

From Open Data Ecosystems to Systems of Innovation: A Journey to Realize the Promise of Open Data

Shubir Kapoor, Aleksandra Mojsilović, Jade Nguyen Strattnner, and Kush R. Varshney
IBM Thomas J. Watson Research Center
1101 Kitchawan Road, Yorktown Heights, New York
{shubirk,aleksand,jade.n.strattner,krvarshn}@us.ibm.com

ABSTRACT

Data has been often described as the new natural resource and the driver of the industrial revolution in the 21st century. An important element of this revolution is open data: data that can be freely used, reused and redistributed by anyone, subject only, at most, to the requirement to attribute and sharealike. Recent years have witnessed the rapid expansion of the open data movement, as governments, public authorities and other organizations across the world are launching initiatives to unlock their data and make it available for broader, public use. Much has been said about the potential of open data to create economic value and societal benefits, e.g. a recent report estimates the economic value of benefits driven by open data at 3 trillion dollars annually. However, despite the vibrancy of the movement, there are still significant challenges to fully realizing this potential. In this research, we study the current state of the open data landscape, outline its challenges and limitations, and present a vision and requirements for systems of innovation, i.e. open innovation platforms that aim to rectify the shortcomings of the current open data milieu by providing mechanisms for engaging all interested stakeholders, such as public authorities, local citizens, private and non-profit organizations, independent developers and entrepreneurs, in data-driven discussions, thereby creating an environment that will accelerate identification and understanding of important problems that can be addressed. Systems of innovation will help unlock the full potential of open data by expanding the network of minds and allowing all stakeholders in the open data ecosystem to jointly: 1) identify, define, debate and understand problems of interest, 2) search for, locate, collect, understand and analyze relevant data, 3) build/share solutions and experiences, 4) engage in developing new business models around open data, and 5) support lean and agile practices with an accelerated feedback loop to innovate with speed and limited resources.

Categories and Subject Descriptors

H.1 [Information Systems]: Models and Principles

General Terms

Human Factors, Management

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Keywords

computer-supported cooperative work, engagement, innovation, need identification, open data

1. INTRODUCTION

Increasingly, open data is being released by governments and other organizations. This data is a resource with much value and promise for good, but most of that value is being left unrealized despite the open data movement's vibrancy and vigor [8]. Many open data projects do not have measurable impact towards problems of consequence and are not innovative in the sense of solutions that meet the broadest needs because civic hackers are left to fend for themselves without guidance on the most impactful analyses they can conduct or solutions they can develop [14, 12]. The data by itself is only a prerequisite for value creation—only a means rather than the end; it does not lead to value without participation and collaboration [5]. Thus we must go beyond open data portals to ecosystems and eventually systems that engage all sides party to the innovation process in data-driven discussions: discussions that lead to the identification of important problems that can be solved and to calls for action that can lead to innovative solutions to the problems.

We present our vision of that journey in this paper. We embark in Section 2 with a discussion of the current state of the open data movement and how we have reached this point. In Section 3, we discuss the conventional wisdom on the perceived benefits of open data. Section 4 presents a view on the ecosystem that has grown up around open data thus far, taking New York City as the main example. We critically examine the current state of open data portals and ecosystems in Section 5 and suggest one way forward that builds toward greater value in Section 6: systems of innovation. Section 7 concludes.

2. EVOLUTION OF THE OPEN DATA MOVEMENT

According to the definition in the Open Data Handbook, *open data is data that can be freely used, re-used and redistributed by anyone—subject only, at most, to the requirement to attribute and sharealike* [1]. Recent years have witnessed the rapid expansion of the open data movement, as governments, public authorities and other organizations across the world have launched initiatives to unlock the data and make it available for broader, public use [6]. Ninety-seven countries and many more municipalities have established open data initiatives [3].

