CITIZEN SCIENCE:
THEORY AND PRACTICE

"Every Small Action Helps Towards the Greater Cause:" Online Communities Scaling Up Online Community-Led Citizen Science in Addressing Litter Challenges in Scotland

RESEARCH PAPER

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ABSTRACT

Social media is now a new means of engagement and a catalyst for citizen science; still, less attention has been paid to understanding the influence of online communities on community-led citizen science projects. This study used the Fife Street Champions public Facebook group as a case study to explore how online community-led citizen science projects generate citizen science data to understand littering challenges in Scotland and to examine the impact of the group's activities and the challenges they face. Data driven-content analysis was used to analyse Facebook user-generated data of 337 posts with comments and images to identify key themes that emerge in the data. Results indicate that group members develop their own data collection tools, share, analyse and present their litter-picking activities to understand the magnitude of littering and the impact of their litter-picking activities. However, the findings highlight inconsistencies in how group members collect and record data from their litter-picking activities. The group also provides informational support, environmental awareness and advocacy, and environmental citizenship. Members also share concerns about eco-anxiety. Lastly, safety and health concerns, COVID-19, and seagulls are challenges experienced by online-based litter pickers. The results contribute to our understanding of the opportunity that social media platforms can provide to build more robust online community-driven citizen science projects that can inform further research. Key stakeholders need to collaborate with such communities to improve on collecting scientifically meaningful data.

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INTRODUCTION

Online citizen science is a rapidly growing field that allows members of the public to participate in scientific research through online platforms regardless of their geographical location, professional qualification, or academic training. The growing use of technology has increased participation in online citizen science and created opportunities for projects to take place online (Reed et al. 2013). As more and more people access the internet, online citizen science provides opportunities for individuals from all over the world to contribute to scientific projects and make a real difference in the world of research. Such citizen science projects carried out online are known by different terms such as citizen cyberscience (Jennett et al. 2016; Grey 2009), virtual citizen science (Wiggins and Crowston 2011), virtual citizen science, crowdsourced science (Uhlmann et al. 2019), and digital volunteerism (Naqshbandi et al. 2020). In this paper, such communities will be referred to as online citizen science (Holliman and Curtis 2015).

The evolution of the term online citizen science has also posed challenges similar to traditional citizen science regarding its ambiguous use and meaning. In recent literature, citizen science has become a contested term from an epistemological and ontological perspective, especially in light of information and communication technologies and different participatory modes of scientific research (Kasperowski and Kullenberg 2019). These sentiments are also raised by Strasser et al. (2019), who question (1) who can produce legitimate scientific knowledge, (2) how it is produced, (3) where it is produced, and (4) why it is produced. These questions challenge the role of professional scientists and non-professional scientists (i.e., the public, lay person) in producing legitimate scientific knowledge. Hence, more knowledge is needed about how citizens facilitate their investigations to understand littering challenges and the impact of their voluntary litter-picking activities in their local community. This case study documents how non-professional scientists from online communities develop data collection tools, and collect, analyse, and present their data leveraging the online communities' social capital. The paper will begin by briefly reviewing the literature on different modes of citizen science and how online citizen science has evolved.

MODES OF CITIZEN SCIENCE

There are many ways to categorise and differentiate citizen science projects, depending on the project's specific goals and methodologies, participant levels of participation, and the contexts of each project, which can lead to blurred meanings (Fan and Chen 2019). Scholars such as (Cooper and Lewenstein 2016; Wiggins and Crowston 2012; Haklay 2012) have attempted to classify different modes of citizen science. Price and Lee (2013) assert that the spectrum of citizen science projects can be categorised into many different and overlapping categories. For instance, Cooper and Lewenstein (2016) discuss two meanings or "strands" of citizen science. The first strand, from Irwin's (1995) definition, emphasises the responsibility of science to society, which they call "democratic" citizen science. At the other end of the spectrum, they position the second strand as "participatory" citizen science, a practice in which people mostly contribute observations or efforts to the scientific enterprise. While Ottinger (2010) categorises citizen science as either "scientific authority–driven" or "social movement–based," which Fan and Chen (2019) have criticised for being too general, going on to categorise the use of citizen science into four dynamic, mutually inclusive categories based on their different conceptions of citizen and citizenship, and how citizen science is conceptualised.

Alternatively, Bonney et al. (2009) classified the different hierarchical types of participatory projects in citizen science, which resonates well with Arnstein's (1969) ladder of participation. These include contributory projects, in which scientists design the research, and the public contributes data. In collaborative projects, the scientist engages the public in refining the project design to disseminate findings. Lastly, co-created projects have the active participation of the public in the scientific process. Similarly, Brandt et al. (2010) developed three citizen science models based on the volunteers' level of participation. The contributory model is when participants actively or passively contribute to project data collection. The collaborative model involves participants developing descriptions and explanations or performing basic forms of initial analysis. Lastly, in the co-created model, participants are actively involved in the research process to publish the findings.

