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Citizen-driven participatory research conducted through knowledge intermediary units. A thematic synthesis of the literature on "Science Shops"

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Abstract

A Science Shop acts as a mission-oriented intermediary unit between the scientific sphere and civil society organizations. It seeks to facilitate citizen-driven open science projects that respond to the needs of civil society organizations and which, typically, include students in the work process. We performed a thematic analysis of a systematically selected literature on Science Shops to understand how the scientific literature reflects the historical evolution of Science Shops in different settings and what factors the literature associates with the rise and fall of the Science Shop. We used the PRISMA methodology to search for scientific papers in indexed journals in eight databases published in English, French and Spanish, and employed the thematic theory approach to extract and systematize our results. Twenty-six scientific articles met the inclusion criteria. We identified three meta-categories and ten sub-topics which can serve as key pointers to guide the set-up and future work of Science Shops. Our results identify a major paradox: Science Shops incorporate public values in their scientific agendas but have difficulties sustaining themselves institutionally as they do not fit the current dominant research paradigm. Science shops represent a persuasive complementary approach to the way science is defined, executed and produced today.

Keywords Citizen science; Community action; Participation and science governance

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Introduction

The definition of research priorities and agendas is generally left in the hands of a small number of individuals, and civil society members are not usually included in the decision-making process concerning research funding [McNie, Parris and Sarewitz, 2016]. This could potentially mean a mismatch between public investment in research and innovation and citizens' concerns and needs

[Petit-Zeman, Firkins and Scadding, 2010; Rafols and Yegros, 2018]. At the same time, scientific research processes remain mostly closed, with only scientists participating in the design of the analytical frames and protocols of research projects and in their subsequent execution, a state of affairs that can generate a considerable volume of inaccurate, redundant research results [Chalmers et al., 2014].

Various initiatives have been taken in recent decades highlighting the widening gap between science and society and urging European science policy to tackle the problem, most notably in the Rome Declaration [European Commission, 2014]. The European Commission has, for the past two decades, promoted 'Science with and for Society' and recently put 'Responsible Research and Innovation' (RRI) and 'Open Science' (OSc) at the core of its research and innovation framework programmes Horizon 2020 and Horizon Europe. These two paradigms advocate the promotion of more ethical, open, inclusive, reflexive and participatory science. RRI seeks to ensure that societal actors work together throughout the entire research and innovation process so that both this process and its outcomes can be better aligned with the values, needs and expectations of society [von Schomberg, 2013]. The RRI package is characterized above all by multi-actor and public engagement in research and innovation, open-access publications that facilitate dissemination of scientific results, and the promotion of gender and ethics in the research and innovation content and process, and formal and informal science education [RRI Tools, 2014]. OSc adopts a democratic, pragmatic and public approach to research in its efforts to promote engagement and collaboration with a broader range of stakeholders and to foster better public access to research projects and publications [Fecher and Friesike, 2014]. At both country and institutional levels, some of these principles are currently being operationalized by different forms of cross-sector and interdisciplinary collaborations, including participatory models in which science and society can work more closely together [Stilgoe, Owen and Macnaghten, 2013].

One example of such collaboration is the "Science Shop", an approach that facilitates collaborative research and the completion of innovation projects that address the concerns expressed by civil society organizations (CSOs) [Mulder and De Bok, 2006]. Science Shops involve civil society members, students and researchers, and allow the creation of synergies between social issues and scientific inquiry. Science Shops, in their role as intermediary units, facilitate citizen-driven research projects that can address the needs of civil organisations. Science Shops are, moreover, considered an original and interactive form of science communication, with the distinct feature that they prioritize research topics according to civil society needs. Even though each Science Shop will tend to adopt a different model, one step in the operational process that is completed by all is the devolution of their research results to societal actors. This can be done in many ways, through the preparation of a report using plain language and infographics or by using other forms of communication such as a public oral presentation, a science café, etc.

Giving engaged, knowledgeable civil stakeholders a co-researcher role in shaping scientific projects is one way to facilitate transformation towards useful and more actionable knowledge [McNie, Parris and Sarewitz, 2016]. Mostly based within universities to date, Science Shops and other similar participatory research units

converge on and also expand into other spaces, such as NGOs, science museums, research centres and companies. They are one of the few 'institutionally nomadic' structures [Pel et al., 2017] promoting participatory approaches that involve a broad range of stakeholders from the very first phase of the research process. As part of this process, stakeholders jointly identify and prioritize research questions as well as jointly execute projects until the research results can be channelled back to the community. With the exception of Science Shops, it is unusual to find CSOs in regular contact with formal academic institutions, and researchers regularly creating partnerships with civil society groups to prioritize research and innovation agendas and jointly implement projects, while engaging students in the research process as a part of their training. Since the beginning of the Science Shop movement in the early 1970s, interest has grown considerably in this mechanism operating at the science-society interface in many countries in Europe and on other continents. By 1999, and thanks to various European funded projects (PERARES, STACS, TRAMS, ISSNET, SCIPAS, etc.), the international Science Shop network — the so-called 'Living Knowledge' network — had been consolidated. However, the new century saw the closure of many European Science Shops and even the Netherlands, the birthplace of the movement, saw the demise of several of its oldest structures. More recently though Science Shops have begun to attract attention again as they seek out new roles within the framework of RRI and the OSc paradigm. Yet, serious concerns about the sustainability of the model remain and these need to be addressed.

In this article we seek to provide answers to the following two questions: first, what features characterise the landscape of Science Shops in the sphere of scientific production? And, second, what factors does the literature associate with the rise and fall of Science Shops? To answer these questions, we performed a thematic analysis of a systematically selected literature on Science Shops with the aim of retrieving, reviewing and analysing the scientific evidence on Science Shops published in scientific journals. We then present the most salient aspects that enable us to respond to our research questions.

Methods

2.1 Search strategy: selection of the scientific corpus

A detailed protocol was drawn up in accordance with the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" or PRISMA checklist [Liberati et al., 2009; Shamseer et al., 2015] so that each step in the subsequent review process could be clearly defined. PRISMA, developed by a group of 29 review authors, methodologists, clinicians, medical editors, and consumers [Liberati et al., 2009], provides a standard protocol that outlines a strict process to be followed when performing a systematic selection of the literature.