In the United States, the opening of government data gained momentum following President Obama's executive order in 2009, which states that all government information that does not have to be kept secret for security or privacy reasons should be made public. The administration also launched the Open Government Initiative to publish government data and the data.gov website to distribute the data, which has grown from 47 'open' data sets in March 2009 to 158,558 data sets in August 2015, covering everything from energy use to consumer complaints [7]. The United Kingdom began its open data effort in September 2009 with 2,500 data sets, which grew to 26,532 data sets in August 2015 [2]. The open data movement is affecting every region of the world and countries at every stage of development. Kenya became the first sub-Saharan African nation to launch an open data initiative in 2011 and India has released 3,635 catalogs containing a variable number of data sets. Singapore has shared 12,020 data sets from 72 public agencies. Today, several efforts and initiatives in the open data community track the progress of 'opening up.' For example, the Open Data Index, launched by the Open Knowledge Foundation in 2013, measures and benchmarks the openness of data around the world and then presents this information in a way that is easy to understand and use [3].

State and local governments are also creating platforms to release their data. For example, in the United States, New York State has a rich open data portal of over 1,200 data resources on topics ranging from farmers markets to broadband availability to texting zones, while California and Texas have identified substantial savings by releasing budgetary information and enabling citizens to spot potential opportunities to cut costs. To improve transparency and citizen engagement, cities such as Boston, New York, London, Dublin and Helsinki have made significant amounts of information public, from restaurant health inspection scores, to school performance ratings, to quality of life complaints and parks/recreation information.

While the open data movement started with governments as natural sponsors of open data initiatives, with the acceleration of the open data movement, other institutions and enterprises are also beginning to release their data and invest in programs that rely on the use of open data. In Japan, for example, citizens mobilized to create an open database of radiation readings in different parts of the country following the Fukushima earthquake [9]. Other examples fall under the banner of data philanthropy by corporations, such as France Telecom-Orange making 5 million mobile phone records from Côte d'Ivoire available and Bitly making billions of records of clicks to their URL shortener available [11].

3. PERCEIVED BENEFITS OF OPEN DATA

Many open data initiatives, particularly in the public sector, have been motivated by societal goals, such as improving the transparency and accountability of institutions, making better governing decisions, and raising the quality of decision making by giving citizens and consumers more tools to oversee businesses and government.

With the rise of the open data movement, it has become obvious that benefits go beyond improving government op-

erations. Open data can create transparencies and unearth information to make better personal and business decisions. Consumers can benefit from open data by gaining more insights into what they buy, where they go to school (e.g. with a mobile app that can help students with disabilities find colleges that meet their needs [10]), or how they get around (e.g. with mobile apps that use open data to show the flow of traffic and public transit). By combining open and proprietary data, businesses are finding new ways of segmenting markets or benchmarking their operations (e.g. Signal and Acorn). Transparencies embedded in open data can also affect markets, fostering competitiveness by making more information available and creating opportunities to better match supply and demand (e.g. Zillow.com and ZocDoc).

Open data is driving a range of innovation, and giving rise to new products, services, and business models. Garmin, a firm that develops consumer, aviation, and marine technologies and The Weather Channel, an American television network, were both built using raw government data. A growing industry of third-party brokers is combining the world's data assets, making data more liquid by aggregating, integrating, and selling access to data oftentimes with consulting, reporting or analytics services (e.g. Enigma and Namara.io). Finally, open data is also enabling new opportunities for large-scale collaboration among individuals, companies, governments, and other organizations, including on platforms as a service such as Bluemix.

In their extensive report published in 2013, McKinsey estimates that open data has the potential to enable more than \$3 trillion in additional value annually across seven major domains in the economy [9].

4. THE CURRENT OPEN DATA ECOSYSTEM

While much has been said about the potential of open data to drive innovation, affect issues and unlock significant economic value, the open data movement is still in its infancy in terms of realizing expected economic benefits. Very few governments and market players are in a position to truly capture the real value and maximize the economic benefits of open data [5].