However, scholars such as Shirk et al. (2012) insist that citizen science occurs on a spectrum of participation, emphasising the "degrees of participation." This typology expands into five modes of citizen science projects, which include contractual, contributory, collaborative, co-created, and collegial. For instance, community citizen science, also known as co-created science, community science, civic science, collegial science, and street science, occurs at the high end of the spectrum of Arnstein's (1969) ladder of participation, where citizens have a high degree of control and ownership of scientific activities (Chari et al. 2017). Chari et al. (2017) also note that community citizen science remains understudied in the scientific literature.

Despite all the different typologies of participation, Strasser et al. (2019) critique a hierarchical interpretation of citizen science, and emphasise three characteristics of citizen science projects. Firstly, they assert that citizen

science entails greater democratisation of science, which is the equal redistribution of epistemic authority between scientists and laypeople in knowledge production (Kurtulmus 2021). For example, the bucket air quality monitoring case study (Ottinger, 2010) demonstrated non-scientists' ability to contribute to knowledge production by contributing information on the local air quality and suggesting alternative ways of assessing air quality. The study findings indicate that standards serve as a boundary-bridging function in which the bucket monitoring data provides a crucial measure of legitimacy among experts. However, standards provide a boundary-policing function, in which experts dismiss bucket data as irrelevant to air quality assessment. Hence, power is shared among all citizens, and concerned citizens actively participate in knowledge production.

EVOLUTION OF ONLINE CITIZEN SCIENCE

Online citizen science has revolutionised the democratisation of science. There have been several waves of online citizen science projects, each with its unique characteristics and goals, as more people access the internet. The first wave emerged in the early 2000s with projects like SETI@home (Anderson et al. 2002) and the Galaxy Zoo (www.galaxyzoo.org), for which the public classifies the galaxies (Raddick et al. 2007). These projects paved the way for other online citizen science projects in various fields, leading to the second wave of online citizen science.

The second wave began around 2010, characterised by different projects and types of activities the public could engage in. This included projects that allowed participants to contribute observations of birds, plants, and animals and to help classify and analyse images from various scientific fields. For instance, the Zooniverse platform, the largest and most popular citizen science platform (Woodcock et al. 2017), grew out of the original Galaxy Zoo project and has more than 1.1 million registered volunteers across the globe (Cox et al. 2015), allowing researchers to collect data on a massive scale that would be impossible without the participation of citizen scientists. Some examples include the eBird (Sullivan et al. 2009); Citizen Sky (www.citizensky.org), a 3-year astronomical citizen science project launched in the USA (Price and Lee 2013); the iSPEX Smartphone Add-On project to make maps of aerosol properties in the Netherlands (Snik et al. 2014); and iNaturalist (Nugent 2018).

The third wave of online citizen science reflects an increasing recognition of the value of engaging members of the public in scientific research, and a growing understanding of the many ways that the public can contribute to scientific knowledge. For example, platforms such as Public Lab and SciStarter emphasise the co-creation of online citizen science projects (Bui 2016). As technology evolves in the 21st century, new and innovative forms of online citizen science have been created**.** Consequently, online citizen science offers unique opportunities to democratise science (Curtis and Curtis 2018) by providing citizens without scientific backgrounds or training opportunities to contribute to meaningful scientific discoveries. For instance, the use of social media has seen the growth of online citizen science on platforms such as social networking sites (e.g., Facebook, LinkedIn, and Instagram); blogs, including microblogs (e.g., Twitter); content communities (e.g., YouTube, Flickr, and Pinterest); and collaborative projects (e.g., Wikipedia). These platforms have presented unprecedented opportunities for volunteers to engage in online citizen science (Wald et al. 2016; West et al. 2016) as scientists now have access to more potential participants for research projects than previously (Wynn 2017). Such studies demonstrate that virtual spaces such as Facebook, Twitter, and Instagram provide avenues to understand human-environment interactions in space and time (Toivonen et al. 2019), to facilitate the exchange of ideas among citizens, and to encourage collective action on environmental issues (Touir 2020) and citizen science (Earp and Liconti 2020).

Furthermore, online citizen science has emerged as a promising approach to engage the public in scientific research and to provide valuable contributions to various fields of study. Previous research has shown that online citizen science initiatives enable different forms of participation, resulting in different forms of learning compared with field-based projects (Aristeidou and Herodotou 2020). Other studies indicate that online citizen science has the potential to increase scientific literacy through informal learning of science (Curtis et al. 2017) and to promote experiential learning (Kridelbaugh 2016).

Additionally, online citizen science allows participants to select the extent to which they want to be involved, depending on their interests and available time. However, online spaces pose challenges in creating a community of practice with other members (Aristeidou and Herodotou 2020). It also allows researchers to crowdsource research, consequently reducing the cost of scientific research, engaging with citizens, and fostering community engagement (Nov et al. 2014).

Therefore, most studies on online citizen science investigate the effects of motivational factors on the quantity and quality of citizen scientists' contribution (Nov et al. 2014). Curtis (2015) has explored the motivations that initiate and sustain participation in online citizen projects, and has examined the different ways individuals contribute to these projects. Another review explored the learning outcomes of citizens participating in online citizen science communities designed for inquiry learning (Aristeidou, Scanlon and Sharples 2020).