Five indexing terms in three different languages were used in the literature search: "Science Shop" OR "Science Shops" OR "Boutique des Sciences" OR "Boutique de Science" OR "Bazar de la Ciencia". We intentionally opted not to include specific aspects related to Science Shops' intermediary structures and projects in this search, or even to include other synonyms because we were solely interested in studying actors that identify themselves as Science Shops. We expand on this point below when we discuss the study's limitations section 2.2.

The scope of the literature review was limited to articles on Science Shops published in peer-reviewed journals before 31 December 2020. All the articles included were written in either English, French or Spanish. We conducted our search in eight databases: PubMed, Scopus, Web of Science, the Cochrane Library, Cairn, LILACS, WHO Global Health Library, and 3ie's Impact Evaluation Repository, representing the largest and most influential databases in the Social Sciences for the three languages selected for the review.

Scientific articles identified by the search that either lay outside the scope of the search or did not mention Science Shops or the co-definition of research questions were discarded. Articles not published in peer-reviewed journals were also excluded from the review. All documents written in languages other than English, French and Spanish and all grey literature (statements, policy reports, conference abstracts, reviews, opinion statements, operational and programmatic reports) were also discarded, although subsequently taken into consideration in the discussion section.

2.2 Limitations

By delimiting the review to scientific, peer-reviewed journals and by excluding grey literature, such as project reports, we run the risk of limiting our corpus of papers and incurring obvious shortcomings. However, several European project reports on Science Shops are, in fact, frequently cited in some of the articles selected. This said, it should be stressed that one of the main purposes of the review conducted here is to assess how Science Shop practices have been conceptualized in the sphere of scientific production, that is, in indexed journal articles.

A second limitation resides in the choice of just three languages, and particularly the absence of Dutch, the language with the richest scientific tradition on the subject of Science Shops. However, we considered that English, French and Spanish represent three of the major languages of science and, as such, we can assume that we have obtained a reasonably good overview of Science Shops in Europe and more globally.

A third limitation lies in the keyword search strategy we opted to employ. By limiting the keyword search to just "Science Shop/s" in the three selected languages, we fail to identify many similar activities in other settings. This includes, for example, Canada, where the term "Research Shop" or "Office of Community-based Research" is used; Australia, where the term "Shopfront" is used; Ireland, which employs names such as "Community-Academic Research Links" or "Students Learning With Communities", and South Africa, where "Knowledge Co-Op" is used. However, in this review, our interest was with actors that specifically identify themselves as Science Shops and, as such, we wanted to focus all our attention on this tradition. We were also concerned that if we opted to include more keywords we would be unable to answer our research questions adequately. For this reason, we took the decision to limit the keywords used; however, it would be interesting for future research to broaden the analysis and to compare and contrast the historical development, traditions and practices of different bottom-up, demand-driven approaches to research and the knowledge intermediary units and organizational models that have implemented processes to bridge science and society across different continents and research cultures over time.

2.3 *Data analysis and synthesis*

The data analysis process began with a familiarization phase, during which all articles were read several times by the researchers in order to extract the relevant data. This was recorded in a form containing the following sections: article title; date of publication; date the research was conducted; authors; study design; other stakeholders involved; theoretical/analytical approach — primary/secondary data; research question; research objectives; country of research; research population; principal research methods used; main results; main conclusions and comments.

The form was designed by the researchers before running the search. After a preliminary review of the articles selected, what immediately emerged was the highly heterogeneous nature of the corpus, in terms of approach, aims, time span, geographical location, and methodology. This, however, is perhaps not surprising given that our study analyses via many different angles a research mechanism — the Science Shop — that can be applied in all scientific disciplines.

Given the heterogeneity of the studies included in this review, the approach adopted in the subsequent analysis and synthesis was configurative as opposed to the more typical aggregative approach followed by systematic reviews and meta-analyses [Gough, Thomas and Oliver, 2012]. To achieve this, we performed a thematic analysis in order to create analytical categories capable of providing information that responded to our research questions.

We used an inductive coding approach that included several cycles of coding. This meant reading the studies and allowing codes to emerge from the data. We, then, grouped the findings under key themes [Dixon-Woods et al., 2005] that represent ways of understanding the combined meaning of the text [Bearman and Dawson, 2013]. Our thematic analysis, therefore, does not reflect the frequency with which the themes appeared in the literature but rather their weight in relation with their explanatory value for our specific research questions [Dixon-Woods et al., 2005]. We ended up with a hierarchical coding frame, comprising three meta-categories and ten sub-themes that give insights and respond to our two research questions: i) What features characterise the landscape of Science Shops in the sphere of scientific production? ii) What factors does the literature associate with the rise and fall of Science Shops?

Thus, given their interlinked nature, we grouped some of the main cross-cutting themes that emerged from the literature under a single heading. These categories can, of course, be debated, but a coherent order was adopted, starting from the macro view of the situation and becoming narrower as the focus shifted to results intrinsic to meso and micro levels.

Results

3.1 *Search results*

Figure 1 shows the search results obtained after applying the PRISMA checklist.

The search strategy identified 94 articles. Following a preliminary screening, 23 duplicates were discarded. Based on an initial review of article titles, abstracts and,

