Open Science, open issues

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Foreword

This book brings contributions by researchers from different areas and a wide range of countries, including Brazil, who have a significant role and reflection in the field of open and collaborative science.

The topic of open science is gaining ground not only within institutional environments for science, technology and innovation, but also in other contexts that, until now, were kept apart from these activities. As a result, it is mobilising other social groups as interlocutors of scientific practices. In turn, the resulting transformations in the relations between science, technology and society integrate the new dynamics of production and circulation of knowledge as well as the new role played by these dynamics in contemporary processes of social participation and change.

It is hoped that this publication will provide an overview of topics and issues that both trace and permeate the topic of open science nowadays from different perspectives and points of view. Above all, it is hoped that it might instigate further reflection and foster new ways of producing and circulating knowledge. Thus, it is geared not only towards the academic world, but also to a broader range of social actors that concern themselves with the democratisation of knowledge and information.

The book is inspired by the results of the discussions held during the International Seminar "Open Science, Open Questions"[1] that took place in Rio de Janeiro in 2014. The Seminar was organised by: the Brazilian Institute for Information in Science and Technology (IBICT), Open Knowledge Brasil (OKBr), the Federal University of the State of Rio de Janeiro (Unirio) and the Interdisciplinary Laboratory for the Study of Information and Knowledge (Liinc).

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The editors

[1] The programme, presentations and links to videos of the International Seminar are available at http://www.cienciaaberta.net/encontro2014/

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1

Open science in question

Sarita Albagli

The movement for open science must be considered within the context of the social movements that have emerged in the scenery of the changing conditions of production and circulation of information, knowledge and culture, and that have destabilised existing epistemological and institutional frameworks. We propose to reflect on the challenges that these changes present to scientific dynamics, its values and practices, as well as on the new perspectives required to best understand and cope with these challenges.

Open science is here understood as a process, something under construction, that mobilises different interests and points of view which are, in some respects, antagonistic. It also allows for multiple (and sometimes conflicting) interpretations.

This chapter proposes to reflect on the open science movement from two major perspectives. One of them refers to the existing tension between the socialisation of knowledge, information and culture on the one hand, and its privatisation on the other (Albagli; Maciel, 2011). We believe this to be one of the main areas of conflict and struggle that permeate the so-called network or information society (Castells, 1999), digital capitalism (Schiller, 2011) or yet cognitive capitalism (Moulier Boutang, 2007). We start from the premise that these different forms of appropriation (social or private) constitute the antagonism characterising the present information in science and technology (S&T) regime (ALBAGLI; MACIEL, 2012).

The other perspective concerns the scope of the meaning of open science. At present, this issue expands or better, transcends, the so-called *scientific field* (BOURDIEU, 2004), encompassing the greater porosity of science and its dialogue with other social segments and other types of knowledge in the context of the broad spectrum of possibilities and spaces for producing knowledge. Open science approaches imply overcoming the perspective of thinking about science based on its intrinsic productivity. They also imply the overthrowing of hierarchies, of established sources of authority and of reputation, moving the focus to the relationship between science and power and, from a broader perspective, to the relationship between knowledge and power.

Whatever the case, this is, from the start, a debate and a struggle at the level of significations which are invested with a straightforward political character and which lie at the core of the construction of democracy nowadays.

The chapter presents the framework of conflicts and contradictions surrounding proprietary and open knowledge; it situates and characterises the open science movement in this context; it discusses the ethical-political dilemmas presented by this movement; finally, it points out the challenges to institutions in attempting to cope with these transformations.

CLASHES IN THE FIELD OF KNOWLEDGE

Since the final decades of the 20th century, the obsession with intellectual property has led to the expansion of the mechanisms of private appropriation of intellectual and cultural production, both broadening and deepening market capitalism relations to include areas that, up to that moment, were a social preserve. The system for protecting intellectual property rights (IPR) rests on a theoretical narrative and on a discursive system that seek to legitimise property rights *tout court*. "In one sense, the dynamics of enclosure is the expansionary dynamics of capitalism itself" (MAY, 2010, p. 13). The toughening of the protection of IPR conferred prominence to the character of the individual author, disregarding the fact that all new knowledge comes from previous knowledge and is, as a result, a social product. At the same time, it benefited above all the go-betweens, the *rentiers of knowledge*, in detriment of the truly creative minds.

This process had direct repercussions on the institutional and organisational formats for producing and disseminating science. From then on, academic and university environments were under great pressure for patenting and obtaining financial return from S & T activities, leading to the establishment of institutional apparatuses as well as legislation relevant to these objectives.

In the same context, the dependency of scientific publications on private publishing was increased, leading to the exponential rise in the price of journal subscriptions. Besides, licenses restricting access and use of digital materials were introduced, eliminating several rights still in place, such as that of *fair use*. This is the reason why the most important initiatives during the initial stages of open science were aimed at free access to scientific publications.

On the other hand, this toughening of the system for protecting intellectual property rights partly constituted a reaction to *transgressions* that were already in place, aimed centrally at freely replicating and disseminating information and knowledge (MAY, 2000; MOULIER BOUTANG, 2010). Free digital culture, inspired by hacker culture and made more powerful by the development of electronic systems and digital platforms, was broadly disseminated. Non-proprietary relations and forms of production have multiplied and spread out, with greater autonomy of participants and in formats that are not necessarily structured and hierarchical, characteristics that have always been more marked in the production and circulation of information and knowledge than in material production (BENKLER, 2006; SODERBERG, 2008). These new practices and spaces of interaction and cooperation generate innovations in productive, political and cultural dynamics, giving rise to notions such as those of co-creation, e-science, peer-to-peer production, wiki production, crowdsourcing, co-innovation, open science, open innovation, among others. Thus, beyond the sharing of culture, it is a culture of sharing that asserts itself (CASTELLS, 2009).

At the same time, new forms of business develop around the idea of open knowledge, within the scope of a cognitive capitalism that reproduces itself based on the private appropriation of information and knowledge collectively produced. Cognitive capitalism lives of and survives because of the parasitical and rentier exploitation of collective production, offering the conditions for its reproduction as in free platforms of access to digital networks. At the same time, it *spoils* this very dynamics of value creation with the toughening of mechanisms for protecting intellectual property (MOULIER BOUTANG, 2011; COCCO, 2012; ALBAGLI, 2012; DELFANTI, 2013).