However, less attention has been paid to understanding the influence of online community–led citizen science on social media platforms. In addition, most studies on littering and citizen science have focused on the opportunities and challenges of using citizen science litter data sets (Jambeck and Johnsen 2015; Vincent et al. 2017; Falk-Anderson, Berkhout, and Abate 2019). However, less attention has been paid to understanding the influence of online community–led citizen science initiatives on social media platforms. Specifically, how online community–led citizen science litter picking volunteers collect their data, the impact of their online litter-picking communities and the challenges they face. Therefore, in this paper, I use a case study approach and content analysis of user-generated data of the Fife Street Champions Facebook litter-picking public group based in Scotland to explore how local communities use social media to engage with and interact in developing online community–led citizen science and assess the challenges they encounter in litter picking, specifically to understand littering challenges. Here, I address the following research questions:

1. How do online litter-picking groups gather, process, and present data related to their activities?
2. What are the impacts of online litter-picking communities and the challenges they face in voluntary litter-picking activities?

The results of the study demonstrate how online community–led citizen scientists develop their own data collection tools to understand the influence of their voluntary litter-picking activities and provide an expansive view of the impact of their online community and the challenges they face. The findings recommend how online community–led citizen science can improve their data collection to maximise the use of the data they collect.

MATERIALS AND METHODS

DATA EXTRACTION AND SAMPLING STRATEGY

My exploratory study used a case study approach to generate initial qualitative insights (Yin 2003) about online community–led citizen science. The study also investigates phenomena within a real-life context (Yin 2009), by examining how online citizen science communities generate their litter-picking data, and the impact of their litter picking activities and challenges they encounter. *Fife Street Champions (FSC)—litter picking and supporting community action* Facebook public group was selected as a case study because it is one of the most active litter-picking public groups in the UK, and the level of activity of group members has been consistent since March 2018, when it was formed, compared with other Facebook groups engaging in similar litter-picking activities. An additional factor in selection was the group's user-generated data. Purposive sampling was used to increase the depth (as opposed to breadth) of understanding (Palinkas et al. 2015) of the group's activities.

DATA EXTRACTION PROCEDURES

Studies in various disciplines, such as health (Bender et al. 2011) and communication research (Naab and Sehl 2017), use content analysis of user-generated data. However, studies using content analysis in online community–led citizen science still need to be completed. The units of analysis for the study are posts, comments, and images posted by group members from March 2020 to July 2022, from a larger data set spanning from March 2018 to the present. Facebook posts from the group with more than twenty engagements (comments) or at least twenty-five emoji reactions were selected for analysis without any private or identifying information. They were purposefully chosen from each year to obtain a more focused and relevant sample of data that is more likely to provide insights into the research question. Data from 2020 to 2022 were manually extracted from 1 July 2022 to 25 July 2022 and imported into an Excel spreadsheet (as in Supplemental File 1: Extracted User-Generated Data). The year 2022 had posts with the highest engagement, resulting in a large sample size of user-generated data (227) compared with other years, as shown in Table 1.

QUALITATIVE CONTENT ANALYSIS

Given the exploratory nature of the research, content analysis was based on grounded theory as we applied inductive analysis, allowing the natural variations in designs and categories to surface from the data (Patton 2014). Data driven-content analysis was used to synthesise user-generated data to develop codes and interpret latent characteristics of the users' data for analysis (Dieronitou 2014; Schwartz and Ungar 2015). Data-driven content analysis requires drawing codes inductively from the data before developing codes into categories (Schreier 2012), and the following six steps were undertaken.

YEAR	MEMBERS	POSTS WITH COMMENTS SAMPLED
2022	3000	217
2021	2700	70
2020	Not known	50

Table 1 Sample of user-generated data selected from the Fife Street Champions as of July 2022.

1) The data was cleaned and prepared by deleting any personal information. All potentially identifiable names of users were deleted to protect the users' privacy and confidentiality. Then the data was exported into NVivo for further analysis. 2) The research assistant and author examined the posts and comments and began assigning initial codes to the data using an open inductive coding process; we met and reached a consensus on different codes and later developed a codebook (Supplemental File 2: Codebook for Data Analysis). 3) Codes were also cross-checked with quotes from the posts and comments. 4) Codes were categorised and later organised and reported as analytical themes. During the coding process, codes were continuously refined in an iterative data collection and analysis process. 5) To validate the legitimacy of analytic interpretations (Braun and Clarke 2013), we carried out member checking, peer debriefing and consensus coding (Kuckartz 2019) to address differences or concerns in assigning codes and grouping codes into categories. 6) Once a consensus was reached, we identified the themes emerging from the data analysis. This resulted in five main themes.

LIMITATIONS

User-generated data has its limitations. Findings have limited generalisability because the data sampled does not represent the entire population. Owing to the large volume of user-generated data, only March 2020 to July 2022 were purposefully sampled. Hutton and Henderson (2018) argue that social media research lacks reproducibility, which makes it challenging to use to inform further work. In addition, user-generated data often lack information on the basic sociodemographic characteristics of users, which limits the understanding of the background context of who generates the data. Users do not give explicit consent to have their data used for research purposes; hence, considerable effort has been made to anonymise user-generated data, de-identified data, and the messages of users. In addition, informed consent can be challenging to obtain because social media users can be inactive. Facebook users can make changes to their public posts, such as deleting or adding comments or reactions to specific posts, which can differ from the archived data analysed and the current Facebook page. One member gave permission to use the interactive maps they created, and the rest did not respond to requests to use their images.