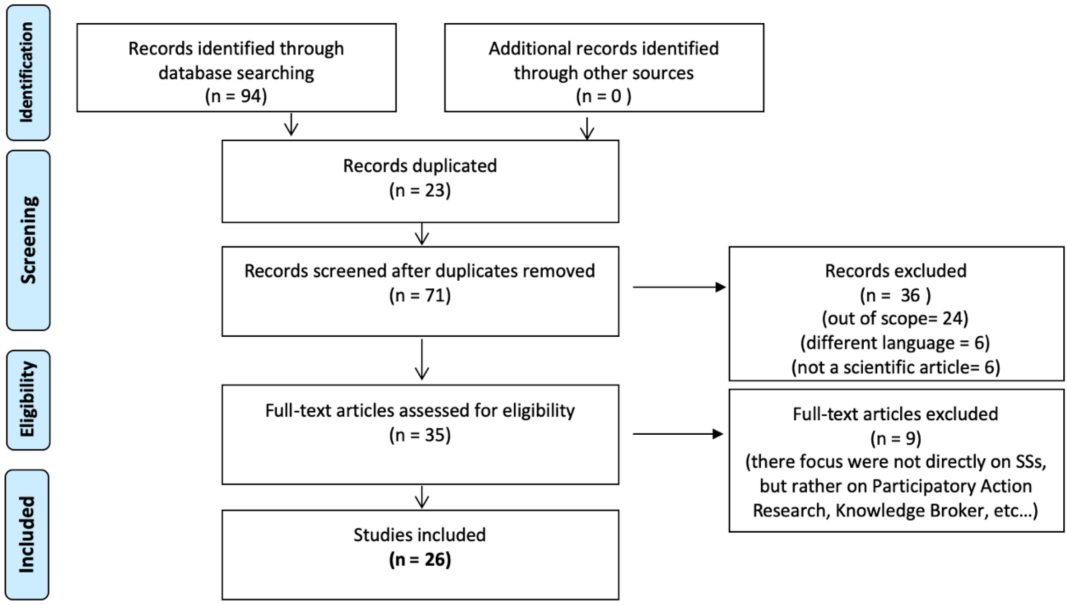

Figure 1. PRISMA flow diagram illustrating the systematic literature review.

in some cases, full texts, we selected all the articles that fulfilled the inclusion criteria. In total 36 articles were excluded either because they fell outside the scope of this study, because they were written in a language other than the three specified in the inclusion criteria, or because they corresponded to conference abstracts, editorials or book chapters and so did not meet the criteria for a scientific paper. After a complete reading of the remaining 35 articles, a further nine were excluded because they did not deal with the structures or projects of Science Shops. Finally, in-depth analyses and data extraction were performed on the remaining 26 articles.

Table 1. Summary of selected articles.

N°	*Title*	*Authors*	*Journal*	*Year*
1	Right idea, wrong time: the Wisenet Science Shop 1988–1990	Bammer, G., Emery, M., Gowing, L. & Rainforth, J.	Prometheus	1992
2	Science shops: a kaleidoscope of science-society collaborations in Europe	Leydesdorff, L. & Ward, J.	Public Understanding of Science	2005
3	Breaking out of the local: international dimensions of science shops	DeBok, C. & Steinhaus, N.	Gateways: International Journal of Community Research & Engagement	2008
4	The University Cheikh Anta Diop of Dakar (UCAD) Science Shop "Xam-Xamu Niep Ngir Niep" (Knowledge of All for All)	Diouf, D.	Expanding Perspectives on Open Science: Communities, Cultures and Diversity in Concepts and Practices	2017
5	Science shops in Europe: the public as stakeholder	Fischer, C., Leydesdorff, L. & Schophaus, M.	Science and Public Policy	2004

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Table 1. *Continued from the previous page.*

N°	*Title*	*Authors*	*Journal*	*Year*
6	Democratizing science: various routes and visions of Dutch science shops	Wachelder, J.	Science, Technology, & Human Values	2003
7	Situating knowledge intermediation: insights from science shops and knowledge brokers	Schlierf, K. & Meyer, M.	Science and Public Policy	2013
8	Amsterdam science shop and its influence on university research: the effects of 10 years of dealing with non-academic questions	Zaal, R. & Leydesdorff, L.	Science and Public Policy	1987
9	Reflexivity in performative science shop projects	Beunen, R., Duineveld, M., During, R., Straver, G. & Aalvanger, A.	International Journal of Community Research and Engagement	2012
10	Sciences participatives ou ingénierie sociale: quand amateurs et chercheurs co-produisent les savoirs	Le Crosnier, H., Neubauer, C. & Storup, B.	Hermès	2013
11	The science shop concept and its implementation in a French university	Savoia, A., Lefebvre, B., Millot, G. & Bocquet, B.	Journal of Innovation Economics & Management	2017
12	Public engagement in energy research	Jellema, J. & Mulder, H.	Energies	2016
13	Science shops in France: a personal view	Stewart, J.	Science as Culture	1988
14	Effects of the wind profile at night on wind turbine sound	van den Berg, G. P.	Journal of Sound and Vibration	2003
15	The social management of environmental change	Irwin, A., Georg, S. & Vergragt, P.	Futures	1994
16	Holland's science shops for "Made-to-Measure" research	Ades, T.	Nature	1979
17	The Dutch science shops	Leydesdorff, L.	Trends in Biochemical Sciences	1980
18	Les courtiers du savoir, nouveaux intermédiaires de la science. Knowledge brokers as the new science mediators	Meyer, M.	Hermès La Revue	2010
19	Dutch science shops: matching community needs with university R&D	Farkas, N.	Science Studies	1999
20	Curriculum development through science shops	Fokking, A. & Mulder, H. A. J.	Environmental Management and Engineering Journal	2004
21	Ensuring durability of community-university engagement in a challenging context: empirical evidence on science shops	Vargiu, A., Cocco, M. & Ghibellini, V.	Gateways: International Journal of Community Research and Engagement	2019

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Table 1. *Continued from the previous page.*

N°	Title	Authors	Journal	Year
22	Space configurations for empowering university-community interactions	Dorland, J., Clausen, C. & Søgaard Jørgensen, M.	Science and Public Policy	2019
23	A bridge between society and universities: a documentary analysis of science shops	De Filippo, D., Bautista-Puig, N., Mauleón, E. & Sanz-Casado, E.	Publications	2018
24	Responsive higher education through transformational practices — The case of a Hungarian business school	Toarniczky, A., Matolay, R. & Gáspár, J.	Futures	2018
25	Using the feminist science shop model for social justice: a case study in challenging the nexus of racist policing and medical neglect	Cruz, M., Jordan, J., Salinas, S. A. B., Jones, R., Thomas, S., Ney, A. & Giordano, S.	Women's Studies	2019
26	A framework for science shop processes: results of a modified Delphi study	Urias, E., Vogels, F., Yalcina, S., Malagrida, R., Steinhaus, N., Zweekhorst, M., on behalf of the InSPIRES project	Futures	2020

3.2 Description of articles

Half (13) of the articles were published before 2008. There are no articles in Spanish, only one in French, and the rest are in English. The articles mainly cite the Dutch experience with 12 articles, followed by experiences recorded in the U.K. (6), France (5), Germany (4), Austria (4), Romania (4), Spain (3), Denmark (4), Senegal (1), Hungary (1), the United States (1) and Australia (1). Most of the articles refer to several experiences in different countries, which is why the number of experiences is higher than the total number of papers.

