Unveiling Research Intermediations in Citizen Science

Evelyne Françoise Lhoste, Loup Sardin

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Abstract:

Drawing on the conceptual framework of intermediations in grassroots innovation for sustainability, this paper presents the first in-depth analysis of the role of third sector organizations in citizen science. The empirical data are derived from 31 case studies of associations (representing 80% of third sector organizations in France). We identify two clusters of associations (social innovation and natural sciences) based on research domain. They differ in epistemic cultures, but they both value experiential and actionable knowledge. We present an analytical framework to characterize the role of these associations in citizen science. Derived from systemic intermediations for transitions, it is based on the association's position in networks, infrastructures, and projects. Our results reveal three categories of intermediations which depend on the organization's position in the network, the degree of structuration of its partnerships with academics, and the goals and achievements in the projects in which it is involved. In addition to articulating different knowledge in projects and learning in networks, associations perform the boundary work required to build hybrid infrastructures with institutions. A fourth category unveils the complexity of structuring hybrid epistemic communities for sustainability. This 4-way categorization of intermediations highlights the crucial roles of associations in a systemic approach to citizen science.

Keywords : innovation studies - community based research - participatory research - actionable knowledge - inclusion

Introduction

This article is intended to characterize the role of third sector organizations in citizen science (CS), with an emphasis on the systemic dimension of knowledge production (Joly 2020). The third sector concept is related to the Anglo-Saxon three-sector societal framework which includes the state, the market, and the third sector (Alcock 2010). According to Alcock, the third sector is associated with values and principles which may balance those of the state and the market. In France, third sector organizations are mostly associations[1], and little is known about their role in CS. To fill this knowledge gap, we mobilize the concept of grassroots innovation for transitions (Seyfang and Smith 2007). This literature explains how grassroots organizations experiment to solve local problems, and network with institutions to contribute to the achievement of the United Nations Sustainable Development Goals (SDGs). These third sector organizations coordinate the contributions of citizens to research, translate and circulate knowledge, and contribute to the problematization of otherwise unaddressed research questions (Seyfang and Smith 2007). Göbel et al. (2021) describe three main roles of these organizations in CS: (1) a technical role in the production of data and knowledge; (2) a governance role in the deliberation on research activities and risk assessment; and (3) an advocacy role by campaigning for transformative knowledge. In social innovation systems, they may be social innovation hubs, open labs, and transfer centers (Terstriep, Rehfeld and Kleverbeck 2020).

To conceptualize the roles of third sector organizations in CS, we draw on intermediations in grassroots innovation. Intermediations are the activities developed by agents to induce and facilitate interactions between actors coming from different worlds to co-produce knowledge for sustainability transitions. We will therefore combine the frameworks of transition intermediation and grassroots innovation for sustainability to analyze the activities of third sector organizations in CS. We will

[1] Under French law, an association is an "agreement by which two or more persons permanently pool their knowledge or activities for a purpose other than to share profits" (our translation, law of July 1, 1901).

address the following research questions: Who are the actors involved? How do they work to foster and facilitate interactions? What are the objectives of such intermediation? What networks and infrastructures are they involved in? We will trace how the actors mobilize and translate their values, knowledge, and rules to solve the challenges they encounter.

The paper is organized in four parts. First, we introduce our conceptual framework, research design, and case study methodology. Second, we present the results in two separate sections. In section 2, we compare goals, role and epistemic practices in 31 associations involved in CS. In section 3, we propose an analytical framework of CS intermediations. This framework highlights the crucial role of associations in a systemic approach to CS. Third, we discuss our findings in light of the literature. We conclude with some reflections that might inform future research on CS for sustainability, and help stakeholders and policymakers identify critical aspects for the societal impact of CS.

Conceptual Framework and Research Method

Our conceptual framework draws from two theoretical fields, innovation intermediation and grassroots innovation for sustainability. We mobilized a qualitative methodology to trace how the actors translate their values, knowledge, and rules into projects, networks and infrastructures to solve the challenges they encounter.