DATA AVAILABILITY AND ETHICS STATEMENT

Data extracted from the social media platforms are available as Supplemental File 1. The University of St. Andrews School of Geography and Sustainable Development ethics review committee exempted the study from a full ethical review because the data collected for the study is in the public domain, and the study did not involve any interaction with human participants or users of the social media platform. However, I contacted the group administrator to inform the group members that their group data would be used for a study and permission was granted. Data were anonymised to ensure that no personally identifiable information was shared.

RESULTS

This section presents the results of the extracted user-generated data from the public Facebook group. The presentation of the results is structured around three components, the role and impact of the online community in litter picking and the challenges group members encounter as they volunteer, as summarised in Figure 1. The online community uses Facebook for online community–led citizen science, which includes data collection, sharing,

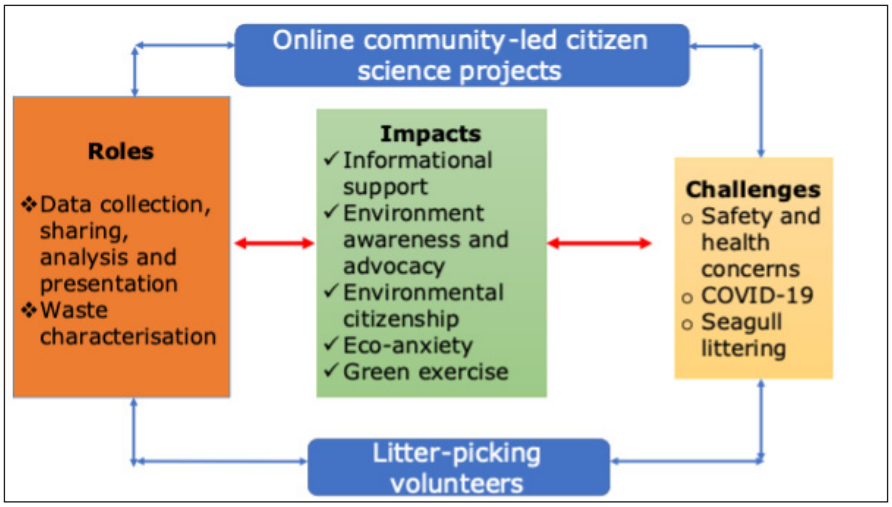

Figure 1 Framework on the role and impact of the online-led community citizen science.

analysis, and presentation. In addition, group members use the group to characterise and quantify the litter they pick. Informational support, environmental awareness, environmental citizenship, eco-anxiety, and green exercise emerged as the key impacts of the litter-picking Facebook group. Safety and health concerns, COVID-19, and seagulls are the challenges experienced by the online-based community engaged in litter picking.

ROLE OF THE LITTER-PICKING PUBLIC FACEBOOK GROUP

The first research question examined the role of the online community of the litter-picking public Facebook group. The social media group uses the platform for online community-led citizen science, including data collection, sharing, analysis and presentation. In addition, group members use the group to characterise and quantify the litter they pick, as discussed below.

Data collection and sharing

A few group members have developed data collection tools for the groups' litter-picking activities. Members either post to the group page or fill in an online data collection form created by some of the group members. The form collects and shares data on the names of waste pickers (optional), the number of bags of waste collected at a specific location, and estimated or exact numbers of the following types of waste: dog poo bags, disposable masks, and reusable masks. Since 2021, the form has also captured the number of hub caps/wheel trims, tyres, nitrous oxide canisters, shopping trolleys, traffic cones, nappies, and pants picked, and in July 2022, they added vapes. For example, after a litter-picking activity in Kirkcaldy, one group member said, "*Tally form done*." Another member posted, "*1 reusable face mask, 1 disposable face mask, 48 poo bags. I'll fill out the form.*"

However, not every group member fills in the form, mainly because they do not know where to access it. One member posted, "*I got a total of 22 disposable masks… I'm unsure where the form to record these is, though?*" Another member said, "*Where is this form everyone's posting about?*" Lastly, other members forget to fill in the form or to post their activity soon after litter picking; hence, their litter-picking activity is not captured. One member said, "*I forgot to post 2 bags from X road a couple of weeks ago ….*"

However, group members have mixed feelings about consistency in either posting to the group page or filling in the online data collection form to collect litter-picking data. Most members understand that using both methods is to find the most effective and efficient way to collect litter-picking data. One member said,

> "*My understanding of running both systems at the same time to start with is to find out how easy it is for users and to get people's feedback. Also, they need to test how easy/accurate the new system is. I'm doing both ways initially until a decision is made.*""

A few members are not interested in capturing their data twice; one member said, "*I'm not keen on doing it twice*." In contrast, another member commented that using the form is an easy way to collate the data collected and posted by group members.