Although the issue of opening up data vaults, unlocking and releasing the data for public use and creating an open data culture and mindset is of tremendous importance [13], on its own the increased adoption and 'openness' will not drive the expected economic benefits. Making data more liquid is necessary but not sufficient for capturing the value of open data. Once data is open, other developments and actions are needed to solve problems, innovate and realize full value potential. Therefore, while many efforts around open data are still predominantly focused on increasing the rate of 'opening up,' creating open data portals, making more data liquid and more societies open, governments and organizations are beginning to invest in strategies, initiatives and tools that would increase availability of open data for exploration by citizens, government agencies, vendors, suppliers, and other stakeholders.

In many places around the world, this has led to the creation of vibrant ecosystems of developers, and the users and stakeholders are increasingly beginning to look into opportunities to solve civic and business problems within this ecosystem. In this section we review the state of the open data ecosystem.

To highlight the key elements of the state-of-the-art open data ecosystem, we will look at New York City (NYC) as an example case, given that it is one of the recognized leaders in civic innovation and the adoption and use of open data. In NYC, open data initiatives are under the supervision of the Department of Information Technology & Telecommunications (DoITT), which provides the foundation for NYC's innovation economy. The DoITT's responsibilities include: modernizing government technology, increasing digital literacy opportunities for New Yorkers, facilitating a more transparent and open government and creating innovative partnerships with today's leaders in technology to improve IT infrastructure, service delivery, and civic engagement across all parts of the city. Through NYC's open data policy—a citywide set of standards and guidelines—DoITT is presenting critical city information on NYC Open Data and ensuring that the NYC government is increasingly accountable and open for future generations. Over 1,300 datasets are available for free, via the NYC Open Data portal on nyc.gov. Today NYC Open Data represents datasets from nearly 60 city agencies, including public safety data, buildings complaints, restaurant inspections and real-time traffic numbers. This website is a core component of the city's open data efforts.

Beyond presenting information to the public, the available data sets serve as a rich resource for developers, civic groups, and anyone else to build applications on their own. In addition to providing data, the city supplies application programming interfaces (APIs) through its Developer Portal. The NYC Developer Portal is a one-stop destination for NYC-specific APIs, apps and datasets. It enables the development of consumer-grade apps using NYC data sets and APIs. The portal was established to be a central hub for engagement with the developer community in the following ways:

- It provides a framework featuring APIs for city data that developers can use to create apps to improve the lives of New Yorkers and the way in which city government serves them.
- It is an official New York City Apps Hub, showcasing both apps developed by the city and apps developed independently that use city data and that have been reviewed and approved by the city as official offerings on the Apps Showcase.
- It is a forum for developers to interact with the city about its public data, suggest ways to improve how the city presents its data, and also find collaborators for their own civic projects.

Today, DoITT sees the portal as the key enabler “to foster innovation and leverage talents beyond City government to create solutions to tough problems.” Furthermore in 2009,

DoITT and the NYC Economic Development Corporation established the NYC BigApps Competition. This annual competition utilizes NYC Open Data and challenges local entrepreneurs and developers to create new and unique tools for public use. Beyond the NYC BigApps Competition, NYC is home to numerous meetups, hackathons, challenges, non-profits, and co-working spaces intended to tackle civic problems within the open data ecosystem.

NYC is also working with large jurisdictions across the country and the federal government to aggregate and share data, and drive new levels of data-driven decision making and analysis across municipalities. Today, cities.data.gov is a new one-stop destination for searchable, sortable, and downloadable data. The website currently includes datasets from NYC, Chicago, Seattle, San Francisco and the federal government. The unified data portal also provides links to download apps, details on civic challenges, and open data policies. This initiative promotes transparency in government while providing developers and the public with the tools to build innovative applications and platforms for their communities.

NYC's open data ecosystem is one of the leading examples in the world, but similar approaches are being taken by many other cities as well.

5. THE CHALLENGES AND NEED TO GO BEYOND

So why, despite all the progress that has been made so far, are we not seeing more benefits?