Conceptual framework

Grassroots innovation for sustainability was conceptualized originally by Seyfang and Smith (2007) as « innovation networks of activists and organizations that lead to bottom-up solutions for sustainable development, solutions that respond to the local situation and the interests and values of the communities involved » (p.587). Smith et al. (2017) suggest three features that typify grassroots innovations (which may be social or socio-technical). First, they are grounded in third sector organizations which follow different strategies and forms of engagement with institutions. Second, they use alternative forms of knowledge production to dominant ones: public participation, epistemic justice, openness, and common good. Third, they are political actors and adapt their strategies of alliances with institutions to advance their own objectives. Similar to social enterprises, they are able to weave

together the market, state, and community contexts (Terstriep, Rehfeld and Kleverbeck 2020; Unceta et al. 2020).

The notion of grassroots innovation is grounded in the Multi-Level Perspective (MLP), a conceptual framework developed for sustainability transitions (Geels, 2002). MLP analyzes the dynamics of transitions at three analytical levels: the niches where grassroots innovation can develop away from regime selection pressures, the socio-technical regimes (the rather stable research and innovation systems with technologies, practices, and institutions), and the exogenous socio-technical landscape (external contextual factors such as climate change or Covid crisis). Yet, compared to mainstream market innovation, grassroots innovations face different challenges for their effective diffusion, replication and upscaling processes which may be overcome by activities conceptualized as intermediations.

Intermediation refers to the involvement of entities or individuals that facilitate and enhance the flow of knowledge and collaborations between different actors within an innovation system (Klerkx and Leeuwis 2009). In the context of sustainability transitions, intermediations facilitate critical reflection and empowering in niche (Smith et al. 2016), and help aggregate lessons across experiments (Matschoss and Heiskanen (2017). Intermediations also aim at reconfiguring socio-technical systems through lobbying activities (Klerkx and Leeuwis 2009; Seyfang et al. 2014), political advocacy work (Smith et al. 2016), championing strategies (Martiskainen and Kivimaa 2018), institutional rule-changing (Polzin, von Flotow and Klerkx 2016), and disrupting incumbents of the dominant regime (Klerkx and Leeuwis 2009; Seyfang et al. 2014). Previous research on grassroots innovation also highlighted the crucial role of intermediations to support volunteer communities with professional skills, and establishment of links between niche actors and regime resource holders in multi-level institutional environments (Hargreaves et al. 2013; Lang, Chatterton and Mullins 2020). Based on a literature review, Sovacool et al. (2020) identified 18 different functions or activities as intermediations. Van Welie et al. (2020) reduced this typology to three: 1. Articulation of activities required to support experimentation and generalization of innovation, 2. Alignment of dispersed resources and talents through networks, and 3. Learning and training-related activities to enhance stakeholder capabilities and share goals and culture i.e. to

establish new institutions. This last function includes knowledge development, knowledge dissemination, entrepreneurial activities, and legitimation of action.

All these authors highlighted the boundary work that agents performk in networks (Kanda et al. 2020; van Welie, Boon and Truffer 2020), and in infrastructures (Hargreaves et al. 2013) to demarcate their activities from other forms of knowledge production. Drawing on this conceptual framework, we will characterize intermediations in third sector organizations both at the project (niche) and at the system (regime) levels. In this systemic approach to CS, our analytical framework gives importance to actors, networks, and infrastructures which are vectors of knowledge creation and social change (Loconto 2023). Such an approach depends on the socio-historical context, the actors involved in the process, and the chronology of events prior to and during a CS project.

Methodology and analysis

We collected the empirical material between 2019 and 2022, as part of a formative evaluation of an experimental subsidy to CS. In France, associations receive wage subsidies for their cultural and educational activities through a measure called FONJEP (Ministry of National Education and Youth) and through public policies on Public understanding of sciences funded by the Ministry of Higher Education, Research and Innovation. They are not eligible to public fundingfor social innovation (Bouges, Zieds, Marielle, and Barth, Mickael 2022). To overcome this imbalance, FONJEP-Recherche, a new public policy instrument was piloted to fund the wage of ½ salaried position dedicated to CS for a period of three years. Between 2019 and 2021, the Ministry of National Education and Youth launched 3 calls for projects for FONJEP-Recherche and selected 60 projects. As part of the pilot, the steering committee of the call for projects commissioned the first author of this article[2] to manage a formative evaluation process through the ASIRPA real time

[2] She is a member of a think tank advocating for support and structuration of a third sector in research and innovation since 2013. This think tank lobbied for the experimentation of the Fonjep-recherche.

