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Commentary

Participatory Modeling in Support of Citizen Science Research

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Abstract: Stakeholder engagement and participation is often an essential ingredient for successful environmental conservation and management. Including stakeholders in participatory environmental research has been an increasingly recognized necessity for understanding the complex nature of social–ecological systems (SES). The public is also essential to help structure environmental problems and decide on management interventions. As a result, new inclusive approaches to scientific research have emerged, such as Citizen Science. While there have been many climate change-related citizen science projects, in this paper, we provide an overview of a specific type of citizen science project. More specifically, we describe a participatory modeling approach to citizen science which can support climate change research.

Keywords: participatory modeling; social-ecological systems; social learning

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1. Introduction

The last decade has seen a vast increase in the number of interdisciplinary studies that seek to explain complex environmental problems, such as climate change, through a lens of both social and ecological processes [1–3]. The popularity of this approach has given rise to a new paradigm in environmental science and natural resource management focused on investigating coupled social-ecological systems (SES). This approach notes that many environmental issues cannot be well understood by relying merely on disciplinary scientific approaches alone [4]. This systems approach has become common-place in the literature and rests on the notion that human societies are nested within nature [5], and there are complex feedbacks between humans and their environment which link them [1,6].

At the heart of participatory approaches in resource management is the involvement of those who are affected by the environmental knowledge and the decisions that stem from that knowledge [7]. Certainly, the best practices in participatory research involve researchers taking the perspective of researching with, not on, participants. In this paper, we introduce an integration of Citizen Science and participatory modeling to address climate changed-related problems of local concern. We begin by introducing Citizen Science and participatory modeling, and then we share a case study of climate-related Citizen Science using participatory modeling and isolate some of the tensions that can arise when integrating these fields. We posit that the importance of integrating Citizen Science specifically with participatory modeling can enable stakeholders to meet goals while gathering important climate-related data.

2. Citizen Science

The last two decades have seen a considerable increase in the number of scientific studies that include the public as a partner in the scientific process through Citizen Science (hereafter CS), also referred to as public participation in scientific research [8,9]. An NSF-funded report [10] defined three major categories of projects including: (1) contributory projects that are usually scientist-designed where the public is included mainly in data collection; (2) collaborative projects that are structured by scientists, but citizens are given opportunities to provide some input on project design and in data collection; and (3) co-created projects which are more democratic partnerships where the public is actively engaged with all steps of the scientific process. In addition, Regalado [11] identified the potential of public-initiated scientific research, in which the project is done by members of the public with the established scientists joining at a later stage. Even though these categories of participation have been further subdivided (see [9]), the assertion is that public participation in science is on a continuum, and that both the scientific and social outcomes that emerge from CS projects are dependent on the context of the scientific problem and the structure of volunteer involvement.

Research on CS often focuses on either the method of generating or analyzing data that relies on distributed individuals or non-scientist communities or the CS participant themselves, investigating psychological, sociological, or other socially-mediated aspects or attributes of the individuals or communities that participate in Citizen Science projects [8]. Studies on CS frequently focus on the nature of the volunteers who participate in these programs, most commonly in terms of outcomes related to changes in knowledge, attitudes, behaviors [12], natural resource policy [13,14] or social capital [15,16]. Additional research explored the motivation and incentives that encourage participants to carry on their activities over time. More recently, this area of research has been extended to include technical aspects of using people as an observing or computational network [17,18], including providing technological platforms and practices meant to ensure data quality [19].

3. Participatory Modeling

Participatory modeling engages stakeholders' knowledge to create shared representations or models. These models are often formalized and can vary in terms of functionality and use. Like CS, participatory modeling (hereafter PM) is both a field of study and practice and also integrates the social, natural, and environmental sciences. Much work in PM has focused on engaging individuals in environmental study and decision-making (e.g., participatory rural appraisal [20]; Participatory Action Research [21]; and soft systems modeling [22]). Essential to PM, however, is the focus on the shared development of a model, or shared abstraction.

The inclusion of models to PM practice stems from the notion that models are central to science and human cognition. Through representing ideas in models, individuals are given a structured method for explaining how they think about the world and how it works. In this way, participatory research can benefit from the development of models as tools that support thinking and communication. More recently, research in PM has seen an increase in involving those who do not typically model (i.e., members of the public, especially those from marginalized or underrepresented groups in decision-making [23]).

4. Combining New Approaches

Recent work suggests that the scope of opportunities be widened to address larger scale social changes that may result from the Citizen Science (e.g., [24,25]). With this, there has been an increased interest among scholars and researchers regarding Citizen Science's contribution to community-level impacts and increasing public representation in scientific decision making [26,27]. Emerging research involving communities has generated new questions regarding how increased participation and community-level (i.e., social) learning, in aggregate with the generation of new data sets, may contribute to broader social or environmental change [24].

5. Justification

A challenge in engaging volunteers with citizen science is that individuals need a common and unbiased space to integrate goals, and research tools into a common space. This space must also allow for individuals to share a common language toward meeting specific goals. Through participatory modeling processes, individuals co-create the goal statement and use modeling in some way to define group actions (see [28,29] for examples).

