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Studying complex systems through design interventions Probing open government data ecosystems in the Netherlands

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ABSTRACT
Recently, we have seen a rising interest in the study of complex systems in public administration. This paper demonstrates how specific design interventions, also referred to as 'probes', can be used to investigate complex systems. The value of this strategy is demonstrated by probing three open data ecosystems in the Netherlands. The probes produce a new understanding of the interrelations between underlying patterns and dynamics of open government data practices. Our research shows that probing is a promising research strategy that can produce rigorous academic knowledge on the underlying patterns and dynamics of complex systems in public administration.

KEYWORDS Complex systems; design interventions; open data ecosystems; open government data; living lab

Introduction

The notion of complexity, which originates from the natural sciences, has enriched our understanding of governance processes (Teisman and Gerrits 2014; Preiser 2019; Klijn 2008; Teisman and Klijn 2008). A broad range of public administration scholars have developed theories to better understand government actions in complex systems (Joosse and Teisman 2020; Eppel and Rhodes 2018; Bason 2017; Teisman and Gerrits 2014; Klijn and Koppenjan 2014; Cairney 2012; Morçöl and Wachhaus 2009; Buchanan 1992; Rittel and Webber 1973). Complex systems are constituted relationally, self-organizing and develop non-linearly over time (Klijn 2008; Brunswicker, Priego, and Almirall 2019; Teisman and Klijn 2008). They consist of different actors and are in a constant state of change that makes them difficult to analyse (Teisman, Gerrits, and van Buuren 2009). Using complexity as an ontologically founded framework in public administration has implications for research strategies in public administration (Preiser et al. 2018; Teisman and Gerrits 2014).

Most traditional research designs focus on isolating the phenomenon of interest to create conditions under which causal relations can be observed (Basso, Lisciandra, and Marchionni 2017; Overman 1996). They focus on the stability of research phenomena

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and are aimed at prediction and control (Teisman and Klijn 2008; Preiser 2019). Other scholars (Preiser et al. 2018; Meijer and Romme 2020; Klijn 2008; Preiser 2019), argue that nurturing complexity requires research designs that analyse systematic properties that emerge from underlying dynamics of complex systems (Preiser et al. 2018; Eppel and Rhodes 2018). Furthermore, they argue that scholars should focus on capturing complex systems and the evolution of the system over time, which requires a shift from objective observation of the system to intervention (Meijer and Romme 2020; Preiser et al. 2018; Bason 2017; Midgley 2003).

The aim of this study is to analyse whether design interventions can help in exposing (underlying) dynamics of complex systems that influence the outcome of system dynamics (Nardi and O'Day 1999). In this study, we explore the value of 'probing' as a research strategy, which entails an approach of intervening in the system to 'probe' new insights (Meijer and Romme 2020; Bason 2017; Snowden and Boone 2007). The contribution of this study is threefold. First, we develop a theoretical argument about the use of probing as a research strategy for studying complex systems, building upon complexity literature in public administration (Eppel and Rhodes 2018; Klijn 2008; Kiel 1989) and on probing as a design methodology (Snowden 2005; Snowden and Boone 2007; Bason 2017). To illustrate our argument, we use an open government data ecosystems as an example of a complex system (Dawes, Vidiasova, and Parkhimovich 2016). Second, by probing open government data ecosystems, we demonstrate that probing not only can produce academic knowledge on the underlying patterns and dynamics of the complex ecosystems, but also allows for strengthening these complex systems thereby contributing to improving public administration practice (Meijer and Romme 2020). Third, we examine the value of probing within three living labs in the Netherlands. A living lab is a research environment that allows for setting up a series of design interventions in a real-life setting. We demonstrate that a living lab can be used as a research environment for probing a complex system in a real-life setting (Gasco 2017; Dekker, Contreras, and Meijer 2020).

Studying complex systems

Defining features of complex systems

The notion of complexity developed from a varied body of thinking, research and disciplines (Teisman and Gerrits 2014; Preiser 2019). Often the term complexity is used interchangeably with complexity theory, complex adaptive systems or complexity science (Preiser 2019). This could indicate that there is one theory of complexity (Preiser 2019). However, what has become known as complexity theory is in fact a collection of different theories (Klijn 2008). Several scholars in public administration (Preiser 2019; Eppel and Rhodes 2018; Teisman and Gerrits 2014; Teisman and Klijn 2008; Klijn 2008; Morçöl 2005) therefore distinguish features that these theories have in common. In this study we focus on three features: complex systems are contextualized and constituted relationally, have self-organizing capacities and develop non-linear over time.

First of all, from a complexity perspective systems are constituted relationally (Preiser et al. 2018; Teisman, Gerrits, and van Buuren 2009; Morçöl 2005; Cairney 2012). Within public administration we can distinguish different components in complex social systems such as individual actors who work in and with socially constructed organizations and institutions (Klijn 2008). In many theoretical

approaches in public administration research, these components are studied separately but theories on complex systems highlight that these levels are all parts of a complex whole (Eppel 2016). Rhodes et al. (2010) make a distinction between the endogenous environment of the system created by agents acting and interacting within the system and the exogenous environment that encompassing rules and factors that influence the endogenous environment. The borders of the system depend on the judgement of the agents in the system (Teisman, Gerrits, and van Buuren 2009). From a complexity perspective, systems are nested in larger systems.

Second, actors in the system do not only behave according to principles but also have self-organizing capacities (Teisman and Klijn 2008; Castelnovo and Sorrentino 2018; Eppel and Rhodes 2018). 'Self-organization is the reflexive capacity of actors and or (sub) systems who are able to receive, encode, transform and store information and use this to consider their actions' (Teisman, Gerrits, and van Buuren 2009, 9). Agents may adapt their cognitions and behaviour based on information (Brunswicker, Priego, and Almirall 2019). Out of these behaviours new patterns may arise (Klijn 2008; Eppel 2016). Thus, self-organization focuses on how processes in the system come about, develop and change (Teisman, Gerrits, and van Buuren 2009).

