CITIZEN SCIENCE AS A SERVICE? A REVIEW OF MULTI-PROJECT CITIZEN SCIENCE PLATFORMS

Carolin Stein, Alicia Wittmer, Jonas Fegert and Christof Weinhardt
FZI Research Center for Information Technology, KIT Karlsruhe Institute of Technology Haid-und-Neu-Straße 10-14, 76131 Karlsruhe, Germany

ABSTRACT

The upswing of projects, conducting citizen science (CS) by means of ICT has resulted in the development of numerous digital participation platforms. Recently platformization as a trend away from individual project platforms towards the domination of larger platforms enabling the support of generic citizen science initiatives could be observed. Through their design and functionality these multi-project platforms thus influence the way research initiatives can be conducted in a participatory manner. By performing a structured artifact review of multi-project citizen science platforms on the market, we provide clarity towards the question, which multi-project platforms exist and how they support research projects. The review identified 16 platforms, that assist the conduction of generic citizen science projects. Demonstrating significant differences in functionality and features of the investigated platforms, the review underlines that the choice of multi-project CS platform presents a key decision for project initiators.

KEYWORDS

Citizen Science, Platform Design, Artifact Review

1. INTRODUCTION

Citizen Science (CS), as the involvement of non-professionals in scientific research, is receiving more attention in academia as well as in media. It is considered to be a means to empower citizens to contribute meaningfully to research and thereby democratize scientific processes (De Albuquerque and Almeida, 2020). The academic discourse, recognizes its ability to generate unique insights and powering up research workforce (Shirk and Bonney, 2018), while presenting a source of learning opportunities to the public (Jennett et al., 2016; Sturm et al., 2018). Citizens have contributed to scientific achievements in a variety of disciplines, such as collecting and sharing geophysical data for earth observation research, or engaging in collective problem-solving and symptom or treatment surveillance in biomedicine (Shirk and Bonney, 2018). Especially in ecological research, it is only through the help of amateur scientists, that researchers have become access to large scale datasets, impossible to collect with traditional methods (Miller-Rushing and Bonney, 2012). This however shows, that the umbrella term, describes a broad range of different initiatives, ranging from crowdsourcing to collegial work with citizens (Shirk et al., 2012; Haklay, 2013). The variety makes it difficult for practitioners and policy makers to navigate the domain (Haklay et al., 2021) and complicates broad claims for learning and transformative effects (De Albuquerque and Almeida, 2020; Bela et al., 2016). The emerging of online or digital CS describing the involvement of citizens by means of ICT (Reed et al., 2012; Weinhardt et al., 2020), additional enriches the variety. While the call for digital support is high (Liu et al., 2021), the heterogeneity of CS initiatives complicates interoperability (Göbel et al., 2017; Liu et al., 2021). At the same time, CS initiatives have limited resources preventing them from developing important functionalities (Wald et al., 2016). As a result, a shift from individual to generic infrastructure can be observed (Baudry et al., 2022). A series of CS platforms with varying focus and functionalities emerged to serve different types of CS projects (Liu et al., 2021). While some platforms are only built for specific projects, others evolve into integrated platforms providing a rich set of functions for generic projects (Liu et al., 2021). These multi-project platforms influence the way digital CS projects are designed and conducted

(Baudry et al., 2022; Liu et al., 2021) what in turn determines project outcomes such as the democratic and transformative impact or learning (Sturm et al., 2018; Bela et al., 2016; De Albuquerque and Almeida, 2020). Navigating the large amount of digital platforms determining whether there is an appropriate solution for their project is a challenge to practitioners (Brenton et al., 2018). Likewise, for citizens the intransparent diversity of platforms can lead to confusion and create an image of competition (Brenton et al., 2018). While, some authors made efforts, to compare or categorize CS platforms (Liu et al., 2021; Wald et al., 2016; Luna et al., 2018; Skarlatidou et al., 2019; Yadav and Darlington, 2016), a structured review of their focus, functionalities and characteristics is yet missing. This however, is indispensable to help practitioners leverage the potential of the digital offer and for the research community to identify structural gaps. We thus turn towards the research question: *What multi-project CS platforms exist and how do they support the conduction of CS projects?*

To answer our research question, we conduct a structured artifact review, identifying 75 CS platforms, out of which 16 platforms qualify as multi-project platforms that allow to conduct generic CS projects. To provide guidance we review the 16 platforms, according to seven platform dimensions. As such, the review enables scientists, practitioners and citizens to understand and compare CS platforms based on key characteristics. Thereby, they can either find suitable platforms to support their needs or identify research gaps that are yet to fill.