method (Matt, Robinson, Joly, Van Dis et Colinet, 2023). This method uses a real time impact assessment tool (called impact pathway) to help project managers to maximize societal impacts of transformative research. The first author participated in the steering committee meetings prior to and after each call, in the three selection processes of grant winners, and co-organised three meetings of the professional network-to-be. She regularly presented and discussed her results with the steering committee. In addition, she conducted 50 interviews: 1. with members of the steering committee, and 2. with staff members of 35 associations (including grant winners). She also performed several days of participatory observation in four associations, and co-organized three one-day meetings to nurture a professional network of grant winners. At the end of the formative evaluation (2022), both authors organized three focus groups with the grant winners (22 participated) and three volunteers of the steering committee. The participants were invited to contribute to the impact pathway of the FONJEP-Recherche through their own experience of the experimentation. They were asked the following questions. What have you achieved in the last 2 years? What new and old players and partners have been involved? What changes have you observed in your organization? Among your partners? What hasn't worked? What impact on society do you think FONJEP-Recherche can contribute to?

Data analysis involved several steps. The interviews were transcribed and encoded using NVIVO software together with field notes. We also read websites and documents provided by interviewees. First, we produced a summary of each association that received a subsidy, based on interviews and on information contained in the application form to the FONJEP-Recherche call. Overall, the history, mission, size, sector, values, projects, networks, and infrastructures are detailed for each association in thirty-five synthetic data sheets and two overview tables (supplemental material). We paid special attention to the organizations' relationships with research institutions, network membership and coordination, and any other activities related to knowledge production and knowledge circulation. Second, we

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These embedded practices allowed her to develop of a deep knowledge of the actors, networks and institutions involved in citizen science in France.

produced an analytical framework of research intermediation categories drawing on the literature on transition intermediations. In addition to data provided by the interviews and application files, this framework was fed with progress reports that the grant winners produced during participatory observations *in situ* and meetings of the professional network. Finally, the focus groups allowed us to assess the changes interviewees had observed, along with the barriers and levers of their contribution to CS. This allowed us to enrich our analysis framework with the contexts, realities, and difficulties of the research activities in the case studies.

Among the 35 associations that received subsidies, 31 were actually involved in CS processes, and therefore included in this case study. Since it is not possible to describe extensively the research intermediations for each case in a single article, we presented the results in three formats. Detailed data are provided in the supplement files: interview guide, synthetic data sheets, and overview tables. The impact pathway has been published separately (Lhoste and Sardin 2022). In the following sections, we focus on a smaller number of cases which represent archetypal examples from the various dimensions we have identified as essential.

Goals, Roles, and Epistemic Cultures of the Case Studies

In this first section of results, we discuss the associations' research domains and values, and other descriptive characteristics. We posit that they all are involved in grassroots innovations since their research projects aim at satisfying unmet needs, and that contributing to at least one of the SDGs was mandatory for eligibility to FONJEP-Recherche. Table 1 gives an overlook of the variety, with 11 associations we consider as archetypal from the different categories. For some of them, producing knowledge is the central objective, while for others, it is a means to fulfill their goals (see column "activity"). Their beneficiaries may be either lay people, professionals, or organizations (see column "beneficiaries"). We differentiated two clusters of associations for CS: social innovation and natural science. There were twenty-six in the first cluster and five in the second one.

At first glance, the two clusters differ in type of production (science vs. innovation), epistemic practices (phenology vs. action-research), administration of evidence (practical implementation vs. scientific publication), and more broadly in

epistemic culture i.e. in epistemologies, history, values, and visions of a scientific field (Knorr-Cetina 1999). Indeed, attitudes to objectivity and neutrality in research practices and to experiential knowledge differ in both clusters. Naturalists seem closer to the professional identity of public scientists they work with. They view citizen participation as a way to raise awareness and develop new skills in lay people. They engage in research projects with social scientists to understand the effects of participation on these individuals –towards science and the environment-, the objectivity and validity of the scientific data produced, and on how to raise engagement of volunteers. They rarely examine how citizen participation might transform epistemic cultures in academia and in research organizations. Overall, these questions are much less self-reflexive than those addressed in the social innovation cluster.

