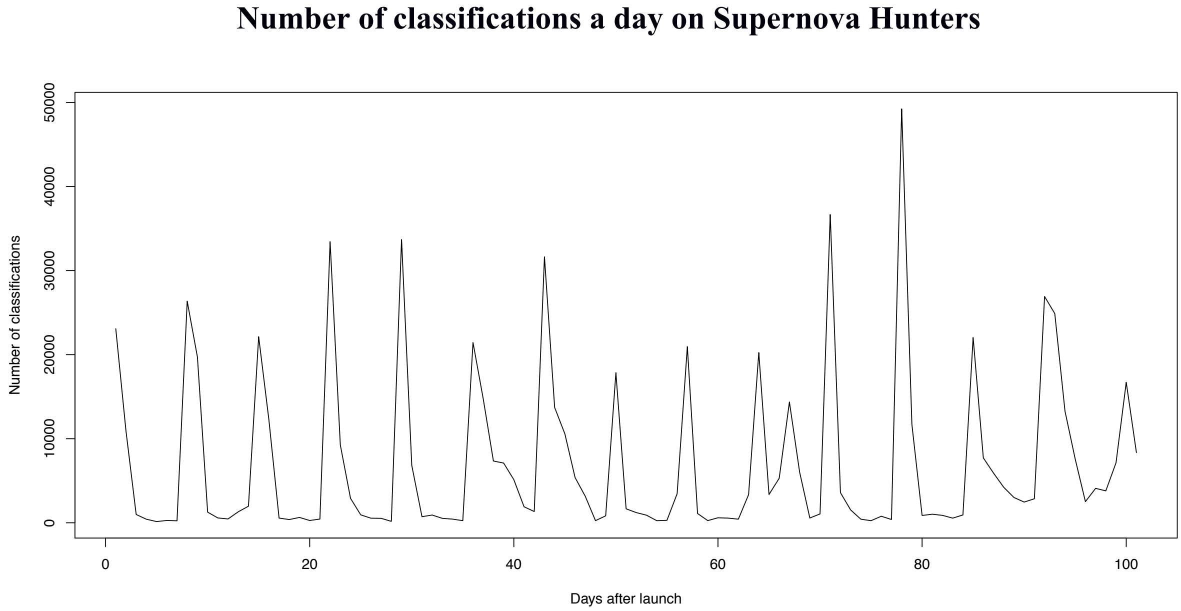
Figure 4. ***Supernova Hunter*s has a distinctive classification curve**

A typical Zooniverse project has a classification curve displaying a peak of activity after launch that rapidly declines a), however there are exceptions to this observation, the most striking of which is the classification curve of the *Supernova Hunters* project b). Volunteers return regularly to this project upon a weekly release of new project data.[1]

a)



b)



[1] This figure has been adapted from a poster presented at the World Wide Web Conference 2018 [Spiers et al., 2018]. Redistributed under the Creative Commons Attribution 4.0 International (CC BY 4.0) license. (https://creativecommons.org/licenses/by/4.0/).

Figure 5. Zooniverse projects show heterogeneity in the number of classifications received a day
Projects are ordered by median classifications a day for the first 100 days following launch.