An issue that has been cited as a barrier limiting how businesses, developers, and citizens can interact with new open information is the ability to search and discover the right information among the ever-increasing amount of open data [4]. Governments are releasing data in different places, on separate portals, and in multiple formats, making it difficult for users to access and leverage the information in an efficient manner. As a result, a great deal of work in recent years has been directed toward ways to effectively summarize and search open data (e.g. opendatanetwork.com and datalook.io). However, in our opinion, this is *not* the key issue.

Most efforts and initiatives start with the premise that by making data more easily accessible and usable, everyone can use it to solve problems. The belief is that more data will directly translate into more problem solving capabilities. As a result, the majority of open data initiatives today are focused on the *systems of record* part of the ecosystem—collection, aggregation, cleaning and filtering of data repositories and making selective data open and liquid.

In the current paradigm, value realization is left to civic hackers, developers, small businesses and entrepreneurs. As a matter of fact, in the current ecosystem, the problem solving part is predominantly carried out via the bottom-up approach, which leverages the power of citizens and developers to analyze and visualize the data or develop new apps. But is this really the best way? And if yes, what else is missing?

As all of us who have been engaged in the business of data mining, data analytics, and predictive modeling (we call it data science these days) know all too well, problem solving starts with a question, not the data. The most difficult part in any process of innovation is determining a problem that is desirable to users, viable in the marketplace and possible with technology, and thus worth pursuing solutions to. As we are increasingly looking to solve difficult and big problems for our cities, societies, and even businesses, we need to be looking at strategies/tools/initiatives that provide better problem definitions and deeper subject matter expertise to all stakeholders in the ecosystem, as an aid in better understanding these problems.

Without such capabilities, the space of problems that can be solved will be severely limited. Let us illustrate this with an example from the Reinvent Green Hackathon. Reinvent Green was a city initiative in NYC aimed at having technologists improve sustainability in the city. Winners of the hackathon included an app to help cyclists ‘bikepool’ together and a farmer’s market inventory app; both are useful applications, but they do not solve the city’s big sustainability problems [12].

Or let us look at the example of the recent Ebola epidemic [15]. Throughout 2014, a great deal of effort in the data science community was directed toward analyzing and visualizing existing data on infection rates and mortalities in West Africa at the district level. Needless to say, given the granularity and quality of the data, such efforts had modest value in combating the disease or improving the decision making in the field, beyond just pure reporting. Only after many months of background discussions with different stakeholders involved in the fight against the disease (e.g. CDC, World Bank, Red Cross, and Sierra Leone government) did it become evident that two pressing problems were far more valuable to focus on: the lack of reliable data on Ebola treatment centers, and the lack of tools and apps to better collect, consolidate and exchange the information available to resources working in the field.

Or let us consider a small city in the United States with a nascent open data portal that we have recently collaborated with; it faces many problems related to health and wellness, and has vibrant civic involvement in dialogues on city issues. In a recent session that we organized, we brought several health experts together in a room, including the city government’s public health specialist, the school district’s head of nursing, leaders from the city’s main hospital and main home care provider, and experts from the state health department and the state university to brainstorm what specific problems and solutions should be tackled using open data. Although the availability of open data was a part of the discussion, the discussion itself was not grounded in the data and no consensus was reached. This example illustrates that because the discussants’ views were mostly anecdotal rather than data-driven and because it was not clear which problems would engage and could viably be solved by technologists and others in the community, the truly important and tractable problems did not emerge. The session can be viewed as a starting point of an iterative and collaborative process that needs to scale in order to identify a set of important problems to pursue.

In different ways, these use cases demonstrate the pressing need to expand the current systems around open data with capabilities that would allow us to collectively understand relevant problems better, before we can start thinking about solving them.

In order to accelerate the collective ability to solve important problems, it is critical to invest in strategies that will open not only the data, *but also the space of problems*, for exploration by citizens, government agencies, vendors, suppliers, and other stakeholders. We believe that this need will be the key driver in the evolution of open data ecosystems into *systems of innovation*, which in turn will become a critical part of how cities and governments operate, innovate, and solve problems in the future.