Data analysis and presentation

A few group members volunteered to analyse and present the data collected on litter-picking activities. The group administrators often post at the end of each month, tallying up the bags the group has collected and the type of waste. Using the monthly data compiled in the group by one of the group administrators, I created Figure 2 which shows the bags of litter picked monthly from 2020 to June 2022. The data reveals that the COVID-19 pandemic closures, from the beginning of July 2020 to March 2021, correspond with the peak for litter picking, which later declined. Since 2022, there has been some inconsistency in litter-picking activities compared with 2020 and 2021.

At the beginning of 2020, this data was organised, put into bar charts, and shared on the Facebook group. However, as membership in the group continued to increase, the charts were no longer created; instead, they shared only the total number of bags collected. One of the group members also created interactive maps showing the amount of waste collected and the locations around Fife where litter was picked, which they shared with the group. For example, Figure 3 shows litter-picking activities from January 2020 to March 2021.

However, the individual group member stopped creating the interactive maps because in 2021 there was a sharp increase in litter-picking recordings, from about 100 to 200 picks a month to about 400 to 800. In reaction, one group member commented,

> "*You've done an epic job! It's beautiful to see but can imagine it's becoming like full-time work trying to keep up with it. The new form will be keeping track of what areas have been worked on, we might just have to make do with a pie chart instead of a pretty map.*"

Characterising and quantifying litter picked

A few of the group members consistently report the number of bags of litter and the type of litter they pick during litter picking, mostly as a post or as comments, or they may fill in a form to record their litter-picking activity. One group member posted in 2021: "*3 black bags, 11 masks, 3 poo bags, 1 bag of bottles recycled, lots of fly-tipping found… form filled out*."

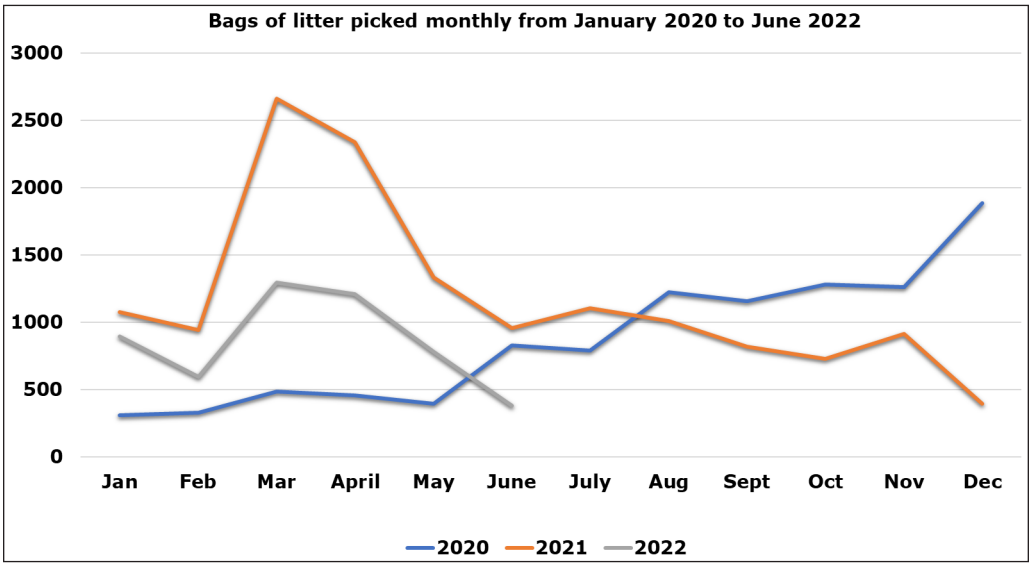

Figure 2 Fife Street Champions monthly tallies of bags of litter picked from January 2020 to June 2022.