A clash thus arises between different forms of appropriation. On the one hand, intellectual property needs to impose itself *through command and control,* requiring a repressive apparatus that seeks to compensate for or to mitigate the weaknesses of a set of laws that are anachronistic and inapplicable in the context of current social and productive dynamics. On the other, the commercialisation of knowledge and information requires the continuity of this process of pollination of networked production (MOULIER BOUTANG, 2011; ALBAGLI; MACIEL, 2011), which, in turn, presupposes the freedom to foster processes of continuous re-socialisation of knowledge.

In this sense, instruments of intellectual property in their current format do not fit the new paradigm. They are mechanisms for producing an artificial shortage of something inexhaustible, which, on the contrary, becomes more fertile and reproducible through free exchange and interactions, in the context of a system of accumulation based on the production of knowledge through knowledge. The duality between abundance/ widened circulation/ social appropriation versus shortage/ concentration/ private appropriation of information and knowledge may present a challenge to current modes of regulation. Thus, against the tide of new *enclosures* of what is commonly produced, the crisis in the execution of property relations arises. In the era of networks (CASTELLS, 1996) and of access (RIFKIN, 2001), the traditional legal frameworks of property themselves are called into question (COCCO, 2006).

OPEN SCIENCE IN MOVEMENT

The movement for open Science is part of this framework of tension between new forms of collaborative, interactive and shared production of information, knowledge and culture on the one hand and, on the other, the mechanisms of capture and privatisation of this knowledge that is collectively and socially produced.

This movement have acquired an international dimension, indicating that the modes of scientific production and communication prevailing today are inadequate, as they are subjected to mechanisms that create different types of artificial obstacles - especially legal and economic ones - to their free circulation and to cooperation and, as a consequence, to their progress and dissemination[1], in a context where there are virtually no technical barriers to the immediate circulation of information.

It is argued that open science promotes growth in stocks of public knowledge, favouring not only the increase in the overall rate of scientific production and innovation, but also the social

[1] On this issue, see the chapter by Cameron Neylon in this book.

return rate of investments in science and technology. It has been historically demonstrated that it is through the sharing and opening of the collective and non-individual production that creativity and innovation are better developed. On the other hand, the complexity of scientific challenges and the urgent nature of social and environmental issues facing science impose the facilitation of cooperation and the sharing of data, information and discoveries.

However, there is no consensus or broad understanding of the extent, the meaning or *modus operandi* of what open science may be, nor of its implications[2]. Some people consider this the resumption of the *true* spirit of science as professed by Robert Merton[3], in the1940s. Others argue that the present movement for open science constitutes not only a new cycle of revitalisation of the Mertonian *ethos* of an uninterested science in opposition to the toughening of the systems of intellectual property from the 1980s. The movement for open science in its current format reflects, in fact, new modes of thinking and of exercising *scientificity*, with direct repercussions on the institutional commitments, rules and frameworks that interfere directly with scientific practices and their relations to society. The development and propagation of infocommunicational platforms, of hacker ethics and of the free digital culture reverberate on the forms of producing and of circulating knowledge and information in science (SORDERBERG, 2008; DELFANTI, 2013).

As it moves forward, the movement for open science changes and incorporates new elements into its agenda. Open science becomes an umbrella term that goes beyond free access to scientific publications and includes other topics such as open scientific data[4],

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[2] On this topic, see the chapter by Alessandro Delfanti and Nico Pitrelli in this book.

[3] This has to do with the norms for scientific activity put forward by Robert Merton referred to by the acronym CUDOS (communalism, universalism, disinterestedness and organised skepticism).

[4] See the chapter by Jorge Machado in this book.

open scientific tools, open scientific hardware[5], open scientific notebooks[6] and *wikisearch*, citizen science, open education (ALBAGLI; CLINIO; RAYCHTOCK, 2014).

Emblematic of the diversity that characterises open science nowadays is the broad range of meanings and premises that surround the idea and the initiatives of citizen science[7]. This range also encompasses two major approaches. One of them brings together initiatives that seek to mobilise voluntary contributions of various types to research efforts by non-scientists, from the sharing of computational resources to the gathering of information of scientific relevance through what is already known as *crowdsourcing science*. Within this approach – which is here called pragmatic or instrumental –, there is not necessarily an opening up of data, and the volunteers do not have necessarily any influence on the design or the results of the research.

The other approach of citizen science includes initiatives directed towards greater citizen participation, intervention and empowerment, not only in the forms of production and use, but also in the course of research itself. This is the case of the development of open and decentralised tools in favour of the democratisation and appropriation of science and technology by citizens in benefit of social innovation. Here we find the participation of local communities in the control and sensing of local of environmental quality as well as in metropolitan public policies and issues reframing the idea of intelligent cities into that of democratic ones[8]. This fosters citizen participation in the co-management of territory and new ways of living. We call this approach a democratic one.

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5 See the chapters by Rafael Pezzi and Denisa Kera in this book.

6 See the chapter by Anne Clinio in this book.

7 See the chapter by Henrique Parra in this book.

8 See this discussion on: http://www.eldiario.es/colaboratorio/Menu-participacion-democracia-plataformas-ciudadania_6_388171211.html . Accessed on: May 5, 2015.

Therefore the idea of openness is under dispute. In fact, it is the idea of science itself that is under dispute.

The culture of sharing is also the culture of *remix*. It is in the arts that the culture of *remix* gains strength with the *avant-garde* counterculture movements started in the 1960s that placed the artist and its audience at the same level. The culture of *remix* takes on a new form of expression with platforms for sharing and with digital culture. In the so-called *netart*, artists and audience are blended and mixed up (CAMPANELLI, 2011).

This reframing of the relationship between the author and the audience contaminates and spreads to the sphere of science. In scientific production, remix happens all the time. We constantly recombine work already completed; these new combinations may be more or less creative, more or less radical in advancing knowledge. R*emix* stands today on an increasingly tenuous line between what is considered legitimate appropriation and plagiarism.

The borderline between producing and communicating science, between producers and users of knowledge is toned down; the process (the flow, the dynamics) is valued above the product (the stock) along the lines of what Cocco (2012), inspired by Paolo Virno and Walter Benjamin, called "labour without work and work without an author"[9]. Scientific production and communication become inseparable processes, communication becoming directly productive. In the case of scientific publications, the system of *peer review*, responsible for ascertaining the quality and for certifying scientific production may give way to a system of curatorship, more closely related to the idea of being together, to attention and care, to co-production.

Thus, in the development of open science, beyond technical and technological problems (such as the development of free tools, the availability of open computational platforms as well as of

9 "trabalho sem obra e obra sem autor"

technological infrastructure for sharing data), formal or informal questions of a cultural, political or institutional order are the ones that most interfere with the open or proprietary character of these practices. More important for this development are new uses that lead to changes in the methods and the logical structure of research and, as a consequence, in its results, in a process of continuous learning and innovation (ALBAGLI; APPEL; MACIEL, 2014).