Third, complex systems are characterized by non-linear dynamics (Klijn 2008; Preiser et al. 2018; Teisman, Gerrits, and van Buuren 2009). They adapt in response to positive and negative feedback mechanisms (Klijn 2008; Preiser et al. 2018; Eppel 2016). An incentive given to a certain system may result in a certain behaviour or response in a certain time. When that same incentive is applied elsewhere in time and place it can lead to a different outcome (Klijn 2008). Hence, outcomes of complex systems depend on multiple causes and these causes interact in an unpredictable manner (Buijs, Eshuis, and Byrne 2009).

Implications for research strategies

Accepting these ontological features of complex systems has implications for research strategies (Preiser 2019). Research strategies are needed that can capture the contextualized and relational, self-organizing and non-linear nature of complex systems. Whereas some scholars study complex systems based on methods from the natural sciences (Eppel and Rhodes 2018), other scholars (Klijn 2008; Preiser et al. 2018; Bourgon 2012; Byrne 2005; Castelnovo and Sorrentino 2018; Buijs, Eshuis, and Byrne 2009) argue that especially participatory action research approaches are suitable for studying complex systems. These approaches allow for stepping into the system, moving with the system, and designing and pursuing interventions in the system (Klijn 2008; Preiser et al. 2018). With intervention, the researcher engages with what is being researched seeking to bring about change or improve the system (Midgley 2003). Furthermore, due to self-organization, complex systems have an ability to learn and adapt (Preiser et al. 2018). Preiser et al. (2018) argue that this calls for research strategies that foster iterative learning and collaborative processes of engagement (Preiser et al. 2018). Additionally, the (non-linear) dynamics of complex systems suggests that cause-and-effect cannot be traced in linear and isolated causal trajectories (Preiser et al. 2018). As Teisman, Gerrits, and van Buuren (2009) point out; varieties of adaptive behaviour can be observed as soon as the actors within the system attempt to adapt themselves to new system's situations. These behaviours may lead to shifts and non-linearity of the system as a whole (Teisman, Gerrits, and van Buuren 2009). This

requires a research strategy that can detect and examine feedback loops that can lead to shifts and tipping points in the system over time (Preiser et al. 2018). In this study, we argue that probing can fulfill these requirements.

Probing as a strategy for studying complex systems

Probing fits within the current development of design methodology, a creative process that engages people in exploring complex public problems and developing new solutions (Dorst 2011; Bason 2017; McGann, Blomkamp, and Lewis 2018; Meijer and Romme 2020). Probing is used in management science for studying complex systems as part of the Cynefin Framework (Snowden and Boone 2007; Kurtz and Snowden 2003). Cynefin is Welsh for 'the multiple factors in our environment and our experience that influence us in ways we can never understand' (Snowden and Boone 2007, 2). The Cynefin framework distinguishes four different situations: simple, complicated, complex and chaotic. Each situation requires different actions. Kurtz and Snowden (2003) argue that in complex situations, the underlying emergent patterns can be made visible, by designing 'probes' or interventions before action is being taken. After all, in a complex situation, the system may appear logical in retrospect but it is only one of many paths, each of which would have appeared logical in hindsight (Snowden and Boone 2007). These underlying patterns can emerge if interventions are conducted that are safe to fail. 'That is why, instead of attempting to impose a course of action, leaders must patiently allow the path forward to reveal itself. They need to probe first, then sense and then respond' (Snowden and Boone 2007, 5). This leads to the sensemaking framework called 'probe-sense-respond' (Kurtz and Snowden 2003, 467).

In the probe-sense-respond' framework, probe refers to a design intervention to stimulate pattern formation. By intervening in the system we can 'probe' our way to new relevant insights (Bason 2017; Snowden and Boone 2007). Following, patterns must be sensed. Sense implies the creation of a shared understanding that is plausible for a group of individuals (Rutledge 2009). Humans can reflect on their experiences and recognize patterns to make sense of their environment (Weick 1995; Eppel 2016). They can sense what works and what does not work (Kurtz and Snowden 2003). Sensemaking implies learning and is a prerequisite for problem solving (Zhang and Soergel 2014). Sensemaking is followed by a response. Respond refers to behaviour in terms of deciding what to do, such as amplifying what works or dampening what does not work (Snowden and Boone 2007). Desirable patterns can then be stabilized, and undesirable patterns can be destabilized, so that patterns we want are more likely to emerge (Kurtz and Snowden 2003, 467). Hence, design approaches such as probing, not only focus on finding out why something is wrong, but also on how something can be improved (Bason 2017; Dorst 2011). By repeating the probe-sense-respond strategy, many feedback loops develop and a holistic perspective of what is happening evolves (Kurtz and Snowden 2003). The Cynefin framework has led to a stream of publications not just in management science but also in other disciplines, such as health (Van Beurden et al. 2013; Gray 2017), education (Shepher, Leigh, and Davies 2019), information science (McLeod and Childs 2013) and policy making (Sharif and Irani 2017; Michaels 2009). So far, the use of the framework in public administration is limited.

Our proposition is that the 'probe-sense-respond'-framework presents a valuable research strategy for studying complex systems in public administration (see Table 1).

Table 1. Overview studying complex systems.