A more detailed analysis of the epistemic cultures within associations also reveals commonalities between the two clusters. They both value experiential and actionable knowledge since they are involved in action, whether nature protection or social services. Indeed, several associations were funded by scientists seeking to reconcile action and research. They also share epistemic practices. Observation is an instrument for both nature conservation and social innovation. In fact, the naturalist associations of our case studies have set up their own observatories. There are also several in social innovation. For example, MA-HdF administers surveys and manage observatories to observe social and cultural practices in France.

224 Table 1. Activities, beneficiaries, research field and epistemic practices of 11
225 associations.

Case	Activities	Beneficiaries	Research field	Epistemic practices
PN	observes, protects and studies the fauna of Picardy	amateurs, scientists	natural science	observational sciences/ phenology
Tela Botanica	leading and managing a collaborative platform of botanists	amateurs, scientists	natural science	observational sciences/ phenology
CREA	Explore the impact of climate change on mountain biodiversity, raise awareness of high altitude ecosystems, and provide expertise to policy makers.	scientists, public authorities, professionals	natural science	observational sciences/ phenology / social sciences
BIO-OC	develop and promote organic agriculture through technical support, training, information, research/experimentation.	organic food sector	social innovation	action-research
Evaleco	steers a bundle of social and environmental research and innovation activities	inhabitants, public authorities	social innovation	action-research
Fab'lim	Brokering of a research-action-innovation cluster for sustainable and inclusive agri-food systems.	scientists, public authorities	social innovation	action-research
AF-UPP	Resource center for action-research projects organised by collectives with/for parents experiencing exclusion.	associations	social innovation	action-research
MAHdF	lobbying, community developpement, coaching of associations, networking for local developpement of associative life.	associations	social innovation	action-research / observational sciences
RNMA	support for the development of association centres throughout the territory (advice and support for communities in the project).	associations	social innovation	action-research/observational sciences
FAPI	improve the care of unaccompanied minors from West Africa.	social workers	social innovation	action-research
APPUII	advice to residents' groups in the field of urban renewal.	inhabitants	social innovation	observational sciences

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227 ***Social innovation***

228 In the social innovation cluster, CS is aimed at producing actionable
229 knowledge (Table 1 column “Activities”). There are three categories of associations:
230 leader associations, innovation brokers or service associations. Leader associations

manage a professional network and mutualize resources for their members. They provide a bundle of services which include facilitation and coordination of action-research projects in multi-actor networks. For instance, BIO-OC represents the interests of the organic food sector in the Occitanie Région. It supports change in practices through action-research projects. Innovation brokers orchestrate innovation networks (Batterink et al. 2010). For instance, Fab'Lim is a research-action-innovation center for sustainable and inclusive food systems which steers and advises social innovation in the Occitanie region (*territoire*). The association manages hybrid networks to address local problems, in partnerships with public authorities and research institutions. Service associations organize action-research projects to improve guidance services to a variety of excluded populations, and support services to professionals, whether social workers, sex workers, or artists. They identify emerging problems and co-create innovations in multi-actor networks. They may also produce relevant data for policy makers. They value epistemic justice and adopt strategies to build trust in science among excluded populations. For example, AF-UPP is a network which support parents' groups (popular universities) in action-research projects on education. The interviewee of AF-UPP testifies that at the beginning, parents suspect scientists to be lesson-givers and disrespectful of their experiential knowledge. Therefore, AP-UPP signs up with analysts from unrelated disciplines, to design a scientific protocol with groups of parents. They also develop participatory methods that respect the weaknesses of the most vulnerable members of society.

Natural sciences

This cluster includes associations generally considered as intermediaries between academia and non-professional scientists, although this notion has never been detailed. Most of these associations have a long-term engagement in natural resources management, and some of them are local activists. For example, PN has been involved in compiling lists of biodiversity in various marine species including seals since 1970 together with seal watching in the Somme bay. Unlike other naturalist associations which claim neutrality, PN regularly file a complaint against poachers, and engage in local controversies on wildlife regulation. They consider that these social actions do not counter to their scientific thoroughness.