Systems of innovation will provide tools, services, data/app marketplaces and collaborative environments, which allow public authorities, organizations and citizens to work together in the open data landscape, and accelerate the creation of economic value. Such solutions will redefine how cities and governments interact with citizens and deliver services, share ideas, benchmark initiatives, and identify new investment opportunities. They will change how vendors create new products and services, how organizations deliver internal projects, and may also create new economic models to monetize initiatives. In the next section, we propose a vision and requirements for systems of innovation in more detail.

6. SYSTEMS OF INNOVATION

The open data ecosystem, as we have described, does not currently support the process of how people successfully innovate and solve consequential problems. The main steps of innovation are: first, developing deep problem understanding and brainstorming or generating ideas; second, screening or evaluating the ideas based on level of impact, technical feasibility, market viability, etc.; and third, developing new products or services based on the prioritized ideas. In our Reinvent Green and Ebola examples above, the first and second stages were shortchanged in favor of jumping directly to the third stage. In our small city example, only the first stage was initiated without the capability to progress to the second stage. Specifically for open data-oriented solutions, an important part of the screening step is the search, discovery and evaluation of relevant data sets.

A successful paradigm in the current open data ecosystem that does allow for all stages of the innovation workflow, but one we do not feel is scalable, is a weekend event bringing together data scientists, subject matter experts and all other stakeholders to determine the important problems that should be and could be solved, and then make progress towards those solutions [12]. Consequently, the capabilities of the open data ecosystem need to grow to support such an innovation workflow taking place in a scalable way. We set forth requirements for such innovation-enabling systems in this section.

Within the open data realm, we think of a system of innovation as a dynamic interaction of three subsystems: a system of record, a system of insight, and a system of engagement. A system of record comprises open data sets and

all of the capabilities that support its lifecycle, such as cleaning, publishing, standardizing, filtering, indexing, searching, and commenting. A system of insight comprises analytics tools, algorithms and services, APIs, and app marketplaces. A system of engagement comprises social and collaborative capabilities within a user-centered design that supports all of the interactions in the ecosystem. In addition to the three systems, we also have a variety of parties that participate, including subject matter experts, citizens, public authorities, entrepreneurs, small businesses, and data scientists and engineers.

Systems of record and systems of insight are nearing a stage of maturity within the current open data ecosystem; they have been thoroughly investigated. The big question moving forward is how to put them together in a way that will effectively support the discovery process and problem solving around open data. The system of engagement and the overall system of innovation design are the keys to unlocking value and need to be developed further.

An overall system of innovation must support the three main stages of innovation mentioned above: an *ideation stage*, an *evaluation stage*, and a *solutioning stage*. In the ideation stage, we would like to emerge with a deep understanding of the topic of inquiry and several high-level questions related to it. Continuing with the small city's health and wellness, for example, the output could include an overall understanding of the health landscape of the city and the questions: is lead paint remediation improving the health and wellness of the children, is obesity a growing problem and what can we do about it, and is fresh healthy food available to all residents. In the evaluation stage, we would like the questions to be summarized and screened to the essential, tractable, specific problems that can be presented as calls for action. Calls for actions can take the form of calls for grants or venture capital funding, open challenges, or calls for research, all for very specific tasks. In the solutioning stage, we would like to emerge with products or services that address the calls for action. Examples of products and services that come out of an open data solutioning stage include those given in Section 3. We diagram the requirements for such a system in Fig. 1 and Fig. 2.

Although presented sequentially thus far, all three stages interact with each other. It may be that the evaluation stage illuminates new questions or shows that certain questions cannot be tractably addressed. Similarly, experimentation during the solutioning stage can reveal that certain actions are not viable or that there are other possible actions to pursue. The ideation stage can reveal that more information is needed on a topic, thus giving information acquisition as an action around which to develop a solution. Deployed solutions can raise new questions. All stages should engage the entire set of stakeholders with subject matter experts taking the lead in the ideation stage and technologists in the solutioning stage.