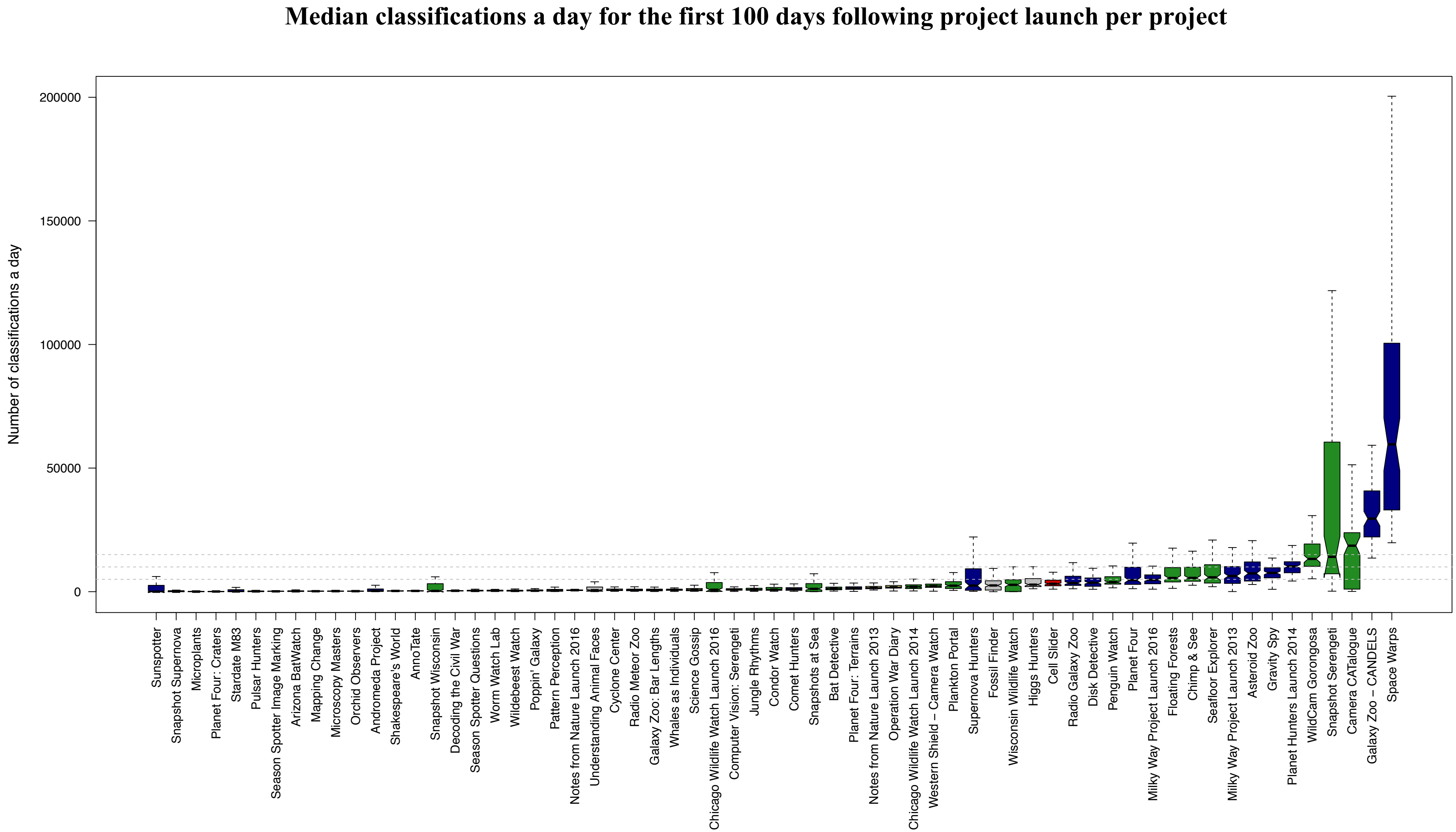