ETHICAL-POLITICAL CHALLENGES AND THE NEW AGENDA OF RIGHTS

Consequently, open science does not concern only the potential or ease for generating or circulating information and knowledge – that is, a new order of productivism. Open science encompasses multiple levels and ranges of openness, including both a pragmatic sense of conferring greater dynamism to activities in the fields of science, technology and innovation, as well as a democratic sense of allowing a wider opening to different perspectives in the sphere of science as well as greater social participation and intervention. These are issues of a qualitative order within which both the ethical and the political dimensions are closely associated (SCHNEIDER, 2013).

From the point of view of open science, the ethical dimension takes on new formats and reaches different levels and ranges. It concerns the ethical commitment to making the research work and its results immediately available for use and remix by others, whereas codes of integrity and ethics in research adopted by scientific and teaching institutions have mostly focused on the combat of plagiarism.

Within the sphere of digital communities for sharing and collaboratively producing knowledge, one finds an intrinsic ethic, ethical principles not always made explicit or formalised that govern the dynamics of these communities. Within these communities, the focus is on establishing protective barriers against free riders:

one participates, one takes possession and one makes available. These principles are asserted less through sanctions than through the collective construction of rules of behaviour that ultimately have to do with issues of informational governance.

Ethical issues are also posed to participatory research approach, when considered both the need of attaining previously informed consent from affected people and social groups, and of providing feedback from research results.

Finally, questions concerning research finality are also raised, such as: which (open) science? In which direction? For whom? For what type of development? Which society do we want?[10] These questions concern not only the progress of scientific knowledge itself, but constitute, above all, indications of its repercussions and social uses[11].

From the start, it should be pointed out that over half of humanity is excluded from major cognitive infrastructures or better, they are included in an excluding manner. Consequently, different geopolitical, geoeconomic and geocultural perspectives are at play – or, frequently, in direct confrontation – that interact with the unequal position of different social segments.

If markets of knowledge and information demand a toughening of legal codes to guarantee the right to intellectual property, new regulatory mechanisms arise aiming at redressing asymmetries resulting from the private appropriation and distribution of scientific knowledge, especially in sensitive areas or those with a strong social appeal such as health, agriculture, food and the environment.

When strongly criticising the present system of IPR, particularly in connection with the pharmaceutical industry, the winner of the Nobel Prize in Economics for 2001, Joseph Stiglitz,

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10 On this topic, see Albagli and Maciel (2007).

11 On this topic, see the chapter by Leslie Chan, Angela Okune and Nanjira Sambuli in this book.

states: "All knowledge is based on prior knowledge, and by making prior knowledge less available, innovation is impeded." (STIGLITZ, 2015, p. 278). In his opinion, the toughening of this system has had a negative impact on social well-being and on the increase of inequality as exemplified by "higher prices for consumers, the dampening effect on further innovation of reducing access to knowledge, and, in the case of life-saving drugs, death for all who are unable to afford the innovation that could have saved them." (STIGLITZ, 2015, p. 281)

Poor people are certainly those most affected by systems of private appropriation of knowledge (and particularly by patents) to the extent that (ALBAGLI, 2012):

a) they artificially raise prices of products, affecting the most needy;
b) they do not disseminate effectively the benefits of the advance of knowledge, particularly among the poor;
c) they shift the focus of research to areas that interest the rich, and not the poor;
d) they set up barriers to research and, consequently, to innovation, particularly in areas that interest the poor.

Thus, the struggle between intellectual property rights and open knowledge leaves a strictly technical or scientific arena that interests only specialists, to mobilise a broad range of social actors whose lives are directly affected by these issues. IPR affect areas that range from cultural production to scientific-technological production, touching on health, the environment, food and agriculture among others. The awareness that legislation governing IPR affects areas beyond the economic is expanded:

> [...] [they] mediate human experience, well-being, and freedom. [...] Because intellectual property law regulates much more – from how we

> are able to learn, think and create together to how and whether we have access to the medicines and food that we need to live – it has become a central site of political struggle, not just locally, but globally. (KAPCZYNSKI, 2010, p. 23-24)

Therefore, one the one hand, open science sets up a new agenda beyond human and social rights, aimed at ensuring sustainability and the survival of life in a broad sense. Here the ethical dimension of open science refers us to the concept of "cognitive justice" (SANTOS, 1987) which in turn implies the possibility and the capacity of formulating other questions and of considering other ways of living together. On the other hand, the need to respond to social demands and development agendas may improve science openness, in its various meanings.

Lafuente prefers to talk about common science[12]. In its conception, common science is understood less as a common *good* (that which at the same time belongs to everybody and, as a consequence, belongs to nobody), that refers to a proprietary economic paradigm, but rather as the science that is *among* all of us. This should be the greatest ethical challenge of open science: the dialogue with *the other*, the building of bridges and mutual fertilisation in the diversity of knowledge. Common might also mean ordinary, different then from the idea of *commons*, which contains the symbolism of the sacred – of earth, water and of knowledge itself. Consequently, a conception that refers to the anthropological imagination rather than to the economic.

To Schneider (2013, p.69), this ethical-political dimension

> […] requires opening up to non-scientific knowledge; in order for reason not to be reduced to technical reason, it is necessary to establish a dialogue with non-systematic thinking, with myth, art, with values,

[12] On this topic, see the chapter by Antonio Lafuente and Adolfo Estalella in this book.

> with the non-rational, that is, with everything in life not reducible to instrumental calculation. Not in order to become the same as this type of knowledge, but to learn from it.

Situated in this context of transformation, the ethical challenges presented by open science are evolving and undergoing fluctuations. These challenges are of different types, requiring answers at different levels and dimensions.

NEW INSTITUTIONALITY

One of the major challenges of the movement for open science concerns institutionality. The efforts of open science involve differentiated instances of action and decision, both internal and external to science, starting from the individual researcher and research teams to the macro level of public policies and international regulation, past the intermediate level of scientific institutions and development agencies[13]. This has to do with different spheres, instances and mechanisms of regulation and governance – more specifically of informational governance – involving specific forms of management and of conflict and power solutions. They are often disconnected, but they exert direct or indirect influence on each other.

On the one hand, new institutional formats as well as normative and legal frameworks are introduced that affect forms of production, circulation, appropriation and use of scientific knowledge. New evaluative models are also required that might help overcome the pressures of academic productivism and find new forms of accreditation that might value the new ethical dimensions of open and collaborative research and that might contribute towards collective creativity and innovation.