Other references, which only briefly cite Science Shop activity, refer to experiences in other countries, including Northern Ireland, Finland, Sweden, Belgium, Portugal, Italy, the Canada, and China. Almost half the articles (11) constitute descriptive studies based on the literature or they report case study analyses; the rest are mainly based on in-depth interviews, workshops, Delphi studies and surveys. The corpus is highly heterogeneous in terms of design, setting, focus and time frame. The articles deal with different aspects of science shops such as their organisational structure, the role played by their stakeholders (including researchers and students), their transformative potential, and theoretical questions. Around a quarter (5) investigate the impact of the mechanism. One article examines an actual science shop project [van den Berg, 2004] and another focuses on participatory methodologies that have the potential to open up the research process [Jellema and Mulder, 2016]. Surprisingly, given the value of openness promoted by the Science Shop movement, only 15 of the articles were published in open-access journals. However, it should be borne in mind that open-access publishing has only recently become common practice (77% of the articles published before 2009 were not open access vs. 38% of the articles published in or

after 2010). Finally, the articles in the corpus can be categorised into several disciplines: philosophy and history of science, sociology, science communication, evaluation studies, and research management. The single article describing an actual Science Shop project was conducted in the field of energy studies. The geographical spread, disciplines and year of publication of the corpus are in line with the findings reported by De Filippo et al. [2018], whose aim was to provide a bibliometric analysis of the Science Shop literature.

3.3 Key results

Having analysed the articles selected, we identified three main themes as being key for understanding the effectiveness and sustainability of Science Shops, each of which includes various associated sub-topics. The three themes, however, cannot be considered independently of each other; rather, they are interlinked and synergetic. In this section, we show i) how Science Shops are extremely *context-based* insofar as they tend to be highly dependent on the political, economic, social, and institutional systems in which they operate; ii) how the *criteria employed for taking on research* and how their *operating modes* have evolved, despite the persistence of their *organizational settings*; and iii) how they have suffered from a *lack of visibility* and *recognition* and the possible causes of these shortcomings.

3.3.1 Understanding the context-based dependency of Science Shops

Political and institutional cultures. The first wave of Science Shops emerged in the Netherlands in the 1970s and benefited greatly from a positive political and institutional climate. Against this backdrop, partnerships between university members, student movement activists and CSOs were forged reflecting their interest in joining forces to examine specific research question, above all in the environmental field, but also in feminism, nuclear resistance, minorities and the workplace [Wachelder, 2003; Leydesdorff and Ward, 2005; Farkas, 1999]. The democratisation of science was deemed to be a priority: on the understanding that scientific knowledge should be built adopting an interdisciplinary approach and a broader social understanding of society, and that it should be made accessible to facilitate the transformation of a new and better society [Wachelder, 2003]. In the decades that followed, we can identify four separate waves in the development of Science Shops, each occurring in a distinct geographical, historical and institutional context and responding to a different underlying motive, reflecting different interpretations of the goals of Science Shops and the democratisation of science [Fischer, Leydesdorff and Schophaus, 2004]. During the first wave, starting in the 70s, almost all Dutch universities had their own Science Shop integrated within the university by the end of that decade [Urias et al., 2020]. This integration guaranteed considerable stability, but it was to be short lived [Fischer, Leydesdorff and Schophaus, 2004]. In 1998, the University of Leiden Science Shop, after years of effective performance, was suddenly shut down. Initially, the closure was blamed on cutbacks, but the truth was that community-based activities of this kind were a mismatch with the government's agenda [Wachelder, 2003]. The University of Amsterdam Science Shop met the same fate. After more than 20 years, it was forced to close because of cutbacks in funding, an emerging entrepreneurial spirit within the university, combined with a reorganization plan that saw staff relocated or opting to resign. For a short time, it attempted to survive by changing its

operational and funding models, but by the early '90s it had no other option but to close [Wachelder, 2003]. In France, by contrast, the Science Shops tended to be independent of the universities [Stewart, 1988]; nevertheless, they were heavily reliant on public funding. In the 1980s, severe cutbacks in financial support from the French government heightened the precarious state of the existing Science Shops and eventually they were all forced to close their doors [Stewart, 1988]. It has become increasingly apparent that when governments and universities prioritise market-oriented knowledge transfer, they prefer to fund science parks and knowledge/technology transfer units, rather than science shops, which tend to be more concerned with the social impact and democratisation of science [DeBok and Steinhaus, 2008; Fischer, Leydesdorff and Schophaus, 2004; Vargiu, Cocco and Ghibellini, 2019; Wachelder, 2003; Urias et al., 2020]. However, Science Shops provide a balance in a context where more commercially oriented technology transfer and science parks are supported for economic reasons [Leydesdorff and Ward, 2005].

Level of engagement of civil society. The literature attaches importance to discussions of the role played by, and the level of engagement of, local civil society. By the late 1980s and early '90s, Dutch NGOs had achieved a high degree of professionalization [Fischer, Leydesdorff and Schophaus, 2004]. They had, moreover, started to recruit specialists who could address simple research questions [Wachelder, 2003]. Science Shops were creative in adjusting to these new circumstances, adopting new operational models, and offering new services. Some specialised in particular fields and adopted a consultancy model, charging for their services. However, the Science Shop movement had been set up to give free support to voiceless CSOs who did not have the resources to pay for research [Ades, 1979; Le Crosnier, Neubauer and Storup, 2013; Zaal and Leydesdorff, 1987]. Indeed, this consultancy model was somewhat at odds with the social activism that had underpinned the movement back in the 1970s. Indeed, the underlying aim of this first wave had been to democratise science by working with low-visibility CSOs on under-researched topics free of charge.

A less engaged civil society is always a hindrance to the opening of Science Shops [Bammer et al., 1992]. In Spain, for example, association membership is among the lowest in Europe: only a third of the adult population belongs to a civil association and only 7% of adults report regularly discussing politics compared to 21% in Denmark [Leydesdorff and Ward, 2005]. A low level of CSO involvement is likely to translate into a low research-request rate and a limited capacity to participate in scientific projects. In contrast, a higher participation of adults in associations translates into greater political participation and more interest [Fischer, Leydesdorff and Schophaus, 2004].