2. THEORETICAL FOUNDATION

CS describes an umbrella term for civic engagement in research that is yet lacking a uniform definition (Haklay et al., 2021). The Socientize project characterizes CS as "the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources" (Socientize, 2014). Originally, CS has been used especially in natural science, which is an important use case to date (Levy and Germonprez, 2017; Pettibone et al., 2017; Miller-Rushing et al., 2012). Nowadays however, it is a useful means to conduct research in various research domains (Pettibone et al., 2017). With the expansion of CS into a variety of fields of application, the heterogeneity of approaches has increased (Spasiano et al., 2021). Depending on the context, CS can be defined from a political, societal or scientific point of view (Haklay et al., 2021). At the heart of all classifications however, is the idea to define the extent and implementation of civic involvement in science (Haklay et al., 2021). The potential involvement can cover different parts of the research process from the creation of the research question and hypotheses, through data collection, to analysis and publication (Shirk et al., 2012). CS platforms, describe web-based infrastructures that are used to support CS initiatives (Liu et al., 2021). As for the term CS itself, CS platforms can comprise a variety of infrastructures that either present CS activities, display project information, provide support material and guidelines or best practices, offer tools, or a combination of the aforementioned (Liu et al., 2021). Different classifications for CS platforms differentiate for instance whether they are commercial or non-profit, domain specific or independent, national or international, or if their focus is on a single project (Brenton et al., 2018; Liu et al., 2021). Additionally, there are platforms for specific functions such as project finders, transcription or education tools (Brenton et al., 2018). Within the platform landscape, a platformization can be observed, describing a shift from individual projects to multi-project platforms (Baudry et al., 2022). These platforms enable the setup of new projects with their distinct goals, sharing a common infrastructure (Baudry et al., 2022). They thus standardize functions, as well as aspects such as community management (Baudry et al., 2022), which makes the choice of platform relevant to initiators. The suitability of the CS platform depends on the project's characteristics and should include several considerations. Brenton et al. (2018) for example highlights, data standards and the connection to open data portals, support features, options for customization and the organization and maintenance of the infrastructure as important platform features. Baudry et al. (2022) adds to this the dimensions of data representation and community management. To get guidance on the aspects that need to be considered when choosing a platform, one can also turn towards the rich literature on best practices for developing CS infrastructure. Several recurring motifs can be identified, that are summarized in Table 1.

Table 1. Key design dimensions identified in the digital CS literature

Dimension	Design Concept	Source
Platform aesthetics (PA)	Reduced information on the platform	(Jennett, 2014; Skarlatidou et al., 2019)
	Standardized naming and navigation	(Sturm et al., 2018; Skarlatidou et al., 2019)
Community organization (CO)	Enable communication between participants	(Sturm et al., 2018; Newman et al., 2010; Skarlatidou et al., 2019; Wald, Longo, and Dobell, 2016)
	Enable communication between participants and researchers	(Yadav and Darlington, 2016; Sturm et al., 2018; Newman et al., 2010; Skarlatidou et al., 2019).
	Validate the credibility of users	(Musto and Dahanayake, 2021; Newman et al., 2010)
Data standards (DS)	Enable secure handling of private data	(Yadav and Darlington, 2016; Sturm et al., 2018; Musto and Dahanayake, 2021)
	Validate user-generated data	(Skarlatidou et al., 2019; Musto and Dahanayake, 2021)
	Facilitate entering user-generated data	(Newman et al., 2010; Sturm et al., 2018; Skarlatidou et al., 2019)
	Enable data analysis and visualization	(Musto and Dahanayake, 2021; Newman et al., 2010; Skarlatidou et al., 2019; Wald, Longo, and Dobell, 2016)
Support information (SI)	Provide separate support pages	(Skarlatidou et al., 2019)
	Provide educational material	(Wald, Longo, and Dobell, 2016)
	Provide interactive tutorials and information	(Jennett, 2014; Skarlatidou et al., 2019)
Platforms usability (PS)	Provide simple and clear project main pages	(Skarlatidou, et al. 2019)
	Ease entry barriers	(Jennett, 2014; Sturm et al., 2018)
	Communicate project goals	(Jennett, 2014; Newman et al., 2010)
Platform utilization (PT)	Enable easy project creation	(Yadav and Darlington, 2016)
	Enable reusability of components	(Sturm et al., 2018; Yadav and Darlington, 2016)