Ontological features	Implications for research strategies	Probing as a research strategy
Contextualized and constituted relationally	Intervening in the system	Probe
Self-organization	Understanding interactions of components	Sense
Nonlinear dynamics	Capturing systemic dynamics emerging from adaptive behaviours	Respond

Probing allows for design interventions in a complex system, that stimulate pattern formation in a specific context. Sense allows for the interpretation and reflection on relations and interactions, leading to understanding the self-organization of the system. Respond focuses on the variety of adaptive behaviours that allows us to capture nonlinear systematic dynamic properties. To explore the value of the proposed strategy, we will apply probing to a specific domain: an open government data ecosystem.

Domain of application: open government data ecosystem

Open government data (OGD) are expected to stimulate more open and responsive public agencies (Piotrowski et al. 2018). OGD are non-privacy-restricted and non-confidential data, produced with public money and made available without any restrictions on its usage or distribution (Janssen, Charalabidis, and Zuijderwijk 2012, 258). Increasingly, scholars argue that OGD initiatives can be viewed as complex ecosystems (Dawes, Vidiasova, and Parkhimovich 2016; Zuiderwijk, Janssen, and Davis 2014). An OGD ecosystem is a 'system of people, practices, values and technologies in a particular local environment' (Nardi and O'Day 1999, 49). An OGD ecosystem consists of five different components (Dawes, Vidiasova, and Parkhimovich 2016; Zuiderwijk, Janssen, and Davis 2014) (see Figure 1): 1) motivation for developing OGD initiatives (policies and strategies) influenced by national and global trends, and advocacy by external stakeholders; 2) OGD providers

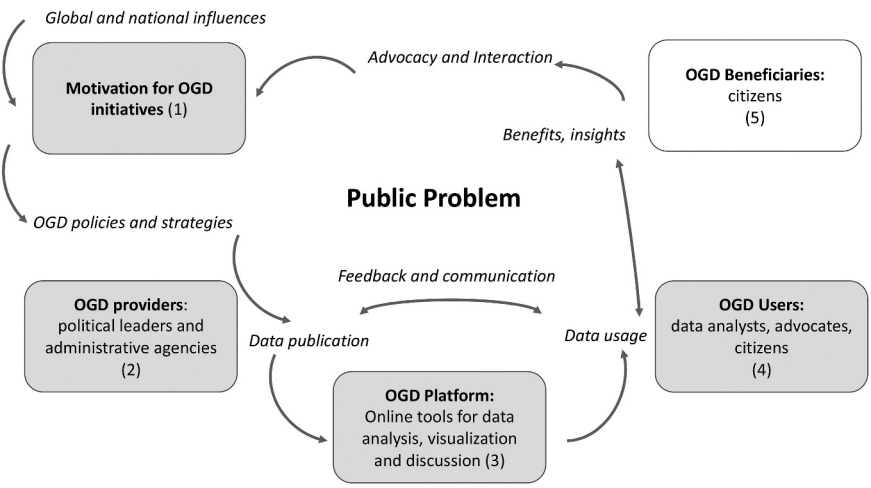

Figure 1. Open data ecosystem. (Adapted from Dawes, Vidiasova, and Parkhimovich 2016).

(administrative agencies) who prepare and publish data for public use; 3) an OGD platform consisting of data resources and tools; 4) OGD users who actually work with data (e.g. data analysts, advocates, citizens) and finally 5) OGD beneficiaries (citizens), who are the consumers of OGD products and may benefit from open data usage. The system is influenced by feedback and communication mechanisms between users and providers to align supply and demand. The aim of the system is to produce benefits and insights based on data for public problems (Dawes, Vidiasova, and Parkhimovich 2016; Harrison, Pardo, and Cook 2012).

OGD ecosystems are complex systems (Dawes, Vidiasova, and Parkhimovich 2016); the five components in the system interact with each other, thereby contributing directly or through other components to the common systems goal, making the whole more than the sum of its parts. OGD ecosystems are self- organizing. The system generates new structures, which is not the result of an a priori design but arises from the interaction of autonomous actors with their environment as well as from interaction between actors (Brunswicker, Priego, and Almirall 2019). The adaptivity of the system leads to non-linear development of the system. In OGD ecosystems, interactions can lead to varying responses and behaviours, such as using or not using features of the technology or publishing certain datasets but not others (Ruijer et al. 2020). Technological systems are socially constructed through the different meanings users attach (Orlikowski 1992). They are embedded in a social context which adapts to and reshapes social worlds over time through their design and uses (Orlikowski 1992).

So far, studies on OGD ecosystems have described and identified elements of ecosystem (Dawes, Vidiasova, and Parkhimovich 2016; McLeod and McNaughton 2016). Increasingly, scholars (Dawes, Vidiasova, and Parkhimovich 2016; Zuiderwijk, Janssen, and Davis 2014) argue that more research is needed to better understand feedback loops and underlying patterns that stimulate or hinder open data ecosystems. In this study we will explore these patterns by using probing. To our knowledge, no studies have been conducted that use probing as a research strategy to study open data ecosystems.

Probing an open data ecosystem

Living labs as a research environment for probing

In order to test the research strategy of probing, we set up living labs. Living labs offer a collaborative environment for research, development and experimentation in real-life settings, through community building activities (Gasco 2017, 91). They involve multiple stakeholders (researchers and practitioners) and users (e.g. citizens, NGO's) as co-creators (Dekker, Contreras, and Meijer 2020). Dell'Era and Landoni (2014) define living labs as: 'a design research methdology aimed at co-creating innovation through the involvement of aware users in a real-life settings'. Living labs are increasingly used as a methodology in the social sciences (Dekker et al. 2020). Concrete examples of living labs are urban living labs. In these living labs, citizens and local actors including government are collaboratively developing innovative solutions for public problems in their own neighbourhoods (Voytenko et al. 2016). In living labs, researchers become part of the field of study and it allows them to step into the complex system to engage in iterative ways of learning by doing (Dekker, Contreras,

and Meijer 2020). Compared to action-research, in living labs there is a more prominent role for users (Dekker et al. 2020).