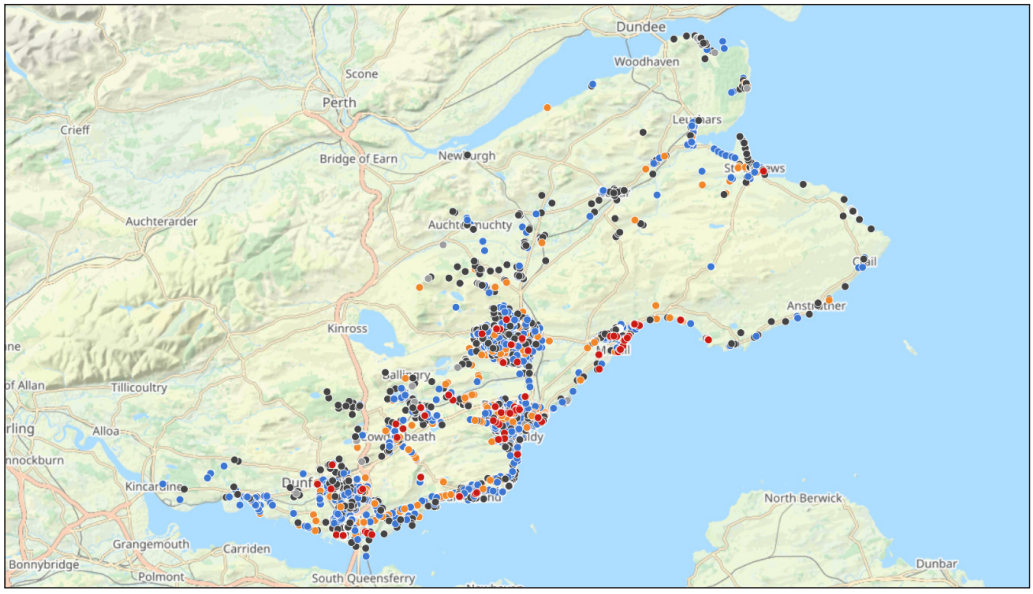

Figure 3 Interactive map showing litter-picking activities in Fife. Source: https://maphub.net/Ross/Fife-Street-Champions (accessed 17 August 2022).

In 2021, members also began counting the amount of disposable and reusable masks picked. As waves of COVID spikes hit, the face mask–related waste increased. Dog poo bags, glass bottles, single-use takeaway materials, and cigarette buts are the most common types of waste picked and reported in the Facebook group.

One of the group administrators acknowledges the limitations of their data collection process as some waste materials are excluded in the statistics of bags of waste picked by volunteers. One of the group administrators posted,

> "*If we assume an average weight of twelve pounds per bag, allowing a mix of bag sizes equates to around seventy-six tons of garbage. However, this does not include the tyres, furniture, hoovers… and other unbaggable items…. the actual total is unknown but will be many more tons than this.*"

Historical waste

A few group members report remnant or historical waste by describing the waste and showing pictures of mainly the best-before date on the litter pick. The historical waste picked ranged from 1972 to 2000, as shown in Figures 4a and b. For example, a group member posted Figure 4a in February 2022, "*… the crisp packet on the left was my oldest from 1973, and the other is from sometime in the 70s/'80s and the right 1977.*"

Figure 4 Historical waste. **(a)** Pictures of old crisps packets from 1973–1980 posted in February 2022. **(b)** Pictures of a packet of crisps from 1981 shared by a group member in March 2021.

Some group members commented on the post, demonstrating their environmental concerns. One member commented, "*That's absolutely awful that it's been there all that time. Stuff really does take ages to break down…*" and another said, "*It certainly hits home when you find something like this, especially being so intact.*"

A member commented on a picture posted as Figure 4b, "*When I think of the amount of 'historical' rubbish we have lifted, it really encourages me to continue.*" Another group member commented, "*That crisp packet! 40 years old!! You should keep a photo of it and email it to all the local schools to let the kids see how long they take to degrade (not that they are the only culprits!).*" Such comments highlight how waste takes decades to degrade; emphasise the importance of the voluntary litter-picking activities; and illuminate how historical waste finds can be used to raise awareness on proper waste disposal. Although finding historical waste can be upsetting, it motivates group members to continue cleaning and helping the environment.

IMPACTS OF THE ONLINE LITTER-PICKING GROUP

The second research question explored the impact of the online community–led citizen science project in understanding and addressing littering challenges. Community support, environmental awareness and advocacy, environmental citizenship, eco-anxiety, and green exercise emerged as the key impacts of the litter-picking Facebook group.

Community support and social capital

The Facebook group provides members with a platform to arrange and plan future clean up together, to engage with each other's questions, and to take action to report issues when needed. The intent of user posts varies from information seeking to giving and sharing personal litter picking and opinions. The findings indicate that the Facebook group offers informational support and social network support.

Analysis of posts and comments reveals collective sharing and learning by users. Members have used the group to share knowledge, expertise, and online resources on waste-related topics. For example, users share individual and community litter-picking activities, clean-up campaign activities, and waste-related information. Most informational support posts are reminders of group litter picks or information regarding where and when group members can collect bags and tools for use.

In addition, most Facebook group members demonstrate that they rely on one another to answer and ask questions. Many have asked how or where to report observed illegally dumped waste incidences known as fly-tipping. Equally, most group members respond quickly and share resource links. In addition, the group provides social network support because it encourages members to share their lived experiences, personal photographs, and litter-picking stories and experiences.

Environmental awareness and advocacy

The study's findings indicate that the public group provides a platform for environmental awareness and advocacy to promote understanding of the fragility of the environment and the importance of its protection. The group members use posts, comments, and hashtags, as well as sharing external website links and reporting fly-tipping as strategies to promote environmental protection.

The group members share their perspectives on environmental protection by addressing the need to reduce and manage litter using posts and comments. One group member posted,

> "*I've read the posts and comments from other members despondent that areas they have worked on recently have immediately been littered again. This, to me, means that something major is failing, and I'm thinking we are shutting the stable door after the horse has bolted so that we are following the horse along the road, helplessly picking up the droppings instead of putting energy into getting the horse back into the stable. Can we make it socially and environmentally unacceptable to drop litter and aim to create conscience and consciousness about littering?*"

Another member posted a comment in response.