Data changes the nature of discussions and dialogues, even among people knowledgeable on a subject, from anecdotes and gut instincts to facts, thereby enabling public collaboration around identifying the important questions [14]. Our vision for the ideation stage is an interactive discussion site

that engages a multitude of different parties in a communication centered around a single topic, such as health, employment or education. The communications should be centered around developing deep problem understanding and be guided by open data sets, visualizations, and insights on the biggest and most impactful issues. This component should allow the participants to search for data sets or identify gaps in available data. The ideation stage needs the system of record to provide the data on which to ground the discussions, the system of insight to produce the visualizations and rough analysis, and the system of engagement to host the dialogues.

As we discussed in earlier sections, open data is often the key enabling raw material in the apps, products, services, or businesses that lead to civic good. We envision the solutioning stage of the system of innovation to be a cloud platform as a service supporting appropriate data science tools and technologies for the development of differentiated solutions and services that interact with open data APIs. Entrepreneurs and local businesses would leverage the platform to respond to the calls for action output by the problem formulation stage, developing solutions with agility while learning from one another. In developing solutions, they may also innovate on business models. The solutioning stage clearly needs the system of insight to enable the development and the system of record to feed the solutions that are produced, but also the system of engagement to encourage collaborative development and co-creation.

We see the evaluation stage as a distiller of the online data-mediated discussions of the ideation stage. This stage requires the greatest interaction between the subject matter experts and the technologists, and between open data as a source of insight for understanding issues and open data as part of a solution to those issues. Data scientists can evaluate if certain initial ideas or questions do not have open data to support solutions, and subject matter experts can evaluate if certain possible solutions are worth pursuing from the perspective of impact. There should be a convergence to concrete problem statements. There should also be appropriate moderation, where the moderator considers the incentives for entrepreneurs and local citizens to participate in the discussion and develop solutions. The system of record and system of insight both interact with this stage, but the critical piece here is the system of engagement to foster the most productive interactions possible. Social and collaborative tools are well-developed for ideation and for collaborative development, but the type of engagement required here is of a different type, that we believe requires new research. The system of engagement in the evaluation stage may be a limited-audience discussion that goes through a moderated narrowing or prioritization to important problems through voting or other means.

In addition to architecting a platform for solving problems using open data, we see a potential for many new capabilities to facilitate discovery, and the connection between problems and data. For example, the system can automatically create metadata on open data sets and parse the results into a knowledge graph. The system can take on the role of an automatic data/problem broker or a cognitive advisor that reacts to an ongoing ideation or evaluation discussion