Naturalist associations are recognized as community managers for amateur naturalists (Table 1 column “Activities”). Simply put, a community manager negotiates the connection between scientists and amateurs. But “amateur” refers to a heterogeneous category in terms of expertise (whether academics or field experience), degree of motivation for collecting samples (for pleasure or work), occupational status (employee or volunteer), and relations to knowledge (bird watcher or resource management). At the end, PN members may be more motivated by seal surveillance than by sample picking. The community manager has to mobilize her knowledge on the community’s preferences, on animals’ lifestyle and behavior, and on scientists’ expectations, to design suitable collection protocols. She has also to enroll researchers in new research programs initiated by the expert amateurs.

Networks, Institutions, and Roles of Associations

In the previous section of results, we differentiated associations according to epistemic cultures, and goals of the associations. In this second section, we propose a typology of research intermediations based on the analyses of the 31 cases for the association’s position in networks, infrastructures, and projects (Table 2). We observed that they play as transition intermediaries in CS system. They develop strategies, tools, and methods to identify goals, link stakeholders, and formulate research questions. They allow actors from different backgrounds and cultures to interact. They provide networks with technical and engineering knowledge. They help these networks to identify unsolved problems, mobilize researchers and stakeholders, and formulate research questions. They may manage an infrastructure, whether open lab or observatory. They advocate for transformations of public policies. As Barré puts it (2020), they “facilitate exchanges and reflexivity while managing conflicts, and promote the cross-fertilization of knowledge and shared decisions” (*authors’ translation*). Intermediations allow the development of common knowledge and collective learning about others’ representation, contexts and activities.

In our case studies, each of these activities meet a specific need at a given time or, on the contrary, constitute the association's mission. We ordered them in three categories according to whether they are related to projects, networks, or

infrastructures. These three categories are not mutually exclusive. In practice, networking can lead to new research projects and/or the creation of infrastructure. Infrastructures such as observatories are fed with the data collected during research projects while open labs require networking with local stakeholders. We also identified a fourth category related to facilitation between citizens and scientists. This fourth category is essential to the success of CS, each association creates tools and methods adapted to its research field and to the actors involved in projects.

302 Table 2. Intermediations in 11 associations.

Case	Role of association	Network leader	Network member	Manager of an infrastructure	Function in CS projects
PN	community manager	no	3 disciplinary networks	observatory in phenology (database)	1. to develop interactions between researchers and volunteers, 2. to maintain regular relations with the other local actors and 3. to be (re)known as a local actor of seal protection.
Tela Botanica	community manager	no	1 network	Digital platform /observatory (data base)	The association runs several participatory research programs: data base management, community management, support researchers in communication and outreach activities.
CREA	community manager	no	none	Collaborative platform and observatory (data base)	1. to value the data collected by participatory research with respect to contributors and stakeholders 2. to understand the motivations of contributors, 3. to compare image analyses according to 3 methods: the expert researcher, the automatic recognition of animals (machine learning), and crowdsourcing.
Evaleco	innovation broker	no	none	Open lab	To animate the third place while developing and structuring a hybrid epistemic community made up of actors from higher education and research, field actors and residents of the open lab.
Fab'lim	innovation brokers	no	3 networks	no	to create, manage and support social innovation projects for sustainable and inclusive food systems based on economic cooperation between local stakeholders.
BIO-OC	network leader	yes	National and regional networks	no	to structure the network in terms of action-research and expertise to support change and improve agri-food practices.
AF-UPP	network leader	yes	1 network	no	After 20 years of UPP, AF-UPP uses its newly formed scientific council to help participants identify new research question, disseminate knowledge in cross-fertilization through training courses for social workers, organizes the restitution of the results of UPP, and advocates on social issues.
MAHdF	network leader	yes	2 networks, 2 associations	no	produce knowledge on regional associative life: survey on the needs/interest of associations in terms of research and development, co-sponsorship of a research program with the French Institute of the Associative World.
RNMA	network leader	yes	1 network	no	share the analysis of local databases, support members in creating a laboratory for digital transformation on a inter-regional scale, develop local partnerships with the academic world, - coordinate a research-action to analyze the different types of structuring of local associations.
FAPI	service provider	no	4 networks	no	Research projects with social workers from both France and African countries: 1/ organize a hybrid research-action seminar on the social accompaniment of unaccompanied minors. 2/capitalize the results of these experiments in the NGO networks and towards institutional actors, 3. disseminate participation of the staff in training programs for social workers, and of the director in union network.
APPUII	service provider	no	1 european network	observatory of urban transitions	Transversal projects for capitalization and advocacy: 1. mapping of urban and social transformation, 2. study o the renewal of forms of solidarity in the context of Covid crisis, 3. evaluation of the cost of destroying solidarit and the energy cost of demolition/reconstruction.