> "*...We are the change. After 30 years of litter picking, I have seen change. In my opinion, it's such a big topic that by doing things like you are, we are, and those that are affiliated with us- we are the change. We regretfully also need to be patient for attitudes to change....*"

Furthermore, a few group members use hashtags regarding environmental awareness, resulting in 177 different hashtags posted, excluding location hashtags. Of those, 129 hashtags, such as #climatematters and #worldcleanupday, had only one post each. The most popular hashtag is #takeyourlitterhome with 126 posts, #lovewhereyoulive with 23 posts, and #bethechange with 12 posts.

Beyond hashtags, posts such as those that share petitions to be signed or those that share information seemed to be posted several times throughout the three years. A few group members shared external links on issues such as the environmental impacts of littering and climate change and other littering activities from different Facebook groups and from individuals involved in litter picking.

Environmental citizenship

The posts and comments in the public groups reveal that group members perceive themselves as agents of change in their community through their individual and collective actions. One member commented on a post, "*...Every small action helps towards the greater cause.*" In addition, group members discuss how littering as an environmental problem can best be addressed.

Exo-anxiety

Furthermore, eco-anxiety is a recurring theme in the public Facebook group as some group members express distress about littering behaviours and their environmental impacts. Posts and comments showing frustration, hopelessness regarding individuals, or feelings that their work in public littering is not valued are common in the group. One member commented,

> "*I'm finally back doing what I love after taking a week off litter picking and gathering my thoughts as it was starting to infuriate and anger me. I was starting to get really angry and upset .... Happy to be back and making a difference, cannot wait to get back out to pick more now that my motivation is back.*"

Group members offer supportive comments after a member shares their frustration with persistent littering, and the members remind each other of the difference they are making. Hence, they have developed online friendships. Another member commented,

> "*... you wrote exactly how I, and many others on here, feel. These are indeed Surreal Times and it's often hard to stay positive. Litter-picking is like Groundhog Day, BUT we are making a difference! ...*"

Green exercise

The posts and comments highlight that group members take litter-picking walks for their mental and physical well-being. Most group members commented that litter picking was their exercise due to COVID restrictions. One group member commented on a post in 2021, "*To be honest... it's the only exercise I've been getting since gyms closed, and I've been stuck ...*" Another member said, "*A bit of exercise and litter pick up at the same time....*"

CHALLENGES EXPERIENCED BY LITTER PICKERS

The third question investigated the challenges experienced by an online community–led citizen science initiative when engaging in litter-picking activities.

Safety and health concerns

The posts and comments reveal that there are concerns for safety and health in litter picking, and group members warn each other of potential risks. The group does acknowledge the risks they take when collecting litter along busy streets or highways. Some group members highlighted that collecting litter along roads with a speed limit above 30 mph poses risk to litter pickers. At the same time, other group members and group administrators recommend that volunteers avoid such areas due to the high risk. One member posted:

> "*... I'm a bit concerned about the traffic on that road and staying safe if I'm picking litter. Can Fife Council provide any safety notices, or do you recommend not trying?*"

Another member responded. "*Please don't attempt this. We all get annoyed about this stuff, but it's not worth risking life and limb.*"

During the months when the pandemic restrictions were at their most impactful, group administrators and a few members shared information and COVID guidelines for litter-picking walks. Group members also revealed the health risks of broken glass, sharp wires, dog poo waste, and COVID-19-related waste. One member posted in 2021,

> "*So, I went back and cleared all the poo bags at the side of the drain now that they weren't frozen…this is disgusting that people do this, and it is a health and safety concern….*"

COVID-19 and litter-picking activities

Effects of the COVID-19 pandemic posed both challenges and opportunities in litter-picking activities. Posts and comments at the beginning of the pandemic in 2020 and early 2021, indicate that group litter-picking walks were cancelled, or group members could not organise due to government regulations or individuals self-isolating and keeping social distance. Later on, when pandemic restrictions were relaxed, there was an increase in litter-picking activities not only for cleaning up the environment; it also provided the group members with physical and mental benefits.

Seagulls

Some members posted and commented on their concerns for seagulls, which remain a nuisance as they scavenge for food from trash cans or rip bags of collected trash. One group member posted, "*I watched seagulls empty the bins near Band Q today just where you recently cleaned. What a mess they made….*" Another group member posted,

> "*…Unfortunately, we can't control the gulls …. With ad hoc picks, we just need to be sensible, and if we can't take them home or to the tip, we should not leave bags in exposed areas.*"

DISCUSSION

The findings from this study demonstrate that online-based communities such as Fife Street Champions Facebook group use the platform to develop online community–led citizen science to understand littering challenges and the impact of their litter-picking activities. The online litter-picking community provides community support, environmental awareness and advocacy, environmental citizenship, a safe space to express eco-anxiety, and a green exercise practice. It also revealed that safety and health concerns, restrictions due to COVID-19, and the presence of seagulls are challenges volunteers encountered in their activities. The study highlights the many possible ways that the public can contribute to scientific knowledge through online platforms.