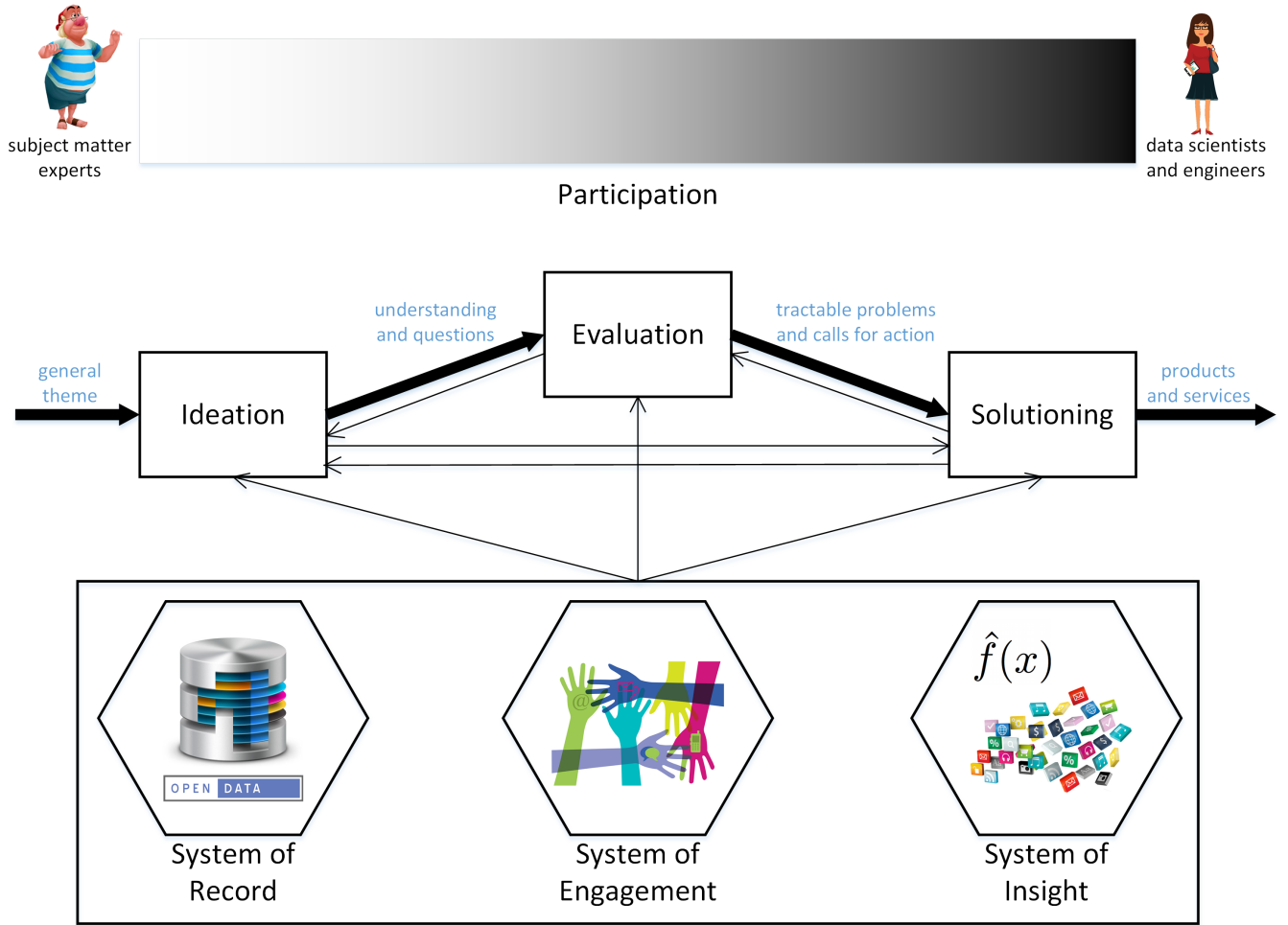


Figure 1: Workflow for a system of innovation.

with novel data-based inputs for the community to consider. The system with cognitive capabilities can also automatically summarize discussions for easy interpretation and consumption by decision makers. These are only examples that will drive new research; there are many other possibilities as well.

7. CONCLUSION

We live in times where we are collecting a lot of valuable data that holds promise to help us solve important problems, improve our lives and our communities. Today we are on the brink of a critical moment, when demand for data-driven insights intersects with more data being made open, followed by rapid advances in analytic capabilities with low barriers for entry, and creation of lively and engaged ecosystems of services and developers around open data. Our next to-do, and our next responsibility to advance this effort even further, hinges on laying the foundation for problem solving, and on enriching the ecosystem with capabilities to bring together *all* participants, allow them to ask the right questions in order to understand the problems, to collaborate on the best interpretations of the data, and understand which data needs to be collected and why.

Solutions, problems, and questions have an interdependent relationship [16]; we must give equal consideration to all three to enable successful innovation that realizes value. As we have seen in the first few sections of the paper, solutions are the main focus at the current point of the open data journey. This imbalanced focus has prevented us from fully taking advantage of the economic and societal promise of open data. We have presented a vision for a system of innovation that scalably allows the open data ecosystem to grow and progress in a way that gives as much importance to ideation and evaluation as solutioning. Online collaborative ideation systems and solution development platforms already exist, but we would need to create a new system of engagement component for the interactive idea evaluation and screening process. Systems of record, systems of insight, and systems of engagement can all benefit from new cognitive capabilities that are motivated by their place in an overall system of innovation.