Besides, client interest was prone to wane quickly when they discovered there were no easy solutions to their research problems [Bammer et al., 1992]. Indeed, it seems that client awareness of the difficulty of obtaining reliable data about the specific questions they raised was poor [Stewart, 1988]. It is more than apparent, therefore, that careful management of expectations is crucial to ensure client engagement, a view expressed by Beunen et al. [2012] who claim that CSOs would, on occasion, ask researchers to defend a certain line of argument as their opinion would carry greater weight with decision-makers. A refusal to comply with such a request could have negative repercussions for the relationship with the citizen

organization. Thus, the role of Science Shops needs to be clear from the outset, and this means entering into discussion with each of the parties involved in the project to avoid subsequent misunderstandings and disappointments which can result in failure.

Level of participation of researchers and students. At the heart of the Science Shop approach lies its capacity to involve researchers and students in its work. This participative mechanism though depends on the support and involvement of these two groups of actors [Dorland, Clausen and Søgaard Jørgensen, 2019]; yet, universities where students are not allowed to participate in real life projects, and where researchers are evaluated against a traditional model in which engagement activities are not taken into account, can end up hindering researcher and student participation in such projects. However, it has been shown that students can learn valuable skills from Science Shops [Fokking and Mulder, 2004; Vargiu, Cocco and Ghibellini, 2019] and that researchers can develop new lines of research [Zaal and Leydesdorff, 1987; Dorland, Clausen and Søgaard Jørgensen, 2019]. Ultimately, the pressure brought to bear by a university on its academic faculty can result in their being reluctant to engage in participatory projects [Fischer, Leydesdorff and Schophaus, 2004; Bammer et al., 1992]. However, it has been argued that researchers have much to gain from opening up their research processes, especially in view of the 'publish-or-perish' pressure they are under [Le Crosnier, Neubauer and Storup, 2013]. Yet, this claim is contentious, because participatory research processes are notoriously complex and time-consuming [Bammer et al., 1992] and do not enjoy the recognition of most evaluation and publication systems operating in academia. Today, only a small number of researchers continue to work in these research lines and are willing to operate outside classical research practices.

Territorial embeddedness and the influence of the Science Shop actors was a recurrent theme in many of the articles in our corpus. Seeing the territory through a multi-level lens appears to be a prerequisite for defining the best model and maximising a Science Shop's chances of success. The choice of a specific model is highly dependent on local circumstances [Wachelder, 2003]. A thorough preliminary analysis of the political and institutional landscape and a good understanding of local networks can provide valuable insights for the structural design of a Science Shop [Savoia et al., 2017]. However, economic, social, institutional and political environments, as well as sector-dependent issues, such as health and the environment, are subject to constant change, so that the gap that needs filling is never the same [Meyer, 2010]. Therefore, the inherent mediating role of a Science Shop is under pressure to change institutionally because the relations between the different groups are constantly changing over time [Leydesdorff and Ward, 2005]. As Wachelder [2003] and Leydesdorff and Ward [2005] argue, the ability to adapt the model to these external changes is what will permit these structures to survive. Science shops, while maintaining their mission-driven commitment to solve societal problems, may have to rethink their focus and alliances on a regular basis to stay resilient [DeBok and Steinhaus, 2008], while upholding the social and public values from which they were initially born.

3.3.2 Shifting criteria for taking on research and changing operating modes within persistent organizational settings

Organizational settings. In the Netherlands, the Science Shops initially worked on collaborative projects promoted by intermediary structures in which students, supervised by senior researchers, conducted research free of charge for underserved CSOs [Fokking and Mulder, 2004; Vargiu, Cocco and Ghibellini, 2019]. Science Shops, to this day, mostly adopt one of three main types of organizational model: primarily university-based — the most common model, integrated within a university, either decentralized and based within a faculty or centralized and acting as a transversal department [Farkas, 1999]; non-university-based — less common, these models are usually independent of academic institutions and rooted within civil society; and, a hybrid model — this model is rare as it requires collaboration between different entities such as NGOs, universities and/or local authorities [Savoia et al., 2017]. The three basic criteria Science Shops typically employ for collaborating with a civil society organization are that: (i) the CSO has no financial resources to undertake the research themselves; (ii) there are no commercial interests involved; and (iii) the CSO has the capacity to disseminate the research results [Ades, 1979; Le Crosnier, Neubauer and Storup, 2013; Zaal and Leydesdorff, 1987; Farkas, 1999; Bammer et al., 1992].

Project selection criteria. However, the criteria for selecting research commissions and the Science Shops' modes of operation have had to evolve to adapt to shifting political attitudes to the conducting of research. Requests can come directly via stakeholders, but may also originate from Science Cafés, participatory research agendas, or public engagement activities [Urias et al., 2020]. Some organizations will now accept requests from larger CSOs and commercial companies, whereas in the early years of the movement these clients would probably not have been considered. Owing to financial constraints, the 'Chemistry Shop' at the University of Amsterdam started to undertake paid research for larger CSOs and commercial companies [Fokking and Mulder, 2004], although it seems that the latter were isolated initiatives [Fischer, Leydesdorff and Schophaus, 2004]. Generally, in the Netherlands, Science Shops no longer accepted projects simply according to whom the request came from but rather according to the nature of the request and the compatibility between the goals of the client and the Science Shop's own goals [Farkas, 1999]. Likewise, they began to conduct some of the research without student support [Wachelder, 2003]. Indeed, there was a gradual evolution towards a more market-oriented body undertaking consultancy work and even towards that of the 'professional broker' operating outside of academia [Wachelder, 2003]. In both cases, Science Shops seem to have relinquished (i) their student-training component and (ii) their influence over the research policies in the institutions in which they operate, two elements that were fiercely defended at the beginning of the movement. The need to prioritize survival appears, in some instances, to have taken precedence over many of the characteristics that once typified the Science Shop movement, namely free research for underserved community-based organizations. These changes highlight the emergence of a variety of stances and aspirations in the Science Shop movement, and divergent views on the democratization of science [Wachelder, 2003].