One group action could be data collection; hence our interest in integrating CS with PM (Figure 1). Below, we describe our case study where we use shared mental modelling, specifically a semi-quantitative form of concept mapping, that would allow for multiple ideas to be discussed and debated in a common online environment. In addition, this space allows for individuals to rule out explanations with evidence and thus play a more meaningful role in data analysis and interpretation, which are all critical skills in many types of Citizen Science projects.

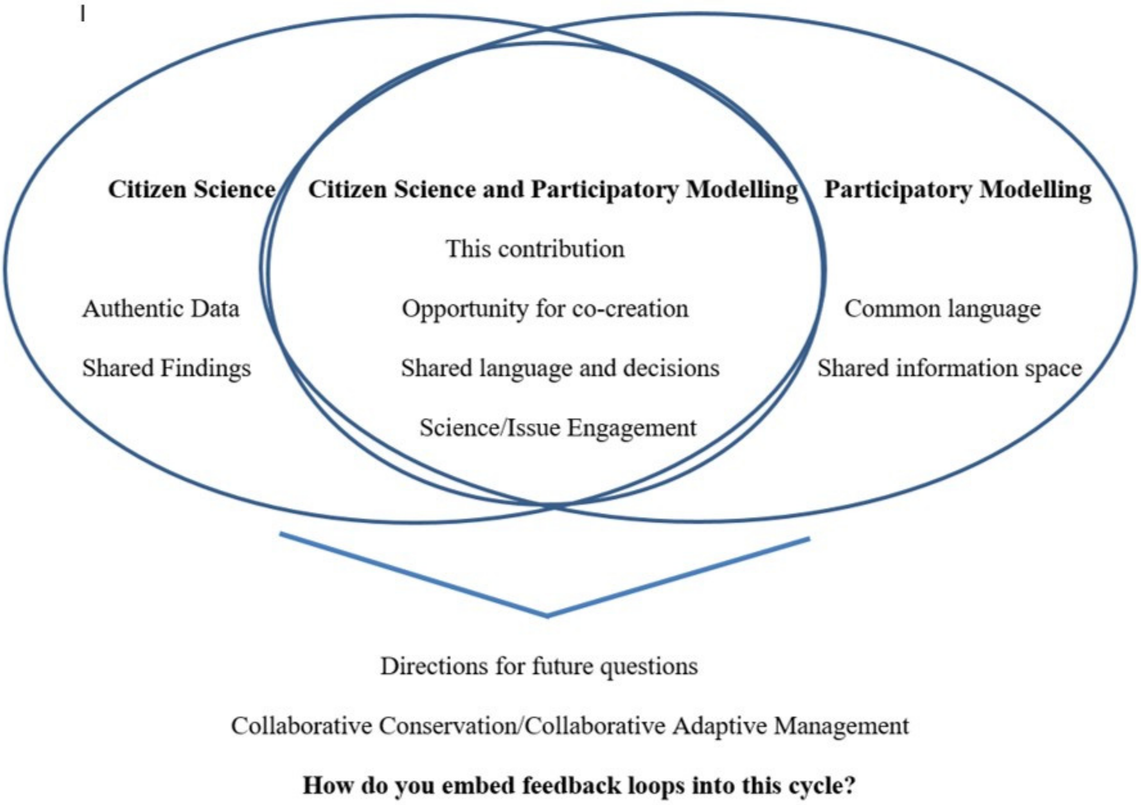

Figure 1. Citizen Science and Participatory Modelling overlap in the opportunities for collaboration and shared engagement in the sciences. This manuscript highlights the ways in which participatory modelling and Citizen Science practices complement each other in the interest of collaborative conservation and adaptive management. In particular, Citizen Science offers opportunities for authentic data gathering and shared results, whereas participatory modelling offers opportunity for common language establishment and shared information visioning and decision making. Critical for future research is the question of how does one embed feedback loops to ensure continued data collection and further refinement of the information that can be used to support decision-making.

6. Collaborative Science: A Preliminary Case Study

Given the changing climate, Sustaining Ecological Communities through Citizen Science and Online Collaboration (hereafter referred to as CollaborativeScience.org) was designed to be an ongoing online program, allowing individuals to identify problems of local concern and collaborate using models with natural resource managers to find solutions and resolutions. The Virginia Master Naturalists (hereafter VMN) is a Virginia state-sponsored natural resource volunteer organization. VMN participants are taught natural resource management, fundamental ecology, and the role of model-based reasoning in science. Volunteers in this program need to identify which information/data are necessary to collect in support or refute of specific resource management practices. Participants are given online and over the phone support throughout this collaborative-type of Citizen Science project.

Members of VMN were specifically targeted because the participants are self-selected enthusiasts of natural resource conservation, and as part of the program are required to participate in Citizen Science, environmental stewardship, or environmental education. We wanted to work with an already motivated group of volunteers because we wanted to ensure sustained participation (e.g., [30]), and an initial survey of these volunteers found that they were highly motivated to collaborate in this kind of work [31]. Prior to joining this project, all individuals participated in a 40-h natural resource training course. In the online environment, users were able to access instruction about ecosystems, ecosystem management, adaptive management, and a collaborative modelling tool that allows users to plan data collection and explore different management scenarios [32]. We chose the adaptive management approach [33] to allow for iterative collaborative learning and development.