We set up living labs in three governments in the Netherlands: a province (an administrative layer between the national government and local municipalities) and two local municipalities. The living lab can be considered the endogenous system (Rhodes et al. 2010). The living labs were selected, based on relevance and accessibility. Each living lab lasted for 1,5 to two years between 2015 and 2019 and involved several participants: providers (civil servants who where either policy experts or open data experts), users (citizens, businesses) and beneficiaires (citizens). The living lab in the province focused on the complex public problem population decline. The living lab of one municipinality on a healthy balance between livelihood and liveability in the city centre and the living lab in the other municipality focused on anti-social behaviour. We used a convenience sample to select the participants for each living lab. We first contacted open data experts from the government organizations and together with these civil servants, we invited other participants to join. The participants in the living lab continuosly interacted via workshops and online via the same open data platform[1] with the aim of finding data-based insights for societal problems. University students participated in the living labs as extra capacity. The role of the students was to analyse and use the shared data and to make visualizations based on data.

Five probes or interventions in the living labs were designed based on OGD ecosystem components (Dawes, Vidiasova, and Parkhimovich 2016) and in interaction with the participants of the living lab (see Figure 2). The first probe consisted of exploring the motivation for participating in the living lab: during a workshop participants in the living lab collaboratively analysed open data policies and identified a broad public problem relevant for both OGD providers and users. Second, the public problem was collaboratively further specified by the participants during

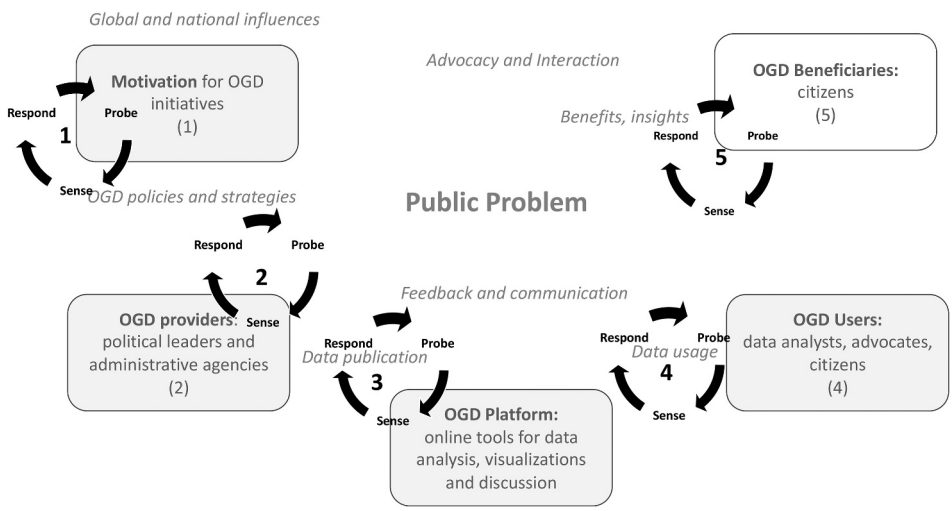

Figure 2. Probing an open data ecosystem.

a workshop so that the public problem could potentially be targeted through open data (see Appendix 1). Working in smaller groups during the workshop, participants wrote down possible questions that can be answered with data. For example: *What different forms of disturbances are there in the city centre? What are trends over time? (living lab healthy balance); What forms of anti-social behaviour are there in different neighbourhoods (living lab antisocial behaviour)*. These questions were plenary discussed and participants indicated in which research questions they were mostly interested. Third, open datasets relevant for the questions were identified by providers and users during a workshop and placed on the online OGD platform. During the workshop, participants worked in smaller groups of three or four persons from different organizations or departments to discuss which department, organization has collected which data that might be relevant but also what categories and indicators are used in these datasets related to the public problem. Fourth, users worked with data on the OGD platform thereby discussing how OGD relates to the public problem, making visualizations, placing comments and writing a report in relation to the public problem. Finally, the participants collaboratively assessed the outcomes in terms of the insights generated for the public problem during a workshop. Students presented their findings to which participants could respond. They could for example point out which results were new and of interest to them and which results they were missing. Hence, in each living lab we used several workshops or probes. This differs from focus groups. A focus group is a group interview in which people provide their thoughts and opinions on a specific topic (Bryman 2016). In a living lab, people not only share their thoughts but they actively participate *by doing* something, such as providing data, providing feedback, and working with data.

Data collection and analysis

The data collection in the living labs consisted of minutes of workshops with civil servants and stakeholders, transcripts of interviews with civil servants and stakeholders, and logs kept by students (see Table 2). The workshops facilitated the process of sensemaking by participants. Sensemaking in the living lab, concerned the collaborative process of the interpretation of an activity by the participants during the workshops (Sandberg en Tsoukas 2015). It allowed participants to organize clues into more coherent interpretations of what is going on and how to act (Sandberg and Tsoukas 2015). Sensemaking should however not be understood as a uniform and harmonious process since processes of change entail conflicting perspectives and interests. In our analysis, we highlight both the shared and the conflicting processes of sensemaking.

The role of the researchers was to structure the workshops, to observe the workshops, take notes and to analyse the results. Researchers also conducted, recorded and transcribed a broad range of interviews, monitored the online activities on the open data platform and analysed the results. In order to balance 'going native' with being a critical observer (Dekker et al. 2019), the researchers clearly defined their role as researchers to all participants in the living lab. Furthermore, the researchers worked in a team of three in order to prevent bias in observations and analyses.

The data was analysed in NVivo. Based on the empirical data collected, themes were identified that related to the research focus and that were built on codes identified in

Table 2. Overview of data collection in living labs.