The most striking finding of the study is that the Facebook group is independent and maintains ownership of the entire knowledge-production process, from designing their own data collection tools, to sharing, analysing, and presenting findings and to understanding the litter-picking challenges and the impact of their voluntary activities in Fife, Scotland. Such online communities provide data that would otherwise have been challenging to collect and access, for instance, the type and quantity of litter picked in Fife and its spatial distribution. These findings are supported by (Liberatore et al. 2018), asserting that increased access and use of online technologies expand opportunities for citizen science, with increased ease of data entry and precise measurements of location. Moreover, utilising open-access tools like maps allows citizens to display the spatial distribution of their litter-picking activities visually. Similarly, Bennett and Segerberg (2012) assert that social media has given rise to grassroots mobilisation in which the local community takes a leading role in initiating and owning research projects (Chari et al. 2017; Dosemagen and Gehrke 2016) without relying on formal leadership or membership in an environmental movement.

Furthermore, this paper notably demonstrates that the digital era has facilitated data production and sharing, allowing citizens to participate in knowledge production based on their social and human capital, thereby contributing to online citizen science literature. However, the sociodemographic characteristics of the user group members in the case study remain unknown; hence, there are concerns raised in the literature about how citizen science–derived data is perceived to be less robust and of lower quality compared with those of professional scientists (Hyder et al. 2015; Kosmala et al. 2016). In addition, the findings highlight the inconsistencies in reporting litter-picking data, which poses a challenge to the quality of data collected. These sentiments are similarly raised by Meijer and Potjer (2018), who highlight that citizen-generated open data raises concerns related to the coverage, representativity, credibility, and comparability of the data. To mitigate these limitations in citizen science–generated data, Kurtulmus (2021) asserts that efforts to democratise science should be coupled with efforts to increase citizen competence to increase the benefits of environmental volunteering because there is increasing dependence on voluntary support (Winch et al. 2021). Hence, there is a need for researchers and key stakeholders to explore how they can strengthen the mix of expertise among online communities to advance robust online community–led citizen science.

Another important finding is that online community–led citizen science promotes the environmental awareness of the group members by characterising and quantifying waste picked at specific locations; online communities share and co-create knowledge on littering challenges and on the impact of non-biodegradable plastic contaminants in land and marine environments. This finding is consistent with that of Curtis et al. (2017), who state that online citizen science promotes informal learning of science. In this case study, informal learning experiences are spontaneous for the group members as there are no explicit learning objectives (Aristeidou and Herodotou 2020) such as the online community–led citizen science project on littering.

Lastly, the results indicate that the Facebook group plays a role in fostering engagement in environmental issues (Johnson et al. 2014), as most engaged group members demonstrate that they understand, value, and act to promote environmental outcomes (Dean et al. 2016). However, low engagement among the group members is a major challenge that online community–led citizen science projects encounter. The findings also indicate that 2021 recorded the highest frequency of bags of litter picked as members engaged in green exercise to foster physical and mental well-being (Kragh et al. 2016; Molsher and Townsend 2016) when COVID-19 outdoor restrictions were relaxed. These findings are similar to previous studies on beach clean-up campaigns, where improved personal well-being and awareness are key to why individuals volunteer (Wyles et al. 2017).

As an exploratory investigation, the findings of this study offer essential insights into how online communities can develop their own ways of generating knowledge to understand littering problems and the impact of their voluntary activities. However, these findings may be somewhat limited as not all group members are active online, and some group members do not record all their litter picking activities. In addition, the study used only 337 posts over a period of 3 years, making the findings difficult to generalise; using user-generated data (i.e., posts and comments) as the sole data collection tool was a limitation in the exploratory study. Future studies can consider using data collection methods such as semi-structured interviews, surveys, focus group discussions and visioning to understand the motivations and perceptions of online communities in understanding and addressing sustainability challenges such as littering.

CONCLUSION AND FUTURE DIRECTIONS

In conclusion, the study provides insights into how local communities use social media to engage with and to interact in developing online community–led citizen science to understand littering challenges and the impact of litter-picking activities. The Facebook group generates valid citizen science data that can help to explore issues such as spatial distribution of litter and litter characterisation, which are necessary to provide importantant waste disposal infrastructure. Future studies may consider co-producing open-source data collection tools that are accessible and can easily be adapted to different litter-picking activities to allow the comparison between case studies. There is a need for key stakeholders to identify grassroots-led citizen science projects and offer support and capacity-building to encourage the collection of more robust data-driven evidence to inform decision-making.

DATA ACCESSIBILITY STATEMENT

Extracted user-generated data and the codebook are available as supplementary information.

SUPPLEMENTARY FILES

The supplementary files for this article can be found as follows:

- **Supplemental File 1.** Extracted User-Generated Data. DOI: https://doi.org/10.5334/cstp.579.s1
- **Supplemental File 2.** Codebook for Data Analysis. DOI: https://doi.org/10.5334/cstp.579.s2

ETHICS AND CONSENT

The University of St Andrews' School of Geography and Sustainable Development Ethics Committee, acting on behalf of the University Teaching and Research Ethics Committee (UTREC), has approved this study (GG16312). The research conducted does not require the consent of participants as there was no direct interaction with human participants.

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COMPETING INTERESTS

The author has no competing interests to declare.

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