Operating modes. Despite these changes, the Science Shops continue to operate a bottom-up approach and they retain the same internal processes. Their work typically begins by entering into dialogue with CSO members to identify their needs. Appropriate research questions are then formulated, and the research project is initiated, with differing degrees of participation depending on the CSO's expectations. This approach has the potential to challenge harmful and unjust practices of research that have been experienced by some minorities [Cruz et al., 2019]. Finally, the results are communicated to the CSO and the process is subject to evaluation [Savoia et al., 2017]. Urias et al. [2020] have proposed adopting a process-based framework to explain the activities of Science Shops, which range from public engagement, participatory research to evidence-based advocacy, as a more flexible way of understanding their operating modes. The level of public participation seems to depend on the level of complexity of the research question: relatively simple or technically challenging questions can be effectively addressed without much community involvement while more socially complex questions require a more collaborative, multi-stakeholder research design in the different phases of the research cycle [Urias et al., 2020]. The strength of this framework lies in its flexibility given that there is no single model that fits all Science Shops [Urias et al., 2020]. In keeping with the expansion of Science Shop units, some authors highlight the additional opportunities that have manifest themselves in terms of bridging the gap between business and science, on the one hand, and research and practice, on the other [Fischer, Leydesdorff and Schophaus, 2004; Diouf, 2017].

Interdisciplinarity & transdisciplinarity, new networks and reflective practices. A guiding principle that lies at the core of the Science Shop is that each stakeholder, regardless of their educational level, has something to teach and to learn [Cruz et al., 2019] through the establishment of equal partnerships [Toarniczky, Matolay and Gáspár, 2019; Dorland, Clausen and Søgaard Jørgensen, 2019; Urias et al., 2020]. The participation of civil society can offer access to domains that otherwise are not readily open to being questioned and studied [Leydesdorff and Ward, 2005]. Moreover, because of the nature of the problems that typically affect people directly, the questions raised do not usually fit within the confines of a specialized research area [Bammer et al., 1992]. As such, this facilitates interdisciplinary collaboration to take place between individuals from both outside and within academia [Dorland, Clausen and Søgaard Jørgensen, 2019]. Science Shops allow the creation and development of new networks and relationships [Cruz et al., 2019; Dorland, Clausen and Søgaard Jørgensen, 2019; Vargiu, Cocco and Ghibellini, 2019] and provide ideas for student projects and this is considered a most positive element by researchers [Bammer et al., 1992]. Science Shops provide an inclusive and safe place and invite participants to adopt a reflective approach and engage in critical thinking, participatory dialogue, citizen science and co-creation enhancing transformative learning [Toarniczky, Matolay and Gáspár, 2019; Urias et al., 2020].

Over the last four decades, the Science Shop movement has, therefore, had to face both operational and financial challenges. As the literature reports, Science Shops act in a range of cultural and institutional settings and have had to adapt to survive. Despite these different settings, they continue to share certain common practices as they foster mediation between citizen groups and the research sphere [Leydesdorff and Ward, 2005] and promote the priorities and concerns expressed by CSOs into research agendas. Science Shops legitimate public views where some

government agencies and industrial organizations might dismiss them as being uninformed or, even, irrational [Irwin, Georg and Vergragt, 1994]. They operate very much from the perspective of the citizens and formulate research questions that take CSOs' views as their starting point, whereas professional consultants would not place such a significant focus on the standpoint of the affected citizens [van den Berg, 2004; Jellema and Mulder, 2016].

3.3.3 Impact, visibility and recognition

Impact evaluation. A key theme that emerged in many articles is the lack of visibility that Science Shops face. Despite being pioneers in incorporating citizen participation, it seems that the general public is still unaware of their existence [De Filippo et al., 2018]: Science Shops have struggled to create visibility [Dorland, Clausen and Søgaard Jørgensen, 2019]. This is pinpointed as a major obstacle to the recognition of their work [Fischer, Leydesdorff and Schophaus, 2004; Schlierf and Meyer, 2013] and, here, performing impact evaluations and communicating their findings are crucial to ensuring their achievements gain the recognition they deserve. However, several authors identify the lack of any tradition for completing such evaluations and the absence of appropriate tools [Schlierf and Meyer, 2013; Savoia et al., 2017]. These issues are exacerbated by the largely invisible nature of their mediation and, to some degree, by the somewhat diffuse social impact of their work. Their work can be said to add value if it generates knowledge deemed of worth by the scientific community, and effects positive social change or achieves relevant outcomes for practitioners. As such, their performance should be assessed using criteria that specifically target these two worlds, the knowledge producers and the knowledge users [Schlierf and Meyer, 2013]. Additionally, Science Shop evaluations need to consider the value added to the research process itself [Leydesdorff, 1980] and so they need to assess performance in terms of processes, outputs and outcomes. However, very few published articles examine these aspects of their work. Some studies discuss the impact of specific projects, but their analyses are limited to individual case studies. Others report positive outcomes, including improved access to relevant data, new research methods, the development of material for educational purposes, and the bolstering of research lines that were not previously very firmly established within the institutions in which they operated [Zaal and Leydesdorff, 1987; Dorland, Clausen and Søgaard Jørgensen, 2019]. However, most evaluations are partial and fragmented and, in most cases, focus on the organisations' priority interests. Thus, university-based Science Shops focus on student learning processes and curricula changes, while non-university-based or market-oriented structures focus more on client satisfaction [Fischer, Leydesdorff and Schophaus, 2004]. Yet, ultimately, the evaluation of Science Shop structures and projects does not conform to the prevailing methodology for assessing knowledge production as they engage in a more complex form of knowledge circulation, exploration and production [Schlierf and Meyer, 2013]. In short, Science Shops have to survive with very limited resources and this undoubtedly hinders their capacity to undertake evaluations on a more regular basis.