Probes	Data collection	Province: Population Decline Participants	Municipality: Healthy Balance Participants	Municipality: Anti-social behaviour Participants
Probe 1: Exploration of motivation	Workshop 1	4 civil servants, 2 stakeholders, 3 researchers	9 civil servants, 2 stakeholders 3 researchers	10 civil servants, 3 stakeholders, 3 researchers
Probe 2: Identification public problem	Workshop 2	2 civil servants, 4 stakeholders, 3 researchers	6 civil servants, 8 stakeholders, 8 students, 3 researchers	9 civil servants, 4 citizen representatives, 10 stakeholders and 3 researchers
Probe 3: Collecting published datasets	Workshop 3	10 students	11 students	8 students
Probe 4: Open data usage on OGD platform	Interviews	2 civil servants, 4 stakeholders	4 civil servants, 1 stakeholder	1 civil servant, 5 stakeholders, 1 meeting with community workers, 1 meeting with 5 employees of CBS.
	Workshop 4	10 students: 5 in each group, 1 researcher	10 students, 1 civil servant, 1 stakeholder, 2 researchers	8 civil servants, 5 stakeholders, 7 students, 4 researchers
	Monitoring open data platform	1 researcher	2 researchers	2 researchers
Probe 5: Assessment benefits	Logs	9 students,	11 students	10 students
	Final workshop 5	5 civil servants, 3 stakeholders, 3 researchers and 2 students	5 civil servants, 6 stakeholders, 9 students, 3 researchers	9 civil servants, 5 stakeholders, 9 students, 2 citizens, 4 researchers

the empirical material (George and Bennett 2005). The five probes related to the different theoretical components of the open data ecosystem, formed the starting point of our analysis, such as 'motivation' and 'open data usage'. At the same time, we were open to adding new possible themes not identified in the literature. Following, we used axial coding (Creswell John 2013) to identify additional categories that resulted from the probes and the responses that followed in each living lab. This included nodes such as 'management support' or 'data skills'. Based on open and axial coding, the coding tree was further refined by identifying themes within the components that naturally emerged from the codes identified in the transcripts, minutes of meetings, results of the interviews, and logs of the students (Bryman 2012). Finally, we used selective coding consisting of comparing, contrasting and synthesizing our results with the literature (Creswell John 2013). We also made comparisons across ecosystems so that patterns could be discovered beyond individual cases (Buijs, Eshuis, and Byrne 2009). Two researchers coded the data. The codes were piloted in an early version of the coding scheme, to identify difficulties and inconsistencies between the coders. Furthermore, the codes were regularly discussed throughout the research project among the researchers.

Findings

Living lab population decline

Probe 1 exploration of motivation

The first probeconsisted of a workshop with civil servants and stakeholders aimed at discussing expectations and practices of open data. The Province is facing the highest population decline in the Netherlands. This public problem was chosen by the Province because it is a priority for both government and citizens. At the time of the project, the Province as the OGD provider had published 70 datasets on an open data portal. The Province sensed gaining value from open data for population decline as a challenge. It was unknown to the Province who the users of the portal were, which datasets on population decline were available and what benefits could be derived from open data. In the Province, there was support for open data practices, but the Province did not yet have an open data management policy. Nor was there specific budget available for open data. In *response*, the open data expert of the Province was motivated to develop best practices in collaboration with users to demonstrate the value of open data (see for an overview Table 3).

Table 3. Overview living lab population decline.

Probe	Sense	Respond
Exploration of motivation	Provider: no open data policy, no budget. Aim is to explore the alignment of supply and demand	Develop best practices together with users
Identification of public problem	Provider: connect data with public problem relevant to user Grass roots organizations (users): lack of alignment between supply and demand.	Invitation of grassroots organizations Provider is searching for new datasets relevant to user that can be made public
Collecting datasets	Collecting data takes time: data is spread out User: Lack of data skills among grassroots organizations	Working with extra capacity: students with data skills Role switch of grassroots organizations from users to beneficiary
Data Usage on OGD platform	Collaboration among participants on open data platform: Limited online communication Lack of data quality discovered when using the data	More offline interaction to communicate among participants Use of other information (reports) than datasets for findings
Assessment benefits	Beneficiaries: findings well received by grassroots, but further alignment of supply and demand necessary Provider: lack of support in the organization	Grassroots would like to continue the collaboration regarding open data Open data champion leaves organization

Probe 2 identification public problem

The Province invited users, grassroots organizations, to collaboratively identify a specific problem related to population decline that could potentially be targeted through open data. The grassroots organizations indicated that the government data they were interested in was not available on the open data portal. In *response*, meetings between civil servants and grassroots organizations took place to align supply and demand. This resulted in two concrete public problems. One public problem concerned a healthcare facility that was about to close down in a rural village of the

Province. A village cooperation, which was trying to keep the facility in the village, indicated that there is a need for open data regarding health care budgets, the number of health care professionals working in the area and demographics. The other public problem concerned a cooperation that aimed to develop sustainable food production in the region. The cooperation indicated that there is a need for data on local food production, (bio) waste and distribution.

Probe 3 collecting published datasets

The collection of relevant datasets for the identified public problems led to several iterative sense-response reactions. Since the existing portal of the province contained only a few datasets directly related to the identified public problems, it was sensed that additional datasets were needed. In *response*, the Province published five new datasets, but also discovered that datasets needed were spread out among different organizations. Furthermore, the grassroots organizations tried to analyse the collected data but experienced working with data as a challenge due to a lack of data skills. In *response*, university students were recruited as open data users, who could help with the collection of data across the different organizations and who possessed the required data skills. Consequently, the role of the grassroots organizations switched from open data user to beneficiary.