[13] On this topic, see the chapter by Alexandre Hannud Abdo in this book.

On the other, tacit agreements are established that are not restricted to formal institutions. They may be understood from a pragmatic perspective of systems of information, resulting from information actions[14]. In addition, this is what makes them dynamic and open to change.

Here, we are talking about both the opening up of existing institutional spaces and mechanisms – from universities to institutions promoting research – to the growth in importance of new spaces of collective and open production of knowledge that have come into being such as hackerspaces and other collective citizen spaces, both in urban and rural environments. The objective is to foster new forms of scientific production, as well as to facilitate the cognitive dialogue and the relationship between different types of knowledge. In addition, to acknowledge and to mobilise the diversity of social actors who produce highly relevant knowledge and learning experiences, but who are disregarded by institutional spaces where science is produced and taught.

Social and institutional innovations that provide protection for what is collectively and socially produced are part of an effort that is becoming increasingly important in the construction of a major common cognitive infrastructure. What are new and innovative forms of constitution and of institutions of open science and of the common is now under discussion. The how and the directions in which these new paths will be built is part of a debate that should be open to a large number of participants and to a broad range of possibilities of alternative future scenarios.

[14] In the conception of information system adopted here, two aspects central to the approaches of Berndt Frohman (1995) and Maria Nélida Gonzalez de Gomez (2002) are emphasised. The first one is the acknowledgment of the role of informational practices (information actions) beyond the formal institutional dimension; the second is the acknowledgement of systems of information as being, at the same time, an area of struggle and conflict as well as of negotiation and stabilisation.

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2

Ways of science: public, open, and commons

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To proclaim the public nature of science has become both commonplace and a much discussed topic. The consensus is sometimes overwhelming: the world calls for more science and everywhere more funding is demanded for research, taking it as a given that science is not only economically necessary but morally irreplaceable. The understanding, however, has never been absolute and there have always been those who denounced a democratic deficit associated to how little discussion there is about the kind of science we want or the fact that we keep addressing as externalities the damages inflicted by the use of technology upon the environment or people's health. It is true that in addition to being public, science is also private and the intersections between academia, the government and businesses are long-standing, intense and, sometimes, obscure.

Science is not only semi-public, but cannot exist without the public (Nowotny et al., 2005). There is an abundance of papers which insist on the urban, social and collective nature of science. Far from what we would be told by the stalest historiography, science is not a business made for geniuses, nor is it something which happens in the brains of a few. It is obvious that the locus of science has always been academia and the laboratory, but it is not less true that it has gained space in company headquarters, boards of directors, trade fairs and the stock exchange. However, our list of urgencies would be incomplete if it did not incorporate the garage, the market and the streets. Science has always maintained a complex, dynamic and vibrant relationship with people, amateurs, artisans, witnesses, spectators, activists and consumers. And yes, it is true that citizenship, for better and for worse, owes much to science, in the same way that the thesis that science owes much to citizenship is also correct. There are plenty of anonymous, invisible and tacit contributions to knowledge that are hard to accept and that our history is determined to disregard. Not only is the modest figure of the *travailleur de la preuve* the majority, as said Gaston Bachelard (1986, p. 56), but the figure of the academic leader, or the group leader or the first signatory is also exaggerated. As a consequence, everyone seems to be accomplices in producing an exaggerated and certainly self-interested image of science.

The author, as we know, has never been the key part in the mechanism that moves the scientific machinery. This recent change is associated with the imperatives of the new public management which, on one hand, claim the capacity to regulate the economy of the reputation and, on the other, the freedom to impose the imaginary that contribute to convert knowledge into coded information. The consequences are catastrophic because not only do they encourage different processes of privatization of knowledge, but they also accentuate the production of new asymmetries that explore the environmental justice studies and increase the severity of practices identified as industrial secrecy, academic fraud, social segregation and economic monopoly.

To develop our argument, we have divided the text in three parts. In the first part, we explore the historical origins of the condition of science as a public good. In the second part we show the problems in making analogous the conditions of commons science and open science, which is equivalent to saying that the demands of the open access and open data movements are necessary but not sufficient. The third section argues that the condition of common good is not reached when the good is for everyone but when it is, among all, that which provides the conditions for the common good, to meet the requirements of the third sector, along with the private and the public. Science understood as a commons would not be public but open science or extramural science yet not merchantilized. Neither would it be formal science, as usual, but capable of including the dimension of citizenship in the design and evaluation of projects and their outcomes. It would not be the same science as always but now in a democratic or postmodern version. Science is not a commons as a result of being more functional, open or militant, but for being the fruit of the implementation of contrastive, collective and recursive cognitive practices. The commons would then be a historically differentiated way of producing knowledge, community and commitment. Thus, in the third part, more than science as a commons, we will discuss commons as a science.

SCIENCE COMMONS AS PUBLIC GOOD

The concept of science as a public good is relatively recent. Philip Mirowski (2011) has devoted many efforts to explain it. In order to understand the concept, one has to accept that the pressure to which scientists have been submitted to by the Church, the Empires and the State has many similarities to what nowadays is practiced by industrial corporations. It is well known that already in the 19th Century university laboratories were intensively searched by industrialists who sought to find among test tubes and reels some discovery upon which they could develop new monopolies. Everything seems to indicate that the communitarian nature of science earned credit because somehow the companies which financed industrial laboratories had to be legitimated as proprietaries of the findings. Thus, if the discovery was the result of collective work, nobody except the owner of the space where that knowledge had been produced could claim the patent.

World War II changed that picture drastically. During the second third of the 20th Century, the State claimed the right to direct science and also to create the conditions to accelerate innovation. The war economy gave birth to a techno-military complex where public sector would invest in basic science in order to guarantee the free circulation of knowledge among entrepreneurs participating in a game whose rules, laid down by the army, served as the reason of State. The condition of public goods meant the nationalization and militarization of the so-called Big Science. From the 1980's, things changed at full speed, as the Bay-Dole Act (1980) and other judicial decisions in the USA created the conditions for the start of an accelerated process of privatization of knowledge. Discoveries, and not only inventions, could be the object of intellectual property rights and, therefore, could be treated as current assets in the stock market and attract risk capital. If, in the 1960's, knowledge had been treated as an imperfect asset which could not survive in a free market situation without government support, twenty years later the necessary juridical, political and financial instruments had been already developed so that science could flirt with neoliberal economy. In this new *academic capitalism* regime, the frontier between the public and the private tends to dissolve (SLAUGHTER; RHOADES, 2004; SLAUGHTER; LESLIE, 2001).