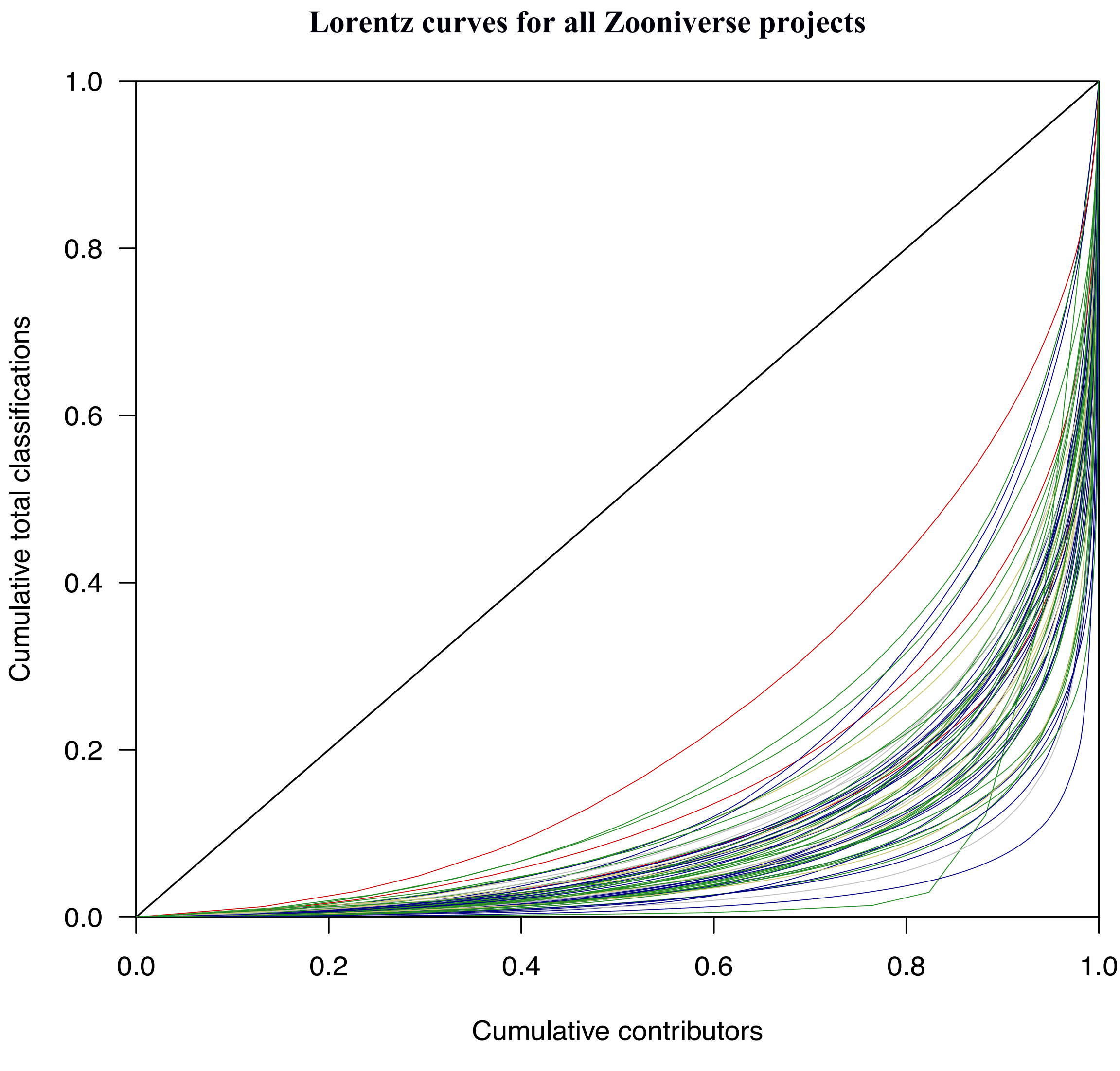