Probe 4 open data usage

Students, stakeholders and civil servants collaborated for five weeks on an open data platform: the collected data were uploaded, visualizations based on data on the open data platform were made and online comments were posted. Here, the participants sensed a lack of online interaction: especially students were interacting on the platform and leaving comments but few civil servants and citizens participated on the platform. In *response*, the stakeholders from the grassroots organizations placed some online comments on the open data platform. However, all participants expressed a need for more personal contact next to the online interaction. Additionally, students sensed that there were limited relevant datasets available. In *response*, an extra offline meeting was planned, and the students started to use other sources of information than open data.

Probe 5 assessment benefits

The final probe consisted of a workshop in which the findings based on open data usage were discussed. The outcomes were sensed as insightful by the beneficiaries, but also showed a gap between the data needed by the users and beneficiaries and the data made available by the provider. In *response*, the grassroots organizations indicated that they preferred to continue the collaboration with the Province on population decline thereby using open data. However, a lack of commitment within the organization was sensed: civil servants responsible for population decline did not attend follow up meetings, nor did the open data expert of the Province experience middle management support for continuation of the living lab. In *response* the open data expert left the organization. The open data expert was not replaced by the Provincial organization and the living lab ceased to exist.

Thus, in terms of insights into the emergent properties of the complex system, the probes in the Population Decline Living Lab showed several feedback loops and non-linear dynamics of the open data ecosystem in a provincial context. It captured the *crucial role of the open data 'champion'* who is initially trying to

mobilize support within the provincial organization but eventually unexpectedly decides to leave the organization, which disrupts the system and prevents the sustainability and scaling-up of the living lab. The probes also showed a lack of data skills among grassroots organizations. Consequently, their role switched from user to beneficiary leading to a new structure that involved students with data skills as users, thereby illustrating the self-organization of the system.

Living lab healthy balance

Probe 1 exploration of motivation

This municipality concerns a large, urbanized city in the Netherlands. The municipality has budget, an open data portal with more than 500 open datasets and there is management support for open data practices. However, it was largely unknown to the municipality, what value from these datasets can be generated for public problems. The first probe consisted of a workshop organized by the open data expert of the municipality to assess the motivation for open data among his colleagues. Six policy makers of different departments showed an interest and during the workshop they identified six public problems. Following, the policy makers and open data expert *sensed* which of these problems was viable for the living lab, in terms of the accessibility of relevant high-quality data, interest of external stakeholders, concreteness and commitment by policymakers. Two out of the six broad public problems were considered viable (response): Homelessness, and a Healthy Balance between livelihood and liveability in the city centre (see for an overview Table 4).

Table 4. Overview living lab healthy balance.

Probe	Sense	Respond
Exploration of motivation	Provider: budget and datasets are available, management support, enthusiasm among different departments. Aim is evidence-based decisionmaking	Assessment of viability of public problems, resulting in two concrete public problems that can be addressed together with users
Identifying public problems	Provider: some nervousness about interaction with users and beneficiaries Gaining political support and support from management	Postponement of meeting with users and beneficiaries Cancellation of Homelessness project
Collecting datasets	Provider: moving along with one project but the relevant datasets not always compatible with the open data platform User: also collected relevant data for project but some sensitivity of citizens generated data	Provider: data quality check User does not share dataset
Data usage on OGD platform	Particpants collaboratively are trying to make sense of data but lack of communication between users and providers	Provider as moderator actively stimulated communication.
Assessment Benefits	Findings based on data led to insights but not to evidence-based decision making, first step in collaboration willingness to move further with data project	Provider postpones further activities due to upcoming elections

Probe 2 identification public problem

The second probe consisted of a workshop to further specify the public problems identified in the first probe. For the Healthy Balance, some civil servants were reluctant to invite users (citizens and businesses) for the workshop. They expected citizens to have diverse and emotional comments that may result in a change of focus of the public problem. In *response*, the civil servants initially postponed the already planned workshop with users. Eventually, the city invited citizens and businesses that they thought could contribute to the workshop in a constructive manner. The workshop with these users resulted in a specified public problem related to the Healthy Balance. Specifically, it focused on how noise disturbances in the city centre can be managed. The participants agreed that there is a need for open data that can substantiate the magnitude of disturbances in the city centre and that can substantiate implications for citizens and economic activities in different neighbourhoods.

In this stage of the living lab, the civil servants sensed that having management and political support for these public problems was crucial in light of the upcoming local elections. Support building resulted in an unexpected shift in the project: the cancellation of the homelessness scenario due to the political sensitivity of the project and privacy issues.

Probe 3 collecting published datasets

The third probe consisted of the collection of relevant data. The municipality identified 168 relevant datasets for the Healthy Balance. In *response* the datasets were assessed on quality and compatibility with the open data platform. This resulted in 96 datasets that were uploaded on the open data platform. The participating grassroots organization aimed at reducing disturbances in the city centre, owned a citizens generated dataset. However, the representative of the organization indicated to the researchers that she had sensed that it was not in her interest to share the dataset on the platform. The dataset showed that citizens were relatively tolerant regarding disturbances. In *response*, the dataset was not shared with other participants in the living lab.

Probe 4 open data usage

The fourth probe consisted of usage of the data collected. Civil servants, citizens and students collaboratively discussed and analysed the collected data on the platform. Several iterative probe-sense-response mechanisms can be identified. First, the participating students sensed a lack of interaction on the open data platform by civil servants. In *response*, the open data expert contacted his colleagues in person and sent external stakeholders a reminder to participate online, resulting in more online interaction between the different participants. Second, the students were asked to post visualizations based on open data and spark discussion about the public problem. However, it was sensed that students had trouble identifying datasets that allowed them to make visualizations of specific neighbourhoods in the city centre. Mostly data at the city level was available. In *response* the moderator suggested some datasets that the students could use. Based on these suggestions the students made new visualization and posted them on the platform. However, visualizations of specific neighbourhoods remained limited due to the lack of detail of the datasets.