The transition, however, did not happen without resistance. What is already obvious to everyone was anticipated just by a few. And those arguments are still valid. Paul A. David (2008) explained to us how – since the dawn of modern science, scientists started to be perceived as people out of control due to the sophisticated nature of their knowledge. In court, given that nobody could act as counterweight, the only option was for open knowledge so that it was scientists themselves who ruled over the quality of their peers' work. This may have been the origin of awards, academies and journals. The autonomy of science led to its organization as a meritocratic, open and cosmopolitan corporation. To distinguish between the wise and the charlatans required the participation of new spaces, different actors and different mediations which, as a whole, lead us to treat the so called Scientific Revolution not as an *epistemic revolution* as it was described by authors like Alexander Koyrée or Thomas Khun, but as an *open science revolution*. Michael Polanvi also wanted to join the club of those who denied that knowledge could be treated as information and then subsequently, having uprooted it from its production place, convert it in monetizable resource. The commodification of science was impossible because one could only patent knowledge that was not tacit. Norman Wiener, for his part, defended that innovation was an emerging phenomenon that, as in any other complex system, was associated to the multiplicity and heterogeneity of the interactions between different actors, while patents would operate like bottlenecks which impaired the flow of information. The three positions mentioned above argue that science only thrives when it is held as a collective business whose fruit are not reducible to codifiable information and whose organization goes beyond attempts to confine them within a protected environment (JONES, 2006). The history of ideas, the anthropology of organizations and the economy of innovation coincided in the need to reclaim from the State an active role in the preservation of science as public goods (MIROWSKI; SENT, 2008; SENT, 1999). It is this tradition that Michel Callon inherits and assumes in his provocative way of thinking science.

Callon 's (1994) reasoning begins by demanding from readers the acceptance that knowledge has always been a very worldly enterprise, never isolated from surrounding interests. To say the contrary is to ignore all the work already done in the field of science. To claim the condition of commons for science implies the acceptance of the erroneous thesis that ideas are easily transported between different sites, be they curricular, cultural or geographic. It is true that for decades, even centuries, we have told the history of science as if it were the global expansion of an oil slick or the spread of an epidemic. There is nothing natural in the transmission of knowledge. It is a mistake to associate the dissemination of science to the propagation of ideas. What the STS have taught us is that verifying any natural law or checking the relevance of a scientific concept requires plenty of machines, technicians or alternatives, as well as time and resources to produce, select, contrast, discuss, standardize and communicate findings. To say that Newton's laws are met in Cuzco means to say that we are able to replicate in the Andes all the paraphernalia needed to verify them. Ultimately, we are saying that ideas exist embedded in things and there is very little which is intangible in the transmission of knowledge. For that reason, it is increasingly more necessary to distinguish between knowing with words and learning with one's hands. To turn science into a commons is a utopian project and makes us ask ourselves if we can truly bear transmission costs which would be extensive (ARVANITIS, 1996).

The *actor-network theory* had questioned for years the notion of scientific community as the basic element and engine of the dynamics of science. If science is a company run in a network, we may demand that more convenient ways are adopted in order to guarantee the diversity and proliferation of actors, questions and processes. Healthy science should promote *Freedom of Association* so that different forms of organization are always in place; Callon also asks for *Freedom of Extension* so that the network prevents the enclosure or the imposition of some form of orthodoxy or canon, and finally invites all the actors involved for a *Fight against Irreversibility*, aimed at preventing monopolies from creating standards that block out innovation. That means that the notion of public goods is explicitly associated with diversity and not to free access. It would be important, then, not to share goods equally, but to create the conditions to prevent the interruption of production processes and the diversification of knowledge. The goods we want to protect are not knowledge, but the plurality of forms of socialization it promotes. We do not need the State to protect knowledge itself, but the networks where it circulates. This is not about the protection of ideas which are published or merit a Nobel Prize, like the infrastructures which support them and that are frequently both opaque and contrary to public domain.

SCIENCE COMMONS AS OPEN SCIENCE

To imagine science as a common good demands that we stop to think of it as something that can be separate from the market (HESS; OSTROM, 2007; CORSÍN-JIMÉNEZ, 2013b). We also need to dissociate those complaints from the notion of free access. Elinor Ostron has argued with memorable forcefulness: nothing could be more contrary to the common good than open access. In fact, the confusion between both concepts is what led Garrett Harding (1968) to proclaim the tragedy of the commons and to demand as a survival strategy the public or private patrimonialization for the goods that really mattered. The commons, repeated Ostron (1990), are not a *thing*, but a form of management which fails when the community that supports them and is maintained by them is not supplied with efficient rules to, among other threats, protect themselves from *free riders*.

During the last decade, we have witnessed the birth of several movements which have claimed for science the status of open enterprises. Although not all proponents use the same arguments or emphasize the same principles, it seems reasonable to mention two of the main types of reasons. On one side, there are those who question the widespread practice of outsourcing of the communication process. All share the criticism that the current system is both wasteful and paradoxical, since it involves huge costs in the production of papers, which then must be bought from those to whom they were previously given at zero price (MOULIA et al.,2013). And what was said about articles worsens embarrassingly when we think about the data, as scientists have got used to a regime of competition which is so compelling that they have turned non-cooperation into the password for their professional ecosystem. If the data is the foundation of academic work, it is not surprising that within a similar knowledge regime, laboratories treat findings as a scarce resource which must be protected from piracy. The academic problem is serious, but it is even more worrying when we think about clinical essays or expert opinions which condition the processes of *technology assessment* and, in general, great part of political decisions which affect our community life.

The second reason to claim free access to scientific information has to do with the aspiration of well-informed policies, faith in freedom of choice and the strengthening of democracy. Discussions on energy options, the consumption of genetically modified food, the quality of the air, food labelling or the treatment of chronic diseases, not to mention the role that our society must assign to homeopathy or the many forms of alternative medicine, open processes which must be openly discussed. Nor is it a less important matter the fact that the exaggerated costs of scientific information or of medication exclude their use from institutions, patients or poor countries, making science another contributing factor for the asymmetries of our world.