Framing and coordinating CS projects

Our case studies illustrate the diversity of CS projects. They also offer an overview of the complexity of nurturing an epistemic community, i.e. a group of people with shared interests, focused on generating and spreading knowledge within a specific field. This community slowly emerges through a bundle of intermediations accomplished during the projects. Intermediations change over time, from animating heterogeneous collectives to framing research questions to disseminating output and outcomes. Dissemination includes scaling of innovations through replication, advocating for policies, and training of professionals to transform rules, cultures and norms within a system. Our case study abounds with examples in a variety of sectors. In urban planning, APPUII offers counter-expertise to a non-participatory rehabilitation project, establishes shared diagnosis with inhabitants, and proposes alternative projects. In social work and inclusion, FAPI co-construct and assess action-research programs with a network of researchers and West African and French child protection non-governmental organizations (NGOs). The organization has developed a social program based on the needs of unaccompanied minors and exchanges between French and Senegalese social workers. Its participation in an Erasmus Plus program should allow its extension to other parts of West Africa and Europe. The association also organizes the generalization of practices within professional networks and allows “learning in project and remembering in networks” (Grabher 2004).

The above examples draw from social innovation. In natural sciences, the goals and challenges of intermediations are different. We observed that managing an amateur community involves more than just mobilizing citizens to collect data for scientists. The case studies highlight the often-ignored expertise of the association’s staff. The naturalist associations manage either small communities of volunteers collecting and handling biological samples, or large virtual communities uploading data on a digital platform. In either case, associations are intermediaries. In PN, a professional ecologist supervises the volunteers who count seals and monitor their mating habits on Picardy beaches. She trains non-experts, validates their observations directly in situ, and can even award them expert status. She also translates the volunteers’ experiential knowledge into protocols co-written with

335 academic researchers not involved in the fieldwork. The digital platform of Tela
336 Botanica has been developed to provide training and meeting facilities for
337 communities to manage themselves. Tela Botanica also organizes on-site gatherings
338 for community members. The staff encourage scientists to attend these meetings,
339 and assists them in their communication and outreach activities. In addition, the
340 integration of the repository of French names produced by the Tela Botanica's
341 community into the national taxonomic repository of the flora required a time-
342 consuming boundary work.

343 ***Designing and co-managing infrastructures***

344 Several of the associations studied manage infrastructures for intermediation:
345 collaborative platforms for community management, a variety of observatories, open
346 labs, and publishing houses (Table 2). The open labs claim to enact sustainability
347 transitions in territories. For instance, Evaleco has been created for this purpose. The
348 association manages an open lab for research and innovation. Intermediations aim at
349 building co-learning strategies in hybrid groups, experimentation, and raising
350 questions on socio-economic models and governance. Our observations confirm
351 previous results on open labs showing that they provide niches to nurture social
352 innovations and experiment with new ways of governing and learning (Lhoste 2020;
353 Terstriep, Rehfeld and Kleverbeck 2020). At the local level, the association's goal is
354 to extend the collective and its portfolio of projects, and to bring together
355 organizations and research institutions into research and innovation networks. At
356 regime level, these open labs belong to national networks and thus can contribute to
357 transformation of the system.

358 Observatories are fed by the associations' databases and co-managed with
359 institutions. In natural sciences, both Tela Botanica and CREA manage two
360 supplementary virtual collaborative platforms and their corresponding databases. The
361 first one was created by CREA to observe the impact of climate change on mountain
362 fauna and flora and the second one was co-founded by Tela Botanica and CNRS in
363 2008 to monitor the phenology of flora and fauna in the plains of metropolitan France.
364 Both platforms work in partnership and share their data and results. In social
365 innovation, La Fonda manages a digital database of social innovations in
366 collaboration with a public organization, the General Commission for Territorial

Equality (*Commissariat général à l'égalité des territoires)* and RNMA manages local observatories of associative life, a result of a long-term collaboration with a CNRS lab (Tchernonog and Prouteau 2019).