3. A REVIEW OF CS PLATFORMS

3.1 Methodology

For the review of CS platforms, we follow the 7-step-methodology for reviewing software artifacts from practice by Gnewuch and Maedche (2022). The method aims at providing methodological guidance to the review of real-world artifacts in a systematic way, as it is a common practice for literature reviews (Gnewuch and Maedche, 2022). Starting with the problem formulation (1), the main objectives and conceptual boundaries for the review are defined. Based on these objectives potentially relevant artifacts are searched for (2) and based on predefined criteria screened for inclusion in the review (3). In a fourth step artifacts are assessed according to their practical quality (4) which can imply the development stage or user feedback. The first four steps of the methodology result in a list of artifacts, that are then used for data extraction (5) and documented and archived (6) for traceability. In a final step, collected data can be analyzed and synthesized (7) to present the findings of the artifact review. While step (1)-(6) has been conducted by one reviewer, for step (7) two independent reviewers have been engaged in coding the documentation. For data extraction and coding, we followed best-practices for structured-content analysis of web pages (Saraswat, 1999).

3.2 Implementation

We implement the review of CS platforms, to provide guidance in the CS platform landscape. Practitioners should be able to select an appropriate platform to conduct their CS initiative, based on necessary functionality and key characteristics. As such, the scope of our artifact review are multi-project CS platforms. This implies the platform must provide opportunities to create and host a new generic project (a) and provide

active participation opportunities for project implementation (b). Based on these two inclusion criteria, our review does not focus on single-project platforms or project overview platforms (Brenton et al. 2018). For the software artifact search, we utilize three search directions, to provide a sufficiently extensive sample: First of all, we utilize provided overviews in the CS platform literature to identify 43 software artifacts (Liu et al., 2021; Brenton et al., 2018; Luna et al., 2018; Yadav and Darlington, 2016; Aristeidou and Herodotou, 2020; Skarlatidou et al., 2019). Additionally, we conduct a search using the commercial database provider Crunchbase, that is focused on technology companies. Through the filter option 'Citizen Science' 14 new platforms could be identified. As a third search direction, we utilized two webpages of national CS information platforms for Austria and the EU, resulting in 18 additional platforms. Thus, our initial sample includes 75 CS platforms, that we screened for inclusion based on (a) and (b). As indicated by the literature, the sample includes different types of CS platforms: 32 platforms were project overview platforms, while five platforms qualified as community exchange hubs for educational material and workshops. Additionally, 12 platforms were single project platforms and six platforms included several projects, however did not allow for the creation of new generic initiatives. After the screening this leaves 20 platforms that were further assessed in the quality assessment. When assessing quality in terms of practical usability for the review, four platforms had to be excluded because they were either not available in either English or German or could not be reviewed free of charge. This was the case for platforms, that were fee-based and did not offer a demo nor linked freely accessible project examples. Thus, the final review comprised 16 platforms, which were archived in *Archive.Today* [1] and can be seen in Table 2. For data extraction purposes, CS platforms were assessed and documented in a concept matrix, according to their offered participatory functionality based on Shirk et al. (2012) and key design dimensions identified in the literature (see Table 1). The matrix served as baseline for data analysis through two independent coders.

Table 2. List of multi-project platforms for the review

	Platform Name	Weblink
A	Biocollect-Atlas of Living Australia	https://www.ala.org.au/biocollect
B	CS Center Zürich	https://citizenscience.ch
C	CitSci	https://citsci.org
D	conserve.Io*	http://conserve.io
E	CyberTracker	https://cybertracker.org
F	DataCertus	https://datacertus.com
G	Epicollect5	https://five.epicollect.net
H	Inaturalist	https://www.inaturalist.org
I	Ispot	https://www.ispotnature.org
J	Just One Giant Lab (JOGL)	https://jogl.io
K	nQuire	https://nquire.org.uk
L	Pybossa	https://pb.citizenscience.ch
M	SciStarter	https://scistarter.org
N	Spotteron	https://www.spotteron.net
O	World Community Grid	https://www.worldcommunitygrid.org
P	Zooniverse	https://www.zooniverse.org

* The review of this platform is based on two freely viewable projects and thus limited.