Probe 5 assessment benefits

The findings of the students were discussed with the participants during a workshop. It was sensed that the outcome of the data usage led to some insights for the Healthy Balance but not to evidence-based decision-making. Furthermore, the participants experienced the process as valuable and considered continuation of the living lab. In *response*, the city planned to organize another meeting across different departments of the city. However, these activities were postponed due to the upcoming local elections. One civil servant remarked that the political impact had been enormous and unforeseen at the start of the project.

Hence, the probes in the Healthy Balance Living Lab captured the non-linear dynamics of the open data ecosystem by exposing *the role of political power* as an unexpected tipping point, causing a disruption in the system. The political dynamics played a growing role in the series of probes and at the end the political dynamics around the upcoming elections even resulted in a termination of the efforts to use open data for producing shared insights around the issue of the healthy balance. Furthermore, the probes showed the self-organizing capacity of actors. After sensing the lack of interaction, the project leader actively moderated the platform leading to more interactions between participants and more data visualizations.

Living lab anti-social behaviour

Probe 1 exploration of motivation

In 2017, a national law on anti-social behaviour went into effect, which gave Dutch local government organizations more options to tackle anti-social behaviour. Consequently, the middle-sized municipality of this living lab signed a covenant on anti-social behaviour together with social housing corporations and local health organizations. Anti-social behaviour concerns noise disturbances in neighbourhoods, fights between neighbours, but also disturbances due to mental health issues of citizens or addiction. In this municipality, there is management and political support for open data. Open data is available regarding anti-social behaviour and the municipality would like to develop a predictive model for anti-social behaviour. The first probe consisted of a workshop with the municipality and a few stakeholders. During this workshop, it was sensed that finding solutions for anti-social behaviour required the involvement of organizations in both the social and security domain. In *response*, the city realized that in order to build a predictive model, data were not only necessary from the municipality but from a broad range of actors (see for an overview Table 5).

Probe 2 identification public problem

For the second probe, a broad range of actors was invited: the Central Bureau of Statistics, the Ministry of Justice, police, health organizations, social housing corporations, community organizations and citizens. During a workshop, participants collaboratively identified that open data could help in substantiating the magnitude of the problem of anti-social behaviour and that open data can help in identifying indicators of anti-social behaviour based on which a predictive models can be developed. During this meeting differences between the institutional logics and priorities of the organizations in the social and security domain was *sensed*, which was reflected in differences in definitions of anti-social behaviour and in differences

Table 5. Overview living lab anti-social behaviour.

Probe	Sense	Respond
Exploration of motivation	Provider: political and management support, a cross-sectoral approach is necessary, high-value city data is available. Aim is prediction.	Collaboration with different partners to get a broader insight in anti-social behaviour
Identification public problem	Broad range of providers involved with different institutional logics, but all interested in same public problem. Providers are also users	Collaborative formulation of indicators, questions and identification of datasets
Collecting datasets	Different providers use categories in the identified datasets	Change in focus in the public problem
Data Usage on OGD platform	Lack of available data and quality of collected data Lack of online communication	Reformulation of questions into more feasible ones More face-to face meetings including collaboratively interpreting data
Assessment benefits	Findings did not lead to a predictive model but to some new insights	No scaling up of living lab, but continuation with data projects in other domains.

of data registration. In *response*, the participants collaboratively identified indicators of anti-social behaviour, defined questions that can be answered with data, and identified relevant datasets.

Probe 3 data collection

The third probe consisted of the collection of relevant identified data. In total 38 relevant datasets were brought together on the online open data platform. Of the 38 datasets, 8 semi-open, anonymized, datasets were shared by three different participating organizations that were used only for the purposes of the living lab. Furthermore, differences in categories in the datasets by the different organizations were sensed at the local level but also between organizations at the local and national level. In *response*, the participants adapted the focus and reformulated questions regarding the public problem. In order to assess the magnitude of the problem, national data was used to compare anti-social behaviour in the municipality of the living lab with other comparable municipalities in the country. Local data would be used to assess anti-social behaviour in different neighbourhoods.

Probe 4 open data usage

The fourth probe consisted of open data usage on the online open data platform. Few participants actively used the online platform due to a lack of time and unawareness of the options of the platform. In *response*, additional face-to-face meetings were planned in which the participants collaboratively interpreted the initial results and visualizations made by the students. The owners of the datasets could provide the context in which the data collected and pointed out the limitations of the dataset. It was sensed that the collaborative interpretation sessions led to new insights and to enthusiasm among the participants. In *response*, two participant organizations offered to share more aggregated anonymized data.

Probe 5 assessment of benefits

The final probe consisted of a workshop in which the findings of the students were discussed. About half of the participants indicated that the data collaborative resulted

in new insights. Others mentioned that it mainly confirmed what they already knew. The living lab however did not result in structural data sharing in the field of anti-social behaviour, nor to a predictive model. The city was however motivated to continue with data projects but perceived that more advanced analysis on the current available data on anti-social behaviour was not feasible. The city therefore decided to scale up the project by initiating projects in other domains based on the lessons learned.

Hence, in terms of insights in the dynamics of complex systems, the probes of the Living Lab Anti-Social Behaviour captured *open data collaboration* between a broad range of organizations as a complex process, illustrating the self-organization of the system. The differences in institutional logics of the different organizations led to non-linear dynamics in the system; the initial expectation of developing a predictive model had to be adapted.