Observatories embody partnerships between associations and institutions. Intermediations allow the construction of coalitions around a common vision for transitions. But the governance of these hybrid networks often does not favor associations. In natural sciences, the staff of Tela botanica testified to the difficulties they encountered in managing data ownership with public research organizations. This is due to the fact that the latter have normalized intellectual property with their private partners, but they confuse public goods with commons. This raises questions about the governance of data collected in CS projects.

Networking with institutions

Networks and infrastructures connect associations to institutions. Networks facilitate reflexivity, organize working groups, and steer research projects. They may also merge with other networks to organize training and advocacy, and construct coalitions around a common vision. These networks are connected to institutions at the local and national levels, and their boundary work progressively transforms them. For example, one of the parents' groups who participated to an AF-UPP program is working together with a police station to improve their relationships with families and youth, At the national level, AF-UPP is connected to *Caisse nationale d'allocations familales*, a public institution that finances all family benefit schemes, and the Ministries of Health and Solidarities, and of National Education. This hybrid network brings together associations, professionals, and institutions to change public policy and establish new rules and practices.

Networking with institutions is a long, time consuming, and uncertain process. Our observations reveal how it is constructed in action. Whether an association networks with academics depends on the association's history. Half of our case studies have been established by scientists who are often affiliated to a public laboratory. Most of them invite researchers to sit on their boards or create scientific councils that facilitate regular exchanges with academics outside the research partnership. They also organize seminars involving academic researchers and field

workers. They participate in training programs: students play an important role in the creation of links between labs and associations through Master's level research often supervised by a senior in the association (master degree or PhD).

Facilitating interactions between citizens and scientists

Intermediations include knowledge brokering between citizens and scientists. Knowledge brokering is bidirectional between actors from different worlds (Kivimaa et al. 2019). In other words, associations symmetrically translate knowledge and cultures for both parties. When they are community managers, they first negotiate between human and non-human agents - whether living creatures or objects- to articulate the expectations of every type of contributor. They develop tools and intermediary objects to enable the building of trust, construct a common vision, and identify the barriers to participation of both scientists and citizens. They are key actors of more horizontal relationships in CS processes. Secondly, they ensure that the association's program is consistent with the aspirations of the extended peer community, whether the contributors are full members of the association, or volunteers with no decision power in the association's board. The community managers constantly adapt to transformations of the community and anticipate conflicts and trade-offs between differing motivations, interests and functions within the community. For example, Tela Botanica recently revised its strategic action plan after staff members realized that most of its contributors were not hobbyists anymore, but professionals who were using biodiversity monitoring as a tool for decision-making.

Intermediations in CSs often include legitimizing experiential knowledge. Association staff and expert volunteers are not only spokespersons for excluded people; they encourage them to speak out to assert their experiential knowledge. They can manage tensions among actors, design and use adapted tools and resources, and convince either volunteers or scientists to contribute to mixed groups and CSs projects. They also design new governance frameworks with boards including representatives of each category of participants. For example, the board of AF-UPP includes parents, academics, stakeholders, and social workers. AF-UPP developed a method of knowledge cross-fertilization based on over 20 years of action-research with groups of parents. AF-UPP organized the publication of

research results and their presentation during a congress for academics and stakeholders.

Finally, associations engage in advocacy activities for inclusion and legitimation of experiential learning. Obviously, social innovation needs more intermediations for crossing knowledge, whether within research projects or governance bodies, and it is also the domain where it is the most actively defended. In more academic disciplines like natural sciences, we have observed tensions within associations which stay at the boundary between two worlds, that of normal science and that of amateur practices.

Discussion

We characterized the role of third sector organizations in CS with an emphasis on the systemic dimension of knowledge production (Joly 2020). The concept of CS gives undue importance to interactions between lay individuals and scientists in temporally limited projects, and neglects the role of organizations in these systems. Institutions characterize CS according to the type of knowledge produced and the level of citizen participation in scientific projects. Briefly, they refer either to crowdsourcing or to participatory research, i.e. co-production of knowledge with lay people, in accordance with the scientific literature on CS (Cointet and Joly 2016; Strasser et al. 2019). None of these typologies acknowledges the role of organizations. Consequently, the transformative potential of CS has been studied at the individual level (development of individual skills and awareness), but seldom at the system level (organizational and institutional levels) (Bela et al., 2016). Yet, the knowledge co-produced by AIDS treatment activists (Epstein 1995), patients' associations (Callon and Rabeharisoa 2008), and environmental justice movement (Ottinger 2010) transformed society. Opposite to CS, the concept of sustainable transitions posits that organizations are part of a socio-technical regime of knowledge production. It also posits that integrating third sector organizations in the system is transformational at the regime level (Schot and Steinmueller 2018).