3.3 Results

The structured artifact review allowed us to characterize 16 multi-project platforms according to key characteristics identified in the literature. This comprised the platforms aesthetics, usability and utilization, as well as functionality in terms of participatory functions, community organization, support information and data standards (see Table 1). In the following, results are reported by dimension:

1) Participatory functions: Platforms provide varying flexibility to support participatory research steps. As such, the lowest degree of participation was found for platform O, were citizens can only contribute to research projects by computational power. On the other hand, many platforms, focus on data collection and analysis: Four platforms (D, E, H, I) provide functionality to upload and classify observations, while one

[1] https://archive.ph

platform (F) allows to upload data sets and use tools for data analysis. Other platforms extend the possibilities for data collection e.g. to surveys (B, G, P), digital diaries (B), or different type of media (B, G, L). The opportunities for participatory data analysis range from functionalities for transcriptions (B, L, P), mapping or classification of images (B, L, P) to pattern recognition in sound or video material (L). In this context, four data collection and analysis platforms (A, C, M, N) stood out through their flexibility, which would potentially allow their usage for other participatory activities. This comprised one platform (M) offering a range of third-party tool integrations, another platform (C) with customizable data sheets and possible integrations, a further platform (A) providing multiple individual applications e.g. for evaluation or learning games, and a platform (N) with functionalities that can be customized on demand. Next to platforms for data collection and analysis, one platform (J) in the sample supports the participatory assignment of tasks, although tasks themselves are not conducted on the platform. This platform enables initiators to structure the project into several project phases. Another platform (K) enables users to define research questions, design a methodological approach and collect data, however except for data collection, activities are not undertaken participatory.

2) Platform aesthetics: To evaluate the platforms' aesthetics, we reviewed whether platforms had a concept for reducing text and for standardizing naming and navigation conventions. To reduce the information load, all platforms utilize pictures or icons, except for platform O, that is primarily text based. In particular, one platform (E) stood out, by replacing texts comprehensively through icons. Additionally, seven platforms (A, H, J, L, M, N, P) use expandable and collapsible text, to avoid information load on first sight. In terms of naming conventions, most platforms try to avoid technical terms and follow easy naming conventions such as 'Project or Community', 'Add' or 'Contribute'. An exception to this was found in the platform I, that uses individual names e.g. 'Spaces', 'Needs', 'Programs' or 'Claps' and technical terms for instance in search options. For the platform's navigation three platforms (B, C, F) allow to search for specific project names and one (E) for a specific web address. Besides that, three platforms enable users to search for names or categories (G, O, P) and three (D, K, L) platforms do not employ any search options. The majority of platforms (A, H, I, J, M, N) however allow for a broad search according to different characteristics such as age, activity or organization.

3) Community organization: Regarding community organization, concepts for the communication between participants, and between participants and researchers were reviewed. Five platforms (A, B, D, E, L) have no concept for a project-based debate of participants, while three platforms (D, E, L) additionally have no possibilities to contact researchers. Five platforms (H, J, M, N, P) enable exchange within the community and to researchers via direct chat options. Nine platforms (C, G, H, I, J, K, N, O, P) allow for communication via forums, either in project-based or general forums. Other concepts for community exchange comprised messages on newsfeeds (J, N), comment options (H, I, J, K, M, N, P) or project-based question and answer options (M). For the contact to researchers or project creators additionally many projects (A, B, C, F, G, K) offered an e-mail option. One platform in the sample (N) especially stood out due to a broad range of options for community exchange. Besides communication, platforms were reviewed for a concept of evaluating user credibility. For ten platforms, no concepts could be detected, while for platform D this could not be reviewed. Other platforms enable the appointment of expert users (N, P) or award collection based on completed learning units (M). Additionally, two platforms implement reputation models, either based on scores (I), or the collection of badges (I, O).