Figure 6. All Zooniverse projects display unequal volunteer classification contribution
a) Lorenz curves were plotted for all n = 63 projects to describe the inequality in number of classifications per registered volunteer, for the first 100 days post-launch. The plot shows the cumulative number of classifications versus the cumulative number of volunteers, with the increased curvature of the Lorenz curve indicating stronger inequality in volunteer contribution. The black 45º line corresponds to total equality, which in this case would represent all users contributing equal numbers of classifications. Although all projects displayed volunteer classification contribution inequality; a large amount of variation was observed between the project displaying the lowest degree of equality; Microscopy Masters (b, c), and the project displaying the highest; *Supernova Hunters* (d, e). Each plot is coloured by domain; Ecology = green, Astronomy = blue, Transcription = yellow, Other = Grey, Biomedical = Red.[1]

a)

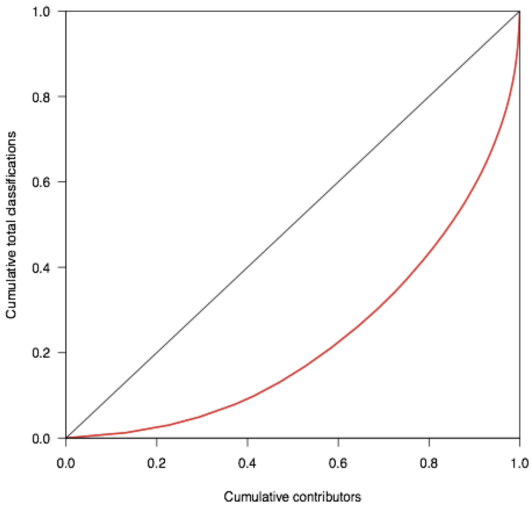


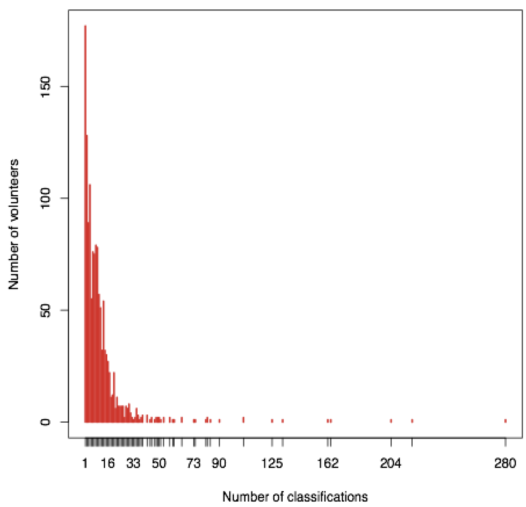
[1] This figure has been adapted from a poster presented at the World Wide Web Conference 2018 [Spiers et al., 2018]. Redistributed under the Creative Commons Attribution 4.0 International (CC BY 4.0) license. (https://creativecommons.org/licenses/by/4.0/).

b)

c)

Volunteer classification contributions in Microscopy Masters

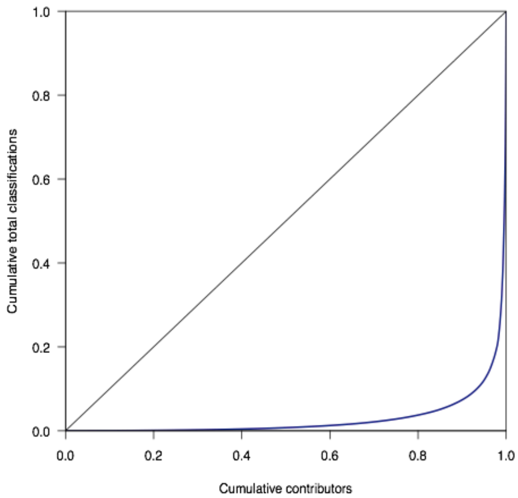




d)

e)