Waste, careerism and opacity are well-deserved criticism that justify the slow move in favour of open access. The quality of democracy and global justice are not minor objectives and perhaps cannot be postponed. However, it is true that something stinks in this whole debate. Open science policies correct some of the urgent needs of the current system, but it is no less true that open, online and free of charge distribution has a cost whose main beneficiaries are great corporations or, in other words, those who have the capacity to capitalize on the information. Moreover, it is not obvious that accessibility corrects the role of science in our world in a more decisively manner. The fact that information is available does not mean that we may use it or do something with it, since it will still be material that is extremely linked to technologies and to the values under which it was produced. Ulrich Beck (BECK, 1992, p. 166) was right in sharpening the pencil to write that facts are nothing more than the possible answer to questions that could have been asked in a different way. Alternatively, and more directly, instruments would be of little use if, once accessible, could only function at the service of the same questions, the same protocols and the same forms of knowledge validation. We need to ask ourselves if things could be different. Is making science more functional everything we can aspire to?

Those who study open science have invited us to consider phenomena like SETI or all crowdsourcing projects associated with the pioneer platform BOINC. Voluntary computing has become a powerful mechanism to address problems which call for huge calculation capacity. Distributed computing, be it private, public or citizen, already has many successes to be proud of: *GalaxyZoo* or *Innocentive* have attracted numerous studies seeking to explain how the world of Big Data or open innovation constitute new hybrids with which we will have to learn to deal with. *Wikipedia* and *Fold.it*, two very different projects, show without attenuation the emerging power that can be unleashed by connected crowds (FRANZONI; SAUERMANN, 2014). We are referring to the colossal devices that interconnect millions of human beings; we are also referring to new forms of producing and validating knowledge (NIELSEN, 2011). But it is not only that crowdsourcing, allied to crowdcrafting and crowdfounding, feed the long deferred dream, capable of replacing the illustrated *technology for the people* with the more empowering *technology by the people* (HAND, 2010). There are examples which lead us to imagine a citizenship capable of producing facts that antagonize with official data, whether we talk about environmental or food crisis, or to the production of new maps, different patterns or institutions. If so, we would be experiencing the dawn of new knowledge regimes which would be organized upon other forms of encoding, filing, communicating and validating knowledge. Laboratory space, formerly reserved for experts, becomes disputed over. Experts have reasons to feel restless. Everything indicates that their consolidated hegemony might be in jeopardy. It is not the first time that some demonstrations of discontent resulted in the widening of knowledge space, including new actors and different questions. Those who accept these propositions treat the influence of *criollismo*, hygienism, feminism, functional diversity or environmentalism as epistemic modernization processes (HESS, 2007; LAFUENTE, 2012). Isabelle Stengers (2005) talks about cosmopolitics to remind us of the forcefulness with which non-professionals have always been expelled from public spaces must be replaced by a more respectful gesture with epistemic pluralism. Peace needs to be settled: we need a lasting agreement that does not insist in the division of the world between those who know and those who do not know, a ceasefire which saves the world from the arrogance of a selected few. To say that we need science to guarantee a prosper future is not enough, given that a number of times there has been a claim for more science which ended in the gassing of troops, bombing of cities or, in general, legitimizing an exclusion policy that, ultimately, guarantees new wars for science (STENGERS, 2006).

Citizen science has shown its ability to secure presence in public spaces (IRWIN, 1995; COLLINS; EVANS, 2002). The Gulf War disease syndrome (BROWN et al., 2011), the struggles of those affected by AIDS (EPSTEIN, 2007), the protest that represents the French Muscular Dystrophy Association (CALLON; RABEHARISOA, 2003; RABEHARISOA; CALLON, 1999), the arguments on breast cancer introduced by feminists (MCCORMICK et al., 2011), or the visibility gained by electrosensitive patients (CHATEAURAYNAUD; DEBAZ, 2010), have much in common. Here we want to highlight, as taught by John Dewey (DEWEY, 1927; BROWN, 2009), that which is crucial for our democracy: to be no longer invisible and to gain the ability to establish a dialogue with public administration. The important aspect is the way in which this was achieved, as protest turned into proposal, demonstrating the ability to produce, mix and communicate information based on data, concepts and validated scientific objects. The scarcity of their means and the political harassment they were subjected to did not prevent the advancement of their proposals. They have gained, as explained by Jacques Rancière, the right to the city. We have been taught different forms of civility, more inclusive and contrasted. They have demonstrated i.e., proved with arguments and occupied with their bodies, their right to take the floor in public spaces (RANCIÈRE, 2007).

If we were to make an urgent appraisal of the meaning of citizen science, we would have to acknowledge that it is more science, in spite of being conducted outside the walls of academia. In fact, citizen science is independent science, knowledge developed by virtuous communities which, being radical in their political rhetoric, are more conservative than what we would imagine in scientific practice. For example, they share with Robert Merton the values that characterize imaginary scientific communities: communitarianism, universalism, unselfishness, objectivity, scepticism. Thus, citizen science would be the last refuge for the fall of Mertonian science, while the so called *Mode 2 science* would be what we have always had – a hubris variable that joins academic, corporate and governmental interests (NOWOTNY; SCOTT ; GIBBONS, 2001; NOWOTNY, 2003; STRATHERN, 2003). They are very distinct, but share the same epistemic project, even if many times citizen science has adopted counter-hegemonic profiles. In the same way that aeolic energy competes with fossil or nuclear energy, the truth is they can all coexist in an orderly fashion.

COMMONS AS A SCIENCE

Citizen science is not monolithic and we need to use the plural to refer to them. All citizen sciences share a resistencialist gesture. Some, in addition, have shown that there are alternative forms of relating to the political, economic, scientific and environmental surroundings. At this point hacker culture must be mentioned. We certainly owe much to Pekka Himanen (2001) and his notion of the hacker ethics, as an expression of technological nonconformity which object to the idea that things can only be what they were designed to be. However, the most radical hacker gesture, as taught by McKenzie Wark (2004), implies not only an argument over the functionalities but also a confrontation of the properties. Hacking the world is not only about inventing new possibilities of inhabiting and transforming it, but also to return to the commons all that has been abusively patrimonialized by states and markets. The first hackers, back in the 1960's and beyond, invented the quadrature of the circle: to be an author there was no need to be a proprietor, given that one could only reach the position of creator of something in the very moment when it was donated.

Nothing has been more radical in these approaches than the hacker movement. Nobody did better in translating into sustainable practices and protocols the commitment for an open, experimental, inalienable, horizontal and distributed culture. The texts written to explore each of these words would make up a mountain. We will not raise it in these pages, but neither will lose sight of it. Writing codes is not all the only action from supporters of free software – an ecosystem which only works through the functional assembly of programmers, documentarians, testers and translators. Good care is required and not all succumb without the guidance of the specialist. The success of free software is linked to the fact that it works, or in other words, that programme run, are functional, do their tasks efficiently. Despite the noticeable fulfilment of this expectation, what makes it an exceptional cultural, political and technological phenomenon are the resulting forms of organization of knowledge. How can that be explained in a few lines?