4) Data standards: In terms of data standards, platforms have been reviewed for their handling of private user data, and concepts for entering, validating, visualizing or analyzing data. For the handling of user data platforms differ in their concepts for registration and user profiles. For the registration platforms either require only a user name (E, N), a user name and an e-mail address (B, C, F, G, H, I, K, L, M, O, P), or more data (A, D, J), for instance the country of residence. The profile page of other users is either not visible (A, B, C, D, E, G), associates a user name with information about their contributions (K, L, P), or displays more information (F, H, I, J, M, N, O), for instance the level of education. Additionally, some platforms enable users to keep their user data private (C, M, N, O). For collecting project data, most platforms facilitate participation through specified entry masks that include for example drop-down menus, checkboxes or drag-and-drop (A, B, C, D, E, F, G, H, I, K, L, N, P). Additionally, some platforms provide extra help for the classification of data (E, H, I, N, P) in form of common mistakes, help information or automated proposals. Two platforms do not support data contributions (J, O) and one platform did not have standardized data entry options (M). In terms of data validation only four platforms present validation concepts: This comprised checking whether all necessary entries were filled (P), flagging of contributions through the community (N),

a like and reputation system (I) or the differentiation between quality levels (H). For platform D data validation could not be reviewed. Regarding the analysis of project data, some platforms have integrated data analysis tools (A, B, C, E, F, K, L, N, O, P), while others focus only on data visualization (D, G, H, I). The tools are either available for project initiators and citizens, or only initiators. Two platforms additionally offer shared codebases for researchers (C, P), while two others (J, M) do not enable data analysis. Besides project data, five projects allow to analyze data about the projects' progress (B, H, N, O, P) and five projects analyze meta-data about the community (L, M, N, O, P).

5) Support information: Regarding support information, three design aspects were reviewed. The first one comprised a concept for a separate support page. Most platforms have help pages for several topics, such as guidelines on how to build a project (A, B, C, E, F, G, H, I, J, L, M, N, P), or general support pages for citizens (A, D, H, I, J, L, N, O). Additionally, most platforms employ an FAQ page for citizens (A, C, H, I, J, L, M, N, O, P). Five platforms (B, E, F, G, K) do not provide any separate help pages for participants. As a second aspect, platforms were reviewed for their provision of educational material. Implementations of this feature comprised workshops (A, M, P), training sections (A, C, D, H, I, M, P), blog or newsletter articles (C, E, H, I, O, P) and community spaces for learning (J). Six platforms did not integrate educational resources by design, however, project-based integrations are still possible. Third, concepts for interactive tutorials or help information were reviewed. Design features that were employed in this category, were pop-up tutorials leading through the platform (J, N, P), tutorials and videos on project pages (H, J, M, N, O, P), or additional information based on hovering over content (A, B, C, K, N, O). Six platforms do not include interactive help information.

6) Platform usability: Three design features, supporting platform usability were reviewed. First of all, as concepts for the design of the project main pages, most platforms follow the principle of deploying the same design for every project. Only two platforms (D, N) vary their design throughout different projects and one platform (E) has no project overview page by design. Five projects (B, H, N, O, P) give an overview over the projects' progress on the main page, while some platforms include information on contributing participants (B, C, E, H, J, M, N, P) or contributed data (A, C, D, E, G, H, I, K, L, N, P). Additionally, outstanding features that were noted are an overview of currently active participants in the project (I, N, P), or the proposition of similar projects (M). Second, for the ease of entry barriers, different concepts could be identified: Some platforms enable participation via the web browser (A, B, C, H, I, J, K, M, P), while the others require the installation of software. Above that, three platforms (D, J, N) include either pop-up explanations, upon registration or entering a project and ten platforms provide example pictures or explanations for project tasks (A, B, D, I, J, K, M, N, O, P). Additionally, four platforms (A, J, M, P) indicate the level of difficulty for tasks or indicate the required skills for participating. Third, in terms of communicating project goals, two different approaches could be identified. Three platforms (E, F, I) include general goals on the platforms main homepage, while other platforms include an explanation of project-specific goals on the individual project pages.