Volunteer classification contributions in Supernova Hunters



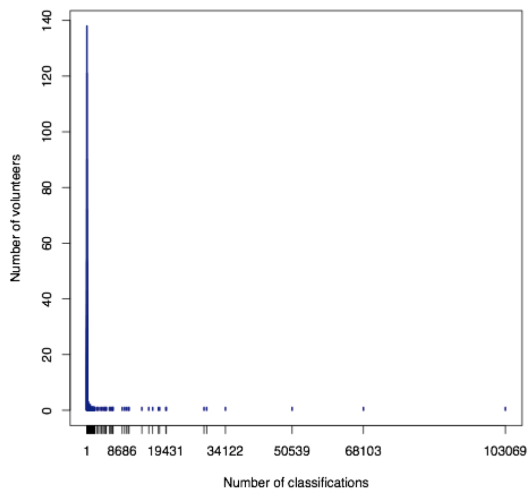
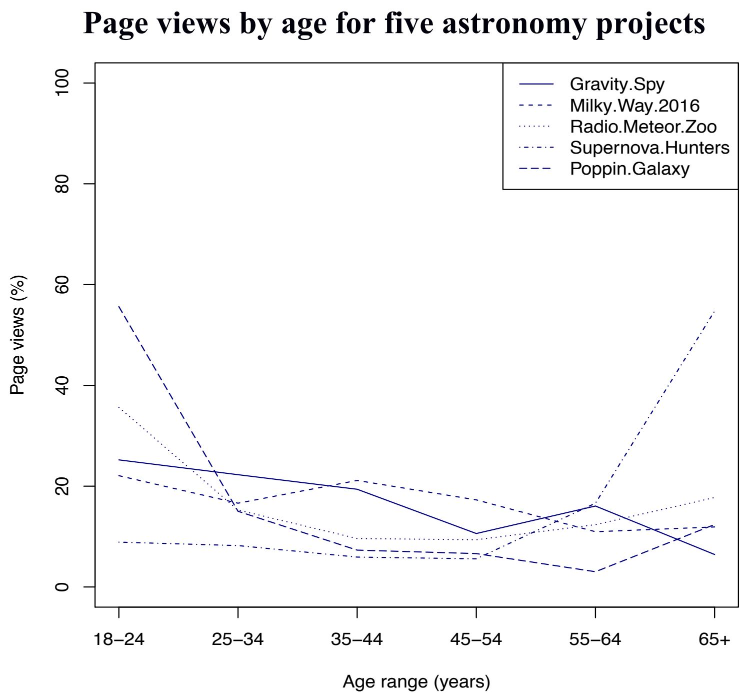
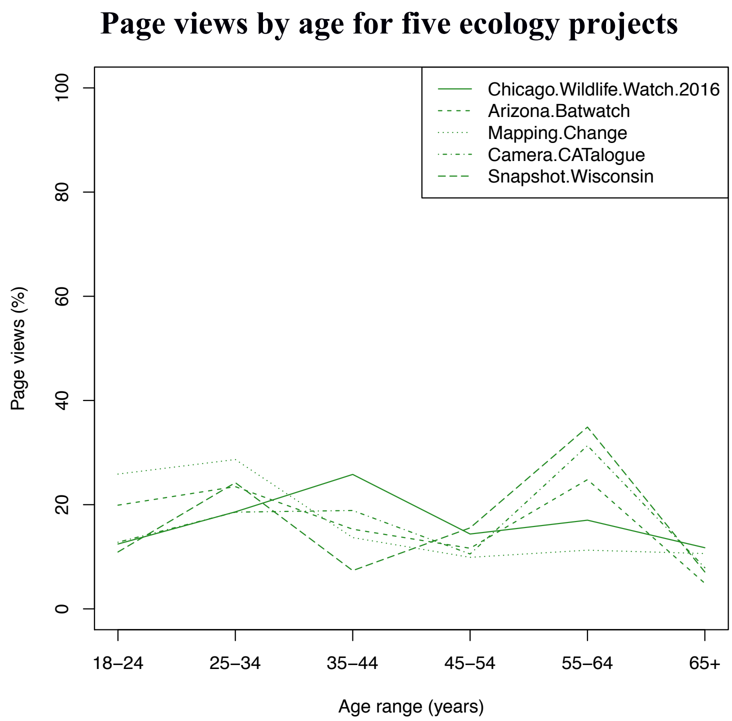


Figure 7. Domain-specific demographic features are observed for Zooniverse projects
Examining classification page views for astronomy and ecology projects, subset by age (a, b) and sex (c) revealed greater uniformity in page views by age group for ecology projects (b) compared to astronomy projects (a), and a clear male bias across astronomy projects (c).[1]

a)