We used the theoretical framework of grassroots innovations for sustainability to conceptualize intermediations in a system of CS. Our results first reveal that associations are engaged in various forms of co-production of knowledge with

academics and other stakeholders. We recognized them as observational science and social innovation. In our case studies, most associations were involved in social innovation and therefore part of a recently described Social Innovation System (Bouges, Zieds, Marielle, and Barth, Mickael 2022; Unceta et al. 2020). Observational science is not exclusive to naturalist associations. They aim at producing both scientific articles and actionable knowledge. The contribution of these associations to CS aims to serve the strategy of the association with regard to SDGs. Second, our results reveal that associations are transition intermediaries (Kivimaa et al. 2019). Transition intermediaries are “actors and platforms that positively influence sustainability transition processes by linking actors and activities, and their related skills and resources, or by connecting transition visions and demands of networks of actors with existing regimes in order to create momentum for socio-technical system change, to create new collaborations within and across niche technologies, ideas and markets, and to disrupt dominant unsustainable socio-technical configurations” (Kivimaa et al. 2019, p.1012). We identified three categories of transition intermediaries in associations. The first one, innovation broker, exactly matches the definition of transition intermediaries as this is their chore business. In the two other categories (leader associations, and service providers), transition intermediations are only part of their business. Our typology may not be exhaustive since the 31 cases do not represent the diversity of CS but only associations that submitted a proposal to the Ministry of Education, a selection process that may have favored associations aware of this finance desk, yet excluding activist associations such as those described in (Göbel, Ottolini et Schulze, 2021). Yet, it differs from Kanda’s typology of intermediaries (2020) which depends on three system levels within which intermediation occurs: (i) in-between entities in a network, (ii) in-between networks of entities, and (iii) in-between actors, networks, and institutions. Our results reveal that associations act indifferently at these three system levels, depending on their needs to overcome the challenges emerging along the way. We also confirmed that although essential to CS, associations are mostly unaware of their systemic function (Hodson, Marvin and Bulkeley 2013; Moss 2009).

Whatever the purpose of the research to which the associations contribute (natural science or social innovation) and whatever the category to which they

belong, our results show that they carry out a variety of intermediations. These intermediations vary in nature and intensity over time as challenges emerge on the way to sustainability transitions, and as a function of the strategic purposes of the organization. We describe four functions, three emphasize the systemic dimension of CS, and a last one highlights their role in the interaction between individual citizens and scientists. They facilitate co-construction and monitor participation of individuals in projects. They also facilitate individual and organizational learning in networks and infrastructures. Yet they contribute to the transformation of organizations, rules, cultures, and epistemologies and to a complete new knowledge structure and cognitive framework (Irwin 2014).

Our case studies confirm the variety of activities and the complexity of intermediations which have previously been described in the literature on grassroots innovation systems. In CS, the results are still scarce although they also demonstrated that third sector organizations were key to a CS system (Göbel, Ottolini and Schulze 2021). In the French context of CS, Barré (2020) identified three key objectives of intermediations : 1. To provide novel responses to new or unsatisfied social needs, 2. To strengthen actors' capacities for action, and 3. To develop and disseminate social innovation. His results also reveal that in practice, intermediations are distributed within networks and spread across time.

Conclusion

This article unveils the neglected role of associations in CS. We propose an analytical framework to better understand the complexity of intermediations occurring at the system level of research and innovation. This framework highlights the role of CS in advancing sustainability transitions (or transformative change more broadly). It is important to articulate the needs of third sector and research organizations, and organize social learning in projects, networks and infrastructures. This should contribute to the generalization of strong participatory paradigms in CS. Future research should examine if and howvalues, rules and norms are transformed.

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Data Availability Statement

As part of the evaluation process of a public funding, interviews, focus groups, meetings and observations in associations were mandatory for the association's staff. Informed consent was not declared. Interviewees have agreed for the diffusion of verbatim in the report to FONJEP steering committee. Data are not available as consent was not sought for this article.

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