7) Platform utilization: In terms of platform utilization, platforms have been reviewed for their concepts of creating and maintaining projects, as well as their concept for reusability of components. Regarding the generation of new projects, we could identify two different types of platforms: Some platforms implement construction tools, that can be used to create new projects yourself (A, B, C, E, F, G, H, I, J, K, L, M, P). Another type of platform creates new projects only on request (D, N, O). Independent of this type, some platforms enable projects to utilize a mobile application (A, B, C, D, E, G, N). In terms of reusability three different level of openness could be detected. Some platforms are entirely based on open source software (A, B, G, H, J, L, O, P), while others were publicly usable and accessible, however not open source (C, E, F, I, K, M). A third platform type presents a chargeable service (D, N).

An overview of the results can be seen in Table 3.

Table 3. Summary of review results

Di-mension	Platforms															
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**
Participatory Functions (PF): computational power (PF1) data collection (PF2), data analysis (PF3), task assignment (PF4) research questions and approach (PF5)																
PF	PF 2,3	PF 2,3	PF 2,3	PF 2	PF 2	PF 2,3	PF 2	PF 2	PF 2	PF 4	PF 5	PF 2,3	PF 2,3	PF 2,3	PF 1	PF 2,3
Platform Aesthetics (PA): reduced information (PA1) easy naming conventions (PA2) search options (PA3)																
PA	PA 1-3	PA 1-3	PA 1-3	PA 1,2	PA 1-3	PA 1-3	PA 1-3	PA 1-3	PA 1,3	PA 1-3	PA 1,2	PA 1,2	PA 1-3	PA 1-3	PA 2,3	PA 1-3
Community Organization (CO): communication between participants (CO1), communication between participants and researchers (CO2), user credibility evaluation (CO3)																
CO	CO 2	CO 2	CO 1,2	-	-	CO 1,2	CO 1,2	CO 1,2	CO 1-3	CO 1,2	CO 1,2	-	CO 1-3	CO 1-3	CO 1-3	CO 1-3
Data Standards (DS): limited private user data (DS1) eased data entering (DS2) data analysis and visualization (DS3) data validation (DS4)																
DS	DS 2,3	DS 1-3	DS 1-3	DS 2,3	DS 1-3	DS 1-3	DS 1-3	DS 1-4	DS 1-4	-	DS 1-3	DS 1-3	DS 1	DS 1-4	DS 1,3	DS 1-4
Support Information (SI): support page (SI1) educational material (SI2) interactive information and tutorials (SI3)																
SI	SI 1-3	SI 3	SI 1-3	SI 1,2	SI 2	-	-	SI 1-3	SI 1,2	SI 1-3	SI 3	SI 1	SI 1-3	SI 1,3	SI 1-3	SI 1-3
Platform Usability (PS): eased entry barriers (PS1) project goal communication on project page (PS2) similar project main pages (PS3)																
PS	PS 1-3	PS 1-3	PS 1-3	PS 1,2	-	PS 3	PS 2,3	PS 1-3	PS 1,3	PS 1-3	PS 1-3	PS 2,3	PS 1-3	PS 1,2	PS 1-3	PS 1-3
Platform Utilization (PT): project builder tools (PT1) mobile application (PT2) open source or free of charge software (PT3)																
PT	PT 1-3	PT 1-3	PT 1-3	PT 2	PT 1-3	PT 1,3	PT 1-3	PT 1,3	PT 1,3	PT 1,3	PT 1,3	PT 1,3	PT 1,3	PT 2	PT 3	PT 1,3

4. DISCUSSION

In this work we followed the 7-step framework for reviewing IT artifacts to provide a structured overview over the availability and functionality of multi-project CS platforms. As indicated by the literature we discovered a notable amount of project overview platforms, community platforms or single project platforms (Brenton et al., 2018), compared to which the share of multi-project platforms was rather small. Nevertheless, we identified and reviewed 16 platforms that enabled the generation and conduction of new CS projects, thus qualifying as multi-project platforms (Baudry et al., 2022). Assessing the platforms' functionalities, as well as their features for aesthetics, community organization, data standards, support information, usability and utilization, the review enabled us to draw a comprehensive understanding of the ways in which platforms support CS initiatives. Generally, a strong focus on functions and features for jointly collecting and analyzing scientific data was visible, which is however only a small part of the spectrum of possible research activities to include citizens (Shirk et al., 2012). Nevertheless, also within this narrow focus, the review showed that platforms present different opportunities and challenges and should be thus selected carefully based on the individual project's needs: First, variations in the platforms' aesthetic and usability allow practitioners to choose a platform according to their target audience characteristics, such as domain expertise or experience with digital platforms. Second, the varying options in the community organization and the provisioning of support enable the initiator to accurately design relationships to and the autonomy of participants. The design of these dimensions can have strong implications for learning or empowerment effects of citizens (De Albuquerque and Almeida 2020; Bela et al. 2016; National Academies of Sciences, Engineering, and Medicine, 2018). To this end, the results demonstrate that many innovative educational concepts from other educational settings such as extended reality (Garzón, Pavón, and Baldiris, 2019) or chatbots (Pérez, Daradoumis, and Puig, 2020; Okonkwo and Ade-Ibijola 2021) are yet missing on platforms. Third, different data standards could be suitable for collecting data of varying complexity, sensitivity or quality. While project initiators are free to choose a platform based on their preferences for the presented variations, their