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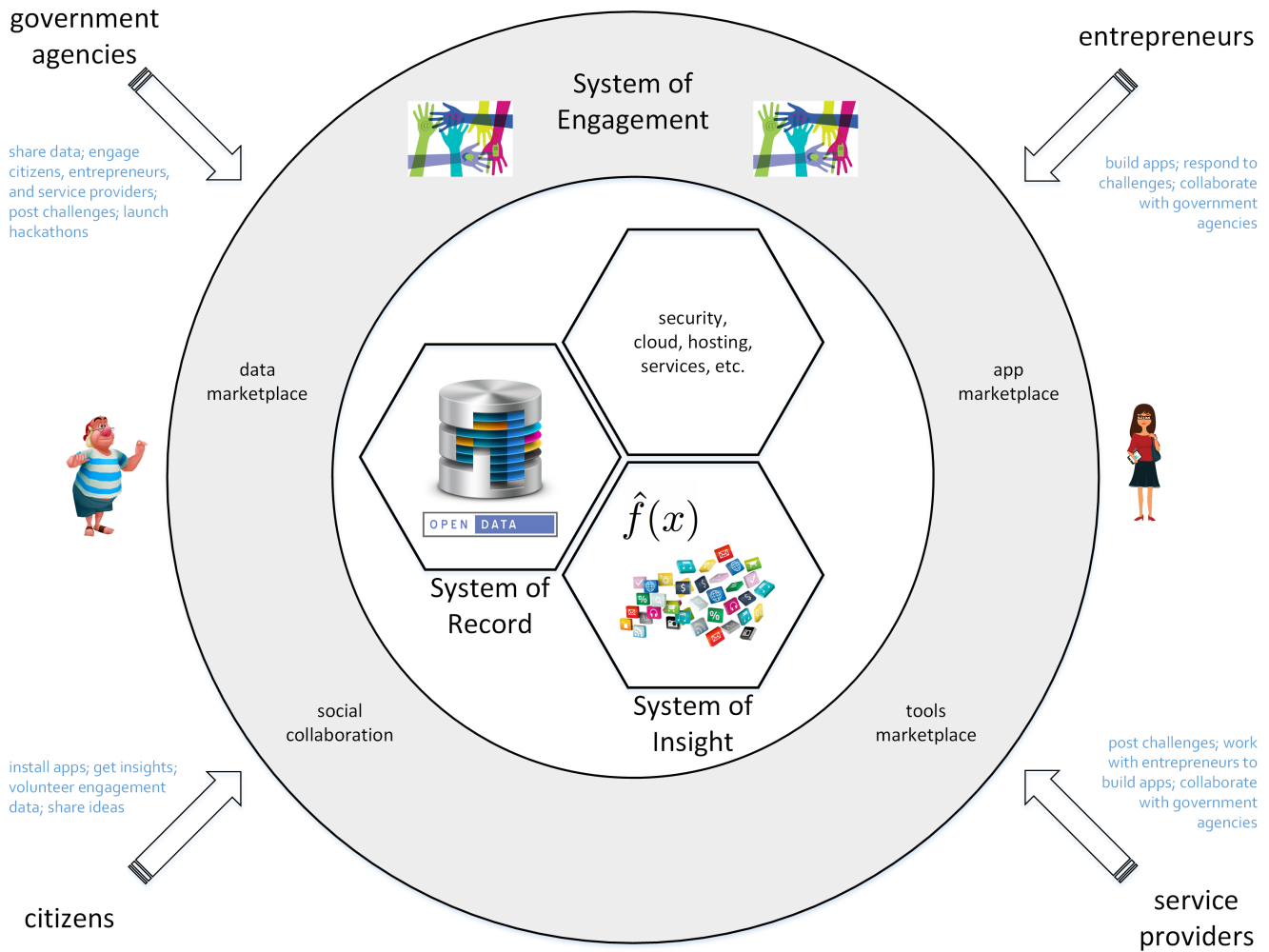


Figure 2: Relationship between parts of a system of innovation.

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