Analysis

In the three consecutive living labs, probing allowed us to learn more about the underlying patterns and structures that impede or stimulate complex open data ecosystems. It exposed the influence of the exogenous system on the endogenous system. To illustrate, in the Healthy balance living lab, local elections turned out to be a tipping point that hindered the sustainability of the living lab. The probe-sense-response feedback also showed the self-organization of the system. In all three living labs the (lack of) data quality can be considered as an impediment for the open data ecosystem, leading to an adjustment of the anticipated outcome. However, due to the reflexive capacity of the actors and the continuous interaction between providers, users, beneficiaries and open data some new insights for the public problem were achieved despite this impediment. Additionally, probing exposed different underlying patterns across the living labs related to data quality: a lack of relevant open data (Population Decline), many datasets but not specific enough to draw conclusions for neighbourhoods (Healthy balance), different providers using different categories in their datasets for the same problem (Anti-social behaviour).

Additionally, probing allowed us to capture the systemic properties of open data ecosystem showing the non-linear dynamics of the system. The Population Decline Living Lab highlighted the importance of a champion to strengthen the ecosystem but also the vulnerability of reliance on this champion when the champion is confronted with the inertia of the system. The Healthy Balance demonstrated how political dynamics can paralyze the system. The Living Lab Anti-Social Behaviour captured the dynamics of data collaboration as an expanding but also limiting process.

Finally, the iterative probing feedback loops over time allowed us to trace paths of development of the different systems over time. In the Population Decline living lab there was initial attention for user patterns but not sufficient attention for provider patterns in the form of enthusiasm by management and policy departments, which eventually prevented the sustainability of the living lab. In the Healthy balance we can observe patterns of enthusiasm by management and policy departments but an initial reluctance of involving users and the role of political power that influenced the motivation to continue with the project. In the anti-social behaviour living lab, supply and demand were aligned from the beginning; political and management support, resources and support form a broad range of stakeholders were available. This living

lab led to a more fruitful interaction and to a continued motivation and partial sustainability of the ecosystem.

Hence, probing allowed us to learn more about the underlying patterns and structure of open data ecosystems. Comparing the patterns across different contextualized OGD ecosystems allowed us to study a wider context and provided insights in the dynamics of ecosystems in general.

Discussion and conclusion

Our empirical study of open data ecosystem through the strategy of probing, results in substantive contributions to the literature on open data ecosystems and methodological contributions to the literature on complex systems in public administration.

The *substantive contributions to the literature on OGD ecosystems* (Dawes, Vidiasova, and Parkhimovich 2016; Zuiderwijk, Janssen, and Davis 2014) entailed the identification of specific patterns that had received little attention in the literature, such as the position of the open data champion, the role of political power and the complexities of open data collaboration. In addition, the findings provided new insights into impediments and facilitators of sustainability and vulnerability of OGD ecosystems. These insights help academics to further model the components that influence the dynamics of OGD ecosystems. For public managers responsible for open data projects, probing showed the importance of management and political support from the start, aligning supply and demand and dealing with unexpected events.

The *methodological contributions to the study of complex systems in public administration* are threefold. First of all, our research shows that the research strategy of probing can produce rigorous academic knowledge on the underlying patterns and dynamics of complex systems in public administration. While prior studies have used participatory research methods to examine complex systems in the public sector (Buijs, Eshuis, and Byrne 2009; Castelnovo and Sorrentino 2018), this study adds probing as a research strategy and highlights its value. Probing however also has some limitations. Sandberg and Tsoukas (2015) argue that the process of sensemaking can be relatively confusing due to the fact that probe-sense-respond are not always distinct activities but often times interwoven. Or, as we have seen in the Population Decline living lab, one probe (open data usage) may lead to several sense-respond loops. Further research into other complex systems in the public sector is needed to expand our understanding of the strengths and limitations of probing as a research strategy for public administration.

Second, our study demonstrated how probing is not only a methodology for studying complex systems but also for making a societal impact through academic work. Not all problems encountered could be solved but probing did facilitate responses directed at strengthening the open data ecosystem. Complex systems cannot be controlled but they can be influenced by continuous reflection on how to work with evolutionary pressures and by trying to guide those pressures towards desirable ends (Snowden and Boone 2007; Colander and Kupers 2014). An example of such a response facilitated by our design interventions was the open data expert in the Healthy Balance living lab, who actively motivated his colleagues to contribute to open data usage on the platform. The combination of knowledge production and societal impact through design interventions is consistent with a pragmatist emphasis on the

connection between theory and practice (Sanderson 2009, 708) and with Meijer and Romme (2020) argument that scholars need to rethink the objective 'bystander approach' and engage in design interventions that can help to change and strengthen systems.

Finally, this study showed that a living lab can be used as a research environment for probing. Living labs use the logic of generative experimentation, an iterative process of continuous feedback with the goal of addressing a problem (Ansell and Bartenberger 2016). The result is not fixed at the beginning but becomes more concrete after successive probe-sense-respond iterations. By focusing on learning, there is room in living labs for adaptation to the evolving circumstances that are typical in complex systems. Furthermore, the living lab allowed for rich data collection and for the observation of the exogenous system and complex interactions of different actors in the endogenous system. However, in line with the findings of Dekker, Contreras, and Meijer (2020) we found that sustainability and scalability of living labs can be a concern. In the living lab in which supply and demand were aligned, partial sustainability took place. In the other living labs scalability and sustainability did not take place.

In sum, this paper presents a research methodology, which is highly different from dominant approaches that emphasize reductionism. In contrast, the use of design interventions for probing complex systems provide a research strategy that can detect and examine feedback loops that can lead to shifts and tipping points in the system over time. Our understanding of this research approach is at an early stage but our analysis of the value of probing for studying open data ecosystems clearly shows the value of this approach. An application of this methdology to various other complex systems is needed to extend our understanding of the strengths and weaknesses of this methodology for studying complex systems in public administration.

Note

1. The open data platform was developed in EU Horizon 2020 project Route-To-PA. The open data platform, contained open data sets but also tools for analysis, discussion and visualization.

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