choice is further constrained by their financial budget and the requirement for transparency and flexibility of the platform.

Considering the multi-project platforms' diversity of feature and design choices, as a practical contribution, our work provides guidance to practitioners in need for a CS platform to conduct their projects. Based on their functional needs and project characteristics they can choose a platform that fits their initiative. Additionally, platform providers can benefit from the insights in different implementations and concepts to refine their digital offer. In terms of theoretical contributions, the structured artifact review is intended to enable scholars to explore the current artifact landscape in a specific domain, thereby demonstrating the need and novelty of new developments (Gnewuch and Maedche, 2022). As such, our work allows IS researchers to compare CS platforms and identify structural research gaps that are yet missing in the CS landscape. In addition, the overview of functionality and implementations for community management, support information, educational material and data standards can serve as a baseline to further research learning and empowerment opportunities for digital citizen scientists. When using the provided review on multi-project CS platforms, some limitations of our research should be named. Methodologically, the presented review is subject to natural limits in the search process as well as the data extraction. For the artifact search, a focus had been set to three search paths. As such, platforms outside this search base might not have been detected. Additionally, four platforms had to be excluded from the review due to their practical accessibility. For the description of CS platforms, data extraction is based on a single reviewer, which could imply that not every functionality or characteristic of a platform might be detected. For future work, it would thus be interesting to broaden this perspective with additional reviewers. The rapidly changing landscape makes it indispensable to constantly screen for additional needs of CS projects, as well as new platforms emerging. As such, our structured platform review provides a valuable baseline for assessing how multi-project platforms support the conduction of CS initiatives that other researchers can build upon. Future research could use the provided sample of platforms to further review aspects of interest or additionally add emerging platforms to the review. In addition, researchers could utilize the review to identify structural gaps and thus specifically develop new functionality for CS projects.

5. CONCLUSION

In this work we have presented a structured artifact review investigating what multi-project CS platforms are currently available in the digital landscape and how they support the conduction of CS projects. We have identified 16 platforms, that support the conduction of generic CS initiatives, presenting a considerable amount of support technology, CS project initiators can choose from. By reviewing the platforms according to seven dimensions, we present notable differences in their functionality and features for various design challenges, as well as structural gaps in the digital landscape. As a result, the choice of multi-project CS platform becomes a key decision for project initiators. Therefore, the artifact review presents a valuable baseline, both for researchers and practitioners to navigate, use and refine the digital CS landscape.

REFERENCES

Aristeidou, M. and Herodotou, C., (2020). Online Citizen Science: A Systematic Review of Effects on Learning and Scientific Literacy. *Citizen Science: Theory and Practice* 5 (1), pp.1–12.

Baudry, J. et al., (2022). Turning Crowds into Communities: The Collectives of Online Citizen Science. *Social Studies of Science*, Vol. 52, No. 3, pp. 399–424.

Bela, G. et al., (2016). Learning and the transformative potential of citizen science. *Conservation Biology*, Vol. 30, No. 5, pp. 990–99.

Brenton, P. et al., (2018). Technology Infrastructure for Citizen Science. In: *Citizen Science*: *Innovation in Open Science, Society and Policy*, pp. 63-80. UCL Press, London, England.

De Albuquerque, J., and Almeida, A., (2020). *Modes of Engagement: Reframing "Sensing" and Data Generation in Citizen Science for Empowering Relationships*. Manchester University Press.