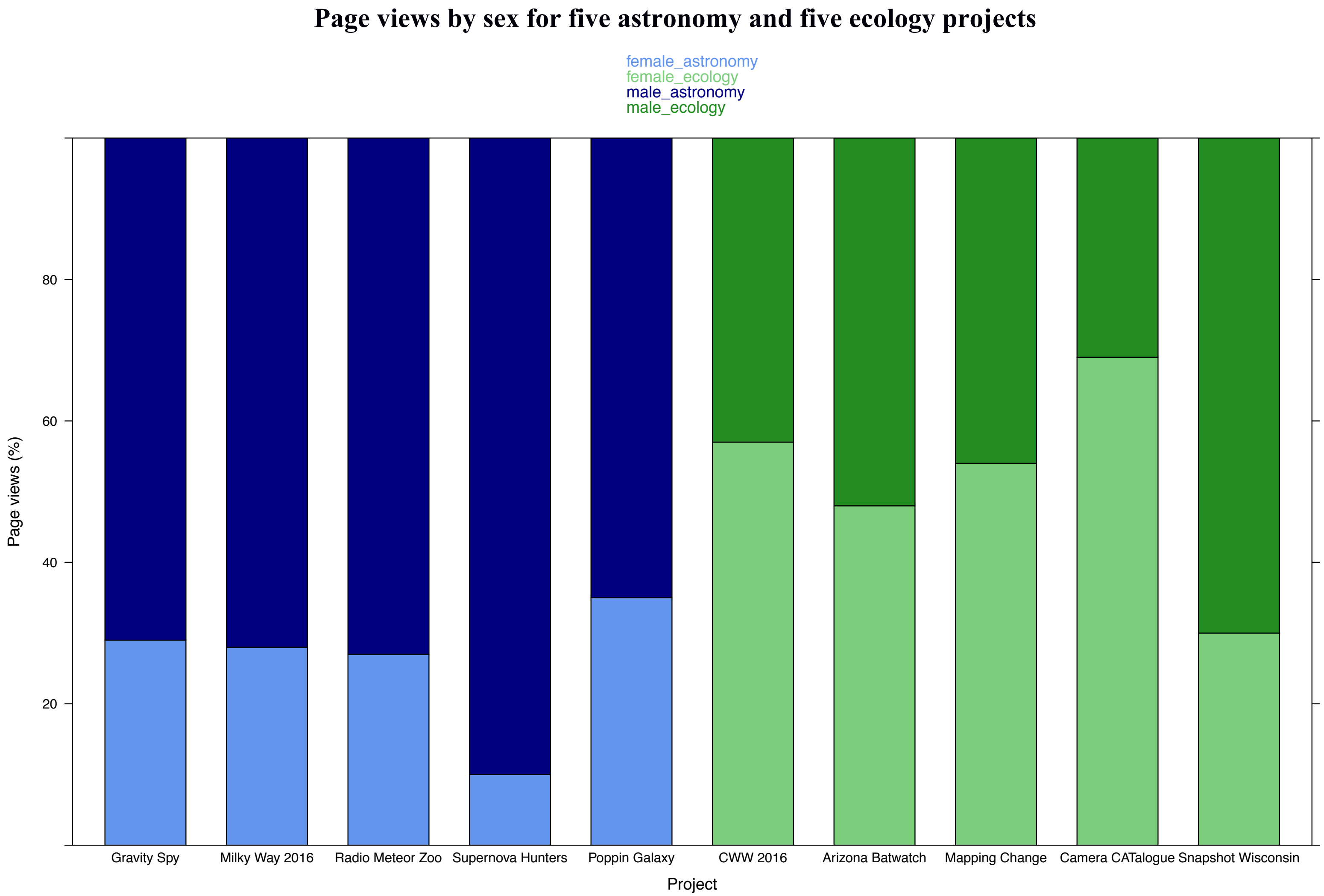


b)



[1] This figure has been adapted from a poster presented at the World Wide Web Conference 2018 [Spiers et al., 2018]. Redistributed under the Creative Commons Attribution 4.0 International (CC BY 4.0) license. (https://creativecommons.org/licenses/by/4.0/).

c)


Page views by sex for five astronomy and five ecology projects
female_astronomy
female_ecology
male_astronomy
male_ecology
Page views (%)
80
60
40
20
Gravity Spy
Milky Way 2016
Radio Meteor Zoo
Supernova Hunters
Poppin Galaxy
CWW 2016
Arizona Batwatch
Mapping Change
Camera CATalogue
Snapshot Wisconsin
Project