We will take two of its characteristics: the *fork* (COLEMAN; GOLUB, 2008) and recursiveness (KELTY, 2008). A fork is produced when part of the community involved in the development of a project decides to opt for another alternative, to separate from the dominant criteria. When that happens, dissidents are entitled to take all the codes which they use to share until then. Free software then is always open to all its possibilities, always turns out to be a beta design, a prototype incarnated by a non identitary community, a project which is always "*more than many and less than one*" (CORSÍN JIMÉNEZ, 2013). Projects which learn from their mistakes are recursive, something that children do naturally, sometimes in order to imitate adults. Nevertheless, here we are interested in the notion of recursiveness when it applies to systems not people or simple projects. In such circumstances, we say there is recursiveness when not only is the functionality of the device preserved, but also its moral integrity or, in other words, when the protocols and the code are responsible for preserving the values that sustain the project, i.e. the community.

What gives a vibrant character to free software communities is not the purpose of producing for all, but to build them together. The commons for which they work is not guaranteed by free access, but by the determination not to exclude any form of collaboration which improves the outcomes. We are not referring to people only but also to cultures. The result, naturally, is not a product but a way of understanding our relationships with technology and with other human beings, based on the principle that the language used for communication between machines should be open and that communities must be formed by peers in order to dissolve the artificial and imaginary borders that our society creates between nationals and foreigners, experts and amateurs, communicate and share, or between free and free of charge. As already mentioned, we are talking about cosmopolitan communities, informal and based on the economy of talent (LEACH; NAFUS; KRIEGER, 2009). Nor is non-payment the divide which makes these productions unique. Sharing the code has led to the creation of alternative business models which do not ruin those who opt for free software.

MAKING THE CITY

The hacker culture is no longer restricted to the *geeks,* nor is it a matter for computer freaks. Nowadays we talk about hacking museums, academia or the city (COHEN; SCHEINFELDT, 2013). There are hundreds of projects which dare look at the arts as if they were companies that we should re-found on less commercial principles, fighting to free the music, painting or architecture activities from the hook of the cultural industries, tourism or real estate speculation. The city itself, our public squares and abandoned building lots may be inhabited otherwise. Not everything should be sacrificed for speed, security and profit. Our needs are not met by transport, the police or trade. Our streets may be a meeting place for neighbours who do not get together to consume or protest. The street is being widened as the space par excellence by a form of sociability which we had never had and that yet it seems we are losing.

Many people are afraid of wandering around, of eating street food, joining spontaneous parties, touching unfamiliar bodies or, worse yet, to have free time (DELGADO, 2011). In short, we no longer live with our neighbours, we just put up with them and our cities are just containers of fleeing humans. There is an increase in the number of cities in whose public squares and building lots there are groups of citizens who, tired of all the submission to the ideals of individualistic consumerism, are recovering the pleasure of sharing dances, food, fairs, bazaars, markets and other forms of popular celebration and interaction. We were nearly convinced that we would better forget these old-fashioned forms of sociability.

Now, however, we see them as a heritage which embodies the best of us, in other words, of all we share and do together.

Many architects, artists and social scientists know and continue to write about the topic. Yet we have not advanced much. The city should be occupied, we need to fight over it against the leisure, insurance and housing corporations (HARVEY, 2012). This is the origin of a whole series of new emerging urbanisms which operate a singular change in a city that represents both the setting for protests and the very object of proposals (VV. AA. 2009; VASUDEVAN, 2014). The new urbanism is emerging in the abandoned lots, urban gardens, bike routes, the nomad streets, neighbourhood associations, neighbourhood parties, the recovery of memory, the local markets and all the many forms of association implied in these forms of collective experience of the city, based on connections at the same time fragile, sporadic, tentative, intermittent and still recognizable, concrete, localized and functional.

We would fall short, however, if we reduced the notion of a proposal to an action plan presented in a document which selects, articulates, schedules and forecasts a packet of specific lines of action. All of that must obviously take place, but the most important thing is how to identify the narrative and the community which supports it. What matters, in fact, are the bits of learning which they had to go through in order to get somewhere together. The important thing is that they learnt to build together. For that reason, the emerging collective urbanisms constitute real citizen laboratories for experimentation with our capacity for learning how to live together while we give form and produce viable proposals to tackle the problems around us. Proposals are made, and above all the urban experience is reconfigured. There is, therefore, a shift in the way of inhabiting the city and making politics: that which goes from discourse to intervention, which takes us from the fleeting word to the problematization of the infrastructure. (CORSÍN JIMÉNEZ, 2014). The global Occupy movement is perhaps a paradigmatic example of this other urban practice. The protest camps set up in the most diverse geographical locations such as New York, Madrid, Greece or Hong Kong were a sign of reurbanization in the city which put into play their own bodies, threw light on a different kind of relationship and of thinking the city, while giving new material to political action (CORSÍN JIMÉNEZ; ESTALELLA, 2014). Something especially clear when related to the cycle started more than a decade before by the alter-globalization movement. If the alter-globalist proposals intended to seize the foreign city, Occupy attempted to literally occupy their own city (MAECKELBERG, 2012). However, Occupy is only an indicator of a movement with global reach which extends back in time and expands in a global geography through initiatives which claim the right to a different city.

Henry Lefebvre (1969) presented us, several decades ago, the figure of the right to the city. A diffuse expression recently recovered by initiatives intended to make a different city; in reality, the right to the city, perhaps due to its initial ambiguity, has become an emblematic symbol of the new urban mobilizations. We refer to initiatives that are not limited to claiming the right to this or that, but that have different aims. It is not about claiming the streets only, but to build public squares. Public space which suffers material interventions empowers those who live in it with new capabilities and renewed sensitivity, while at the same time equipping the right to the city with new infrastructure (MARRES; LEZAUN, 2012). The urban gardens that dot the abandoned lots, furniture that organize neighbourhoods and the initiatives to occupy empty urban areas are instances where the right to the city is no longer an exercise in complaining but the work to build a different kind of city which dissolves the split between the urban and the rural, turning the street into a hospitable extension of the home and filling with a neighbourhood spirit what before was only a wound, an empty urban space.