The modelling space was a shared type of cognitive map that allowed for ideas to be made visible and discussed via online communication tools (see www.mentalmodeler.org (accessed on 2 February 2022) [32]). In addition, the web-based CitSci.org (citsci.org) was modified by its developers to accommodate data collection and the creation of management plans that could accompany the models. Each stage of the adaptive management plan (discuss, plan, implement, evaluate, and share) was listed on separate tabs and featured a discussion forum, question prompts, and collaborative "wiki" space for volunteers to share ideas. In addition, the "discuss" page had space for individuals to create and discuss their models, and the "implement" tab had the CitSci.org project information, which enabled individuals to create project data sheets, upload observations, view data, and share features (e.g., identification guides, tutorials, maps, etc.). Finally, the "share" page compiles the information into each wiki to create an executive summary of the project relevant that was relevant to participants and the stakeholders that participants were seeking to engage.

Throughout the training, participants were able to contact experts who provided feedback as the group defined the conservation issue to be addressed in the project. With the Collaborative Science project, participants noted that they were able to target questions for quick answers from experts, which resulted in more successful responses than when participants previously sought help with what they thought were vague questions (Jordan, pers. obs). With new data, groups were able to update and share their models online through an ongoing and iterative process of project design.

Jordan et al. [34] detailed outcomes from early iterations of Collaborative Science through two example projects. First, VMN volunteers were interested in the conservation and management of a Nature Conservancy (TNC)-owned property that contained a rare, fire-mediated pine savannah habitat and the endangered Red cockaded woodpecker. These participants worked with a TNC land manager and created a data plan to test different management regimes in the face of changing climate. The TNC gave the participants permission to test their ideas. Not only did their project enable them to work with TNC to better manage the space, but they also had the opportunity to publish their work [35]. Second, volunteers were concerned about a lack of riparian buffer in agriculture areas surrounding a wetland of interest, which was subject to increased bacterial counts and eutrophication, given increased warming. Therefore, with permission from landowners, and using their collaboratively developed model, citizen scientists gathered coliform data in the presence and absence of riparian buffers cattle grazing areas. They found evidence to suggest a need for riparian buffers as a means of maintaining water quality. After sharing these data, the Soil Conservation District awarded this team of volunteers USD 200,000 for site remediation [36].

7. Lessons Learned

We frame this section with the question, given the resource expense both in terms of time and dollars, was engagement in Collaborative Science worthwhile from the perspective of the researchers and participants? First, we focus on the participants. Based on data from Collaborative Science, Jordan et al. [34] found that group participation and engagement afforded individuals a sense that their ideas mattered with respect to the issue under investigation. Given this importance surrounding an issue, individuals can feel "membership, influence, [and an] emotional connection" with the work that are doing [37]. These factors in combination promote cohesion which can encourage a strong sense of place [38] and likely a desire to not only gather data but also to take action; the latter of which being critically important for climate change type projects.

Because research-driven adaptive management is necessarily iterative, from the researcher perspective, individuals need to repeatedly use tools to refine the information they gather over time. For example, citizen scientists who are gathering information about cattle, water quality, and heat stress will likely need to work with many individuals to gather these data over several locations and across time. CS projects like the one we described can add to larger data sets and will increase data generating capacity for the scientific community. What is essential to the stewardship through data gathering process, however, is the need for decision-makers to use the data in a truly iterative manner and in support of explanations with rigorous evidence. Adequate examples of this remain scant (e.g., [39]), but by providing the public with insight to one of the most powerful tools used by scientists, i.e., models, we argue that individuals can engage in reliable data collection and analysis across time and scale, in terms of producing a peer-reviewed paper while meeting local needs. Future questions include, how do we think the act of stewardship, which seemed to emerge through projects like ours, makes a change in the individual, and how does this feed back into data gathering goals in an effort to address complex problems that stem from climate change?

The outcomes of the sixth IPCC assessment (IPCC Report 2021; [40]) discussions indicated a number of tipping points (i.e., points of no return). These are points where the expected changes will not be reversible in any near term. The information that feeds into climate future forecasts is becoming better understood, increasingly refined, and more regionally and locally based. The latter presents a unique opportunity for individuals to continue to gather regional and local information with a clearer picture of how this information can be used in the broad landscape of climate models. Doing so will aid regions and localities in planning for a more dynamic future. Further, the local engagement in citizen science and participatory modelling may serve to motivate individuals to more deeply engage with local environments, histories, and decision-making. This IPCC report highlights a number of levers than can be engaged to meaningfully impact a global future where the least damaging future can be realized.

In conclusion, we saw from the VMN citizen scientists, through their use of Mental Modeler software, that they were able to ask and answer locally relevant scientific research questions and organize their data collection around answering these questions. Further, they were able to translate the results of their research to actionable, real-world change. From this case study, we see the beneficial outcome of creating change around environmental issues as a result of the deeper engagement in CS through social learning in participatory modeling (i.e., [24]).

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