Publications. To date, the scientific production of Science Shops has tended to be very meagre [De Filippo et al., 2018], their resources being principally available in 'grey literature', primarily in the form of Master's theses and CSO reports [Vargiu,

Cocco and Ghibellini, 2019]. This situation is doubtless attributable to the lack of time and resources available to Science Shop staff [De Filippo et al., 2018] who are obliged to focus mostly on their primary research goal rather than on communicating and publishing their results. Indeed, this grey literature enjoys only limited visibility and recognition in the world of scholarly publication [Le Crosnier, Neubauer and Storup, 2013]; moreover, as Fischer, Leydesdorff and Schophaus [2004] note, Science Shop reports are often poorly documented or difficult to access due to the informality of the work management methods they employ. If we focus our attention specifically on scientific publications, it has been reported that about 14% of the reports prepared by the University of Amsterdam Science Shop become scientific publications [Zaal and Leydesdorff, 1987], but our search failed to identify any. This might be because the articles were published in Dutch or the term 'Science Shop' was not included in their abstract or among their keywords. Leydesdorff and Ward [2005] also conclude that limited access and availability of Science Shop reports is symptomatic of this visibility problem; however, scientific publications describing both the Science Shop structures and the projects they undertake would boost the long-term impact of their scientific production [Wachelder, 2003; Leydesdorff and Ward, 2005].

Potential use of information and communication technologies. Developments in information and communication technologies (ICT) and the democratisation of internet have changed the way science and society work together, as illustrated by crowd-sourced community research projects. Science Shops, however, have yet to fully exploit the opportunities offered by ICT; yet, communicating via the internet would enable them to reach a wider audience, better shape public demand for science and technology, and open up possibilities for innovative collective action. Employing internet-based databases, moreover, would allow them to make reports of their work available and ensure their long-term visibility [Leydesdorff and Ward, 2005]. Indeed, the Loka Research Institute took the initiative of creating such an archive, but it proved unsuccessful as the Science Shop community did not use it [Leydesdorff and Ward, 2005].

Discussion

This thematic analysis of systematically selected literature on Science Shops conducted here has highlighted how the Science Shop movement has evolved since its creation in the 1970s, having to adapt to periods of austerity and ideological change in higher education. From the outset, Science Shops faced institutional constraints, but they have shown considerable resilience to institutional leadership changes that have impacted their priorities, work focus and sustainability. It is apparent that some science cultures, and their associated institutional strategies, have tended to promote the democratization of science and its social impact through Science Shops while others have opted for the commodification and marketisation of knowledge through knowledge transfer units. Science Shops are highly dependent on university culture and on national research and innovation plans and these can have shifting and antagonistic political priorities, ranging from the democratization of knowledge production to the neo-liberalisation and corporatization of higher education. The work undertaken by Science Shops can be considered "an experimental zone in a democratic tradition" that seeks to serve the interests of a minority and to promote citizen initiatives [Beunen et al., 2012]. The mechanism employed is complex and only fulfils all its potential when the

participation of civil society members, students and researchers is institutionally ensured, incentivized and celebrated. However, this is highly conditioned by such factors as the level of citizen engagement in public life and whether research regulations and higher education norms facilitate the participation of students and academic staff in such research projects. However, given that the prevailing system for evaluating international research does not contemplate citizen-driven open science projects, it remains something of a challenge for Science Shops to attract researchers on their projects. Today, these units remain outsiders and continue to be marginal practices that barely challenge the dominant paradigm. The participation of non-scientific actors at the micro level through single research projects will not achieve a significant impact until the political and economic conditions governing research are redirected [Lengwiler, 2008].

Although operating since the 1970s, Science Shops have suffered from considerable problems of visibility, a shortcoming documented in earlier European reports on participative research [Søgaard Jørgensen et al., 2004; Millot, 2014]. Indeed, the size of our corpus here reflects the scant scientific publication generated by these projects over the four decades of their existence and the small impact the movement has had on science. The surprisingly few publications can, however, be explained by the limited time and financial resources available to them to systematically report the outcomes of their research. An alternative hypothesis, though, is that some publications might not have revealed the fact that they are the result of a participatory research project involving non-professional scientists and citizens [Cooper, Shirk and Zuckerberg, 2014]. Nonetheless, without scientific publications bearing testimony to their potential, it is hard to imagine how Science Shops will ever gain in recognition and visibility within the scientific sphere.

However, the relatively limited scientific impact of Science Shop projects must be treated with some caution. First, more often than not, their projects are carried out by undergraduate students as part of their coursework or as research for dissertations. Thus, such projects are intrinsically limited in terms of any impact they might have on mainstream science — typically measured in terms of publication and citation volumes. Second, a good number of Science Shops are first and foremost public engagement platforms that prioritize communication, mediation, advocacy, moderation, consultancy, evaluation, development and implementation of innovation-oriented solutions. The chances of these activities generating scientific publications are not high as they do not adhere to the systematic, structural methodological procedures commonly accepted as scientific method.

Therefore, we need better ways to assess the impact of Science Shops as tools that facilitate interaction between science and society. Since their birth, Science Shops have provided an inclusive, safe space for citizen science, participatory dialogue, and mutual learning among, and co-creation with, a wide range of stakeholders, including not only educational and research communities, but also civil society, public authorities, small and medium enterprises, designers and innovators. As such, Science Shops are often closely aligned with the RRI dimensions and OSc principles, and are a natural niche for experimenting and scaling up initiatives, such as the European Commission's 'Science with and for Society' programme. Thus, it is important to assess the extent to which Science Shops live up to expectations and deliver what is required of them, especially as they form part of

several policy initiatives. Moreover, more appropriate ways need to be developed to assess the impact of Science Shops beyond, that is, the scientific impact of their projects. Such attempts are very much in line with the 'Measurement School' of OSc, which aims at creating alternative standards to ascertain scientific impact and promote a more open and transparent system that can contribute to solving key societal issues.

The systematic review has shown that while there might not be just one model of Science Shop, nor a single aspirational approach, operational structure, set of internal procedures or business model, the majority mostly adhere to a bottom-up approach to research, with questions being extracted, defined and prioritised through dialogue with societal actors. Science Shops contribute to incorporating social and public values onto scientific agendas as they jointly establish research programs with society members and knowledge users [European Commission, 2003]. Today, questions are accepted from a broader range of commissioners and the focus on working with socially marginalized social groups — a prerequisite for their actions on their foundation — may have been weakened somewhat. Still, Science Shops continue to be one of the few research intermediaries bringing bottom-up, demand-driven research into higher education and other institutional settings with an essentially transformative ambition. They operate at the interface of science and society and need to be managed accordingly to accomplish two mutual goals: ensuring that research responds to the needs of social beneficiaries while assuring the credibility of science [McNie, Parris and Sarewitz, 2016]. Science Shops seek to involve several actors originating from different worlds, each operating with different codes, agendas, interests, and timings, and this is not an easy task to coordinate. The neutral agents within these units play a crucial role in handling these encounters and supporting participatory and power-balanced research processes [Meyer, 2010].