Garzón, J. et al., (2019). Systematic Review and Meta-Analysis of Augmented Reality in Educational Settings. *Virtual Reality*, Vol. 23, No. 4, pp. 447–59.

Gnewuch, U., and Maedche, A. (2022). Toward a Method for Reviewing Software Artifacts from Practice. *International Conference on Design Science Research in Information Systems and Technology*. St. Petersburg, USA, pp. 337-350.

Göbel, C. et al., (2017). *Stakeholder Analysis: International Citizen Science Stakeholder Analysis on Data Interoperability. Final Report.* Woodrow Wilson International Center for Scholars. Washington, DC, USA.

Haklay, M. et al., (2021). What Is Citizen Science? The Challenges of Definition. In: *The Science of Citizen Science*, pp. 13-33. Springer International Publishing, Basel, Swiss.

Jennett, C., and Cox, A., (2016). Eight guidelines for designing virtual citizen science projects. *Second AAAI Conference on Human Computation and Crowdsourcing.* Pittsburgh, USA, pp. 16-17.

Jennett, C., et al., (2016). Motivations, Learning and Creativity in Online Citizen Science. *Journal of Science Communication* Vol. 15, No. 3.

Liu, H., et al., (2021). Citizen Science Platforms. In: The Science of Citizen Science, pp. 439-459 Springer, Cham, London, England.

Luna, S. et al, (2018). Developing Mobile Applications for Environmental and Biodiversity Citizen Science: Considerations and Recommendations. In: *Multimedia tools and applications for environmental & biodiversity informatics*. Springer, Cham. pp. 9-30

Miller-Rushing, A., Primack, R., & Bonney, R. (2012). The history of public participation in ecological research. *Frontiers in Ecology and the Environment*, Vol. 10 No. 6, pp. 285–290.

Musto, J., and Dahanayake, A. 2021. An Approach to Improve the Quality of User-Generated Content of Citizen Science Platforms. I*SPRS International Journal of Geo-Information* Vol. 10, No. 7, pp. 434.

National Academies of Sciences, Engineering, and Medicine. 2018. *Learning Through Citizen Science: Enhancing Opportunities by Design.* National Academies Press (US).

Newman, G., et al. (2010). User-Friendly Web Mapping: Lessons from a Citizen Science Website. *International Journal of Geographical Information Science*, Vol. 24, No. 12, pp. 1851–69.

Okonkwo, C. and Ade-Ibijola, A. (2021). Chatbots Applications in Education: A Systematic Review. *Computers and Education: Artificial Intelligence*, Vol 2.

Pérez, J., et al., (2020). Rediscovering the Use of Chatbots in Education: A Systematic Literature Review'. *Computer Applications in Engineering Education*, Vol. 28, No. 6, pp.1549–65.

Saraswat, Satya, (1999). Structured Content Analysis of Corporate Web-Sites: A Methodological Perspective. (1999). *AMCIS 1999 Proceedings*. Pittsburgh, USA, pp. 206-208.

Shirk, J. et al. (2012). Public Participation in Scientific Research: A Framework for Deliberate Design. *Ecology and Society* Vol. 17, pp. 29–48.

Shirk, J., and Bonney, R. (2018). Scientific Impacts and Innovations of Citizen Science. In *Citizen Science: Innovation in Open Science, Society and Policy*, pp. 41–51. UCL Press, London.

Skarlatidou, A. et al., (2019). What Do Volunteers Want from Citizen Science Technologies? A Systematic Literature Review and Best Practice Guidelines. *Journal of Science Communication*, Vol. 18, No. 1.

Sturm, U. et al., (2018). Mobile Learning in Environmental Citizen Science: An Initial Survey of Current Practice in Germany. *it-Information Technology*, Vol. 60, No. 1, pp. 3-9.

Sturm, U. et al., (2018). Defining Principles for Mobile Apps and Platforms Development in Citizen Science. *Research Ideas and Outcomes*, Vol. 4

Wald, D. et al., (2016). Design Principles for Engaging and Retaining Virtual Citizen Scientists. *Conservation Biology*, Vol. 30, No. 3, pp. 562–570.

Yadav, P. and Darlington, J., (2016). Design Guidelines for the User-Centred Collaborative Citizen Science Platforms'. *Human Computation*, Vol. 3, No. 1, pp. 205-211.