The use of participatory methods in scientific research is of course not new and can be traced back at least until the late nineteenth century, clearly predating the Science Shops concept. There is a long tradition of participatory-action research and community-based participatory research in the fields of international cooperation and the social sciences [Lengwiler, 2008]. However, what actually makes research participatory is not so much the techniques employed but their context of application, including researcher attitudes which in turn determine "how, by and for whom the research is conceptualized and conducted" [Cornwall and Jewkes, 1995], a belief that is also captured in the concept of 'open-air' research as proposed by Callon, Lascoumes and Barthe [2001]. It has been suggested that researchers stand to gain by opening up their perspectives to include societal views in the different phases of translations. Research processes supported by Science Shops would appear to have the intrinsic capacity to promote these collaborative attitudes and practices from the problematization, execution and return of results back to the CSO's members.

The last decade has been witness to the emergence of other types of open collaborative project between science and society, which have rapidly gained recognition and visibility. These projects — variously labelled as "citizen science", "crowd science", "networked science" or "massively-collaborative science" [Franzoni and Sauermann, 2014] — have exploited ICT to the full as they have established massive remote collaboration between scientists and citizens. Such

projects adopt a trans- and cross-disciplinary approach to knowledge production and engage citizen participation in early phases of the process in order to provide new perspectives and information, in addition to forming new partnerships [Hecker et al., 2018]. The roots of crowd science lie in biology, conservation, and ecology where citizen collaboration was sought to collect and classify data. But the methods have now been taken up in other fields, including the social sciences and epidemiology where public participation is sought in projects related to environmental issues and health [Kullenberg and Kasperowski, 2016; Froeling et al., 2021]. Crowd or citizen science clearly illustrates how scientific research benefits from ICT tools which facilitate the broad involvement of different actors. If such projects initially sought citizen collaboration in the data collection phases, today some also promote participation in the defining the project problem and establishing priorities [Davies et al., 2016]. This so-called "Extreme Citizen Science", like Science Shops, shares the goal of co-defining research questions, responding to public concerns, and incorporating citizens in the execution of their projects [Buckingham Shum et al., 2012; Den Broeder et al., 2018]. This means that Science Shops have much to learn from citizen science projects in terms of how to exploit the potential of ICT and the internet both in executing projects and in coordinating their efforts. In this respect, Science Shops could usefully pilot new forms of knowledge mediation and capitalise on their social capital. Likewise, Citizen Science can learn a lot from Science Shops especially as regards how to define a joint research question together with civil society members and organizations and how to maintain an equitable partnership throughout the research process.

Finally, Science Shops are not the only intermediary units bridging the gap between different spheres, be they research and practice or business and science, etc. [Fischer, Leydesdorff and Schophaus, 2004; Diouf, 2017]. By building links with these other intermediaries in the ecosystem, as they consider how best to strengthen their territorial embeddedness, Science Shops could further their understanding of their best strategic fit and enhance their impact by joining forces with knowledge brokers, citizen-labs and public-labs, among others. By developing a full understanding of their ecosystem, either by collaborating with or taking on the role of these other intermediary structures, Science Shops would strengthen their capacity to push forward results and increase their impact and visibility.

Conclusion

The thematic analysis of a systematically selected literature on Science Shops reported here is the first to be published in the scientific literature since the inception of the Science Shop movement in the 1970s. Although our corpus is relatively small (26 articles), it has allowed us to obtain a clear picture of the scientific evidence available on Science Shops, providing an overview of their historical development and identifying three themes and ten key sub-topics that have the potential to guide their future: (1) context-based dependency (political and institutional cultures, level of engagement of civil society, and level of participation of researchers and students); (2) evolution of criteria for taking on research and changing operating modes within persistent organizational model (organizational settings, project selection criteria, operating modes, and interdisciplinarity & transdisciplinarity, new networks and reflective practices); and (3) impact, visibility and recognition (impact evaluation, publications, and potential use of ICT).

Science Shops represent a persuasive complementary approach to the way science is defined, executed and produced today. They have the potential to promote participatory and OSc projects by specifically (i) supporting researchers to adopt an 'open-air' approach to research that complements the dominant 'confined' research paradigm, (ii) providing students with better insights into scientific research and social issues, and (iii) capacitating civil actors to engage with the scientific community. The uniqueness of the Science Shop approach lies in the intervention that this intermediary unit and its agents make in the research process and the support they then provide it with. These neutral agents contribute to the creation of new networks, supporting the incorporation of public values and civic perspectives within research projects, and facilitate the exploration of common worlds by groups that do not usually work together. As such, it is evident that the contribution of Science Shops has additional impacts that are not currently being captured by the evaluation systems in operation.

Although Science Shops have not generated much scientific literature, they have however produced a wealth of grey literature in the form of case studies and anecdotal evidence. Indeed, it would be a valuable exercise for researchers in the social sciences to examine, evaluate and publish articles on this research work in peer-reviewed journals. Through retrospective and external evaluations of this type, researchers would be able to shed considerable light on how Science Shops have contributed to solving real life problems, jointly generated actionable knowledge, empowered citizens and students, opened up new research ideas for scientists, and, ultimately, how Science Shops have contributed to bringing science closer to society in a constructive and positive way.

More research also needs to be performed to gain a better understanding of the profiles, skills and competences required by intermediary agents that can provide these participatory dynamics and ensure project success. Further research also needs to examine the techniques adopted and the participative procedures employed (focusing on problematization, data collection and analysis and the communication phases) and to give careful consideration to how processes, outcomes and impacts for all parties are assessed and communicated in both the short and long terms. The analysis of the actors involved, the degree of dialogism characterizing the procedures (their intensity, openness and quality), and the execution of procedures (the conditions of access, transparency and traceability, and clarity of the rules) could serve as a useful framework for such an analysis [Callon, Lascoumes and Barthe, 2001].

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