In all these projects, people are learning to experiment their city in a different way, and although accredited people are well received they never act as experts. No knowledge is dismissed in these collective experiments which always go beyond formal and traditional expertise. These are projects in which everyone can experiment, investigate, interpret, contrast, reach an agreement, learn and among them create new knowledge (ESTALELLA; CORSÍN JIMÉNEZ, 2014). Literature exploring other forms of experimenting which are not associated to the idea of contrasting hypothesis is increasingly abundant. There are many experimental cultures, historically open, and not all of them have their development associated to the idea of demonstration. Testing, along with naming, collecting, describing and changing the world are gestures that conform different styles of experimentation (KLEIN, 2003). What we have learned from studies of science is that the task of knowing something has less to do with the task of assembling proposals than with building relationships with the environment: it is not an effort of mental musculature but a relational practice (ROUSE, 2002). No example is clearer than these interventions in the city of a tentative, precarious, vulnerable and hopeful nature, or said in a different way, experimental. No one is surprised by those solutions, unless they are simplistic and discriminatory, therefore more time is dedicated to listening than to planning, to doing not thinking and to saying not writing. In order to pose a good proposition it is necessary to put the logic of caring before that of the evidence, and plural episteme before functional ones. A good proposition assembles actors who are potentially very heterogeneous and makes up an open space ready to the identification of matters to be clarified, the discussion of ready-to-wear ideas, the contrast of personal experience, the criticism of circulating interpretive patterns, the examination of the value to be assigned to data or the analysis of other alternative approaches. Altogether, people, instruments, models and practices form an experimental system that, as happens in the best academic science and as explained by Rheinberger (1997), sets off without the safety of the result and among fuzzy and fluid convictions which are not described in methodology manuals and the majority of scientific accounts. There is a risk in wanting to try other forms of inhabiting the city and wanting to turn our vulnerabilities in an opportunity to recognize the emergency of new urban textures, or as Despret and Galetic (2007) said, to be affected by this unprecedented vibration, this uncoded throbbing (LATOUR, 2004a; SANCHEZ-CRIADO, 2005). Thus, the city (in) common that we are evoking does not spring from the expertise of urbanists or politicians, but is brought into existence to respond to other propositions to inhabit the city.

Latour (2004b, 2010) says that we are facing new forms of making up the world which we must mix with those forms which are typically modern and based on contrasted facts or agreed opinion. Politics and science must admit that their allocation of powers over the world are not enough: not everything is a matter of law or fact. Not everything may be managed through laws, agreements, standards and innovation. There is much to be admired in all these entities that science brought to the world and of which we cannot or do not want to dispense with. The world is full of neurons, ozone and neutrinos, not to mention hadrons, transgenics, bits and Cro-Magnons. It is useless to paint the full picture, but it would be unfair not to mention the atmospheric carbon market, the bee crisis, the endocrine disruptors and the desecration of intimacy. Neither have politicians renounced to sowing our lives with a multitude of prodigious objects: rights, infrastructure, standards, labels, taxes, flags and holidays are just a tiny part of this legacy. Politics is not a matter to be taken lightly: our debt with those elected is immense. However, it would be insensitive if we did not evoke the prevarication, the inequality, the secrets, the war, the pillaging and other monstrous productions. All these entities have widened our world, our sky, our bodies, our city, our language and our privacy.

Making a city amongst all, build a common city, calls for something beyond codes and congresses. We repeat it: we do not want, or know, or play at destroying the world of politics and the world of science.

However, it is true that the world of the elected and of the selected no longer represents us completely. We have to, we can and we know how to build a common world. In order to build it we need to bring to existence entities that still do not inhabit it like, for example, a new right to the city, a new urban dweller, new sensitivities, new organs... a series of entities that will help that which is common to rise, in other words, that which is created by all. Making up a city does not imply the production of new consensus or dissensus; neither does it claim for new maps of the reality which may expand our capacity to know or to disdain the environment. The world in common does not claim for more experts, or more mayors, not even more agnostics, more paranoids or atheists. The common world is a world (in) common, made by all, with words, practices, protocols and infrastructure that, as mentioned before, must be open, emerging and recursive. The hardest thing to accept is that we still do not know, as Newton or Montesquieu did not know their creatures, which will be the entities that will make up the common world.

CREATING A BODY

The city looks like a manageable object by non-accredited actors. But what about the body? Must we also reinvent a body (in) common, a body amongst all? The answer is yes (LAFUENTE; IBANEZ-MARTIN, s/d). The accelerated expansion of chronic ailments, together with the growing number of people with serious mental disorders, eating disorders, addictions or behaviour disorders, added to the existence of many groups of people affected by allergies or intolerance, turn diseases with no cure expectancy into a new and disturbing phenomenon. We have been educated in the conviction that all evil would have a technical or scientific – therefore political – solution. We were not prepared to confront the obvious and to admit that human bodies are not the same and that each one reacts differently to the same therapies or circumstances.

Thus, general solutions always produce affected minorities. In addition, not everyone tolerates equally well the bad quality of our air or the contact with chemical substances whose effects on people's health are ignored. It seemed that all of a sudden we had been attacked by an epidemic of fragility. Many people – we do know if the more lucid or those who have lost all hope – have lost the confidence that institutionalized knowledge may offer them some consolation. There are answers for everything, from those who have fallen captive of some alternative and confusing discourse, to those who talk among themselves to explore what is happening (to us).

The first inexcusable example is Alcoholics Anonymous, AA (KURTZ, 1982). A well-known case which has been shown on the cinema many times. Its cognitive and political relevance are quickly verified, because we are referring to an initiative of those affected, which develops at the margin of public institutions, be they academic or related to assistance, sanitary or police services. In AA meetings, it is assumed that there is no individual cure and that it is the strength of the group (sometimes identified, especially in the beginning, with the presence of some divine or transcendent force) which allows those who succumbed to addiction to be rescued from the hell in which they inhabit, and all the lies told to pretend they had the situation under control. Admitting their own weaknesses becomes the key which leads each one of the participants to feel recognized and comprehended in other people's accounts. Evil, consequently, ceases to be the result of individual failure to become the expression of a culture which causes the hypertrophy of the individual as opposed to the relational. An addict would be someone who has taken too seriously the fiction that they have an inner self perfectly confined in space and time, which is the same as saying that it fits perfectly in their bodies and their memories. An addict would be someone incapable of admitting the systemic nature of that which we call personality. What the participants of the AA meetings are doing in their meetings, based on their experiences and through the spoken word, is to reunite with themselves around an inner self which is more distributed, open and emerging. Nobody carries a hero inside except the candidates to fall down, and the alcoholics are the wound through which bleeds a world excessively prone to competition and to heroic gestures. The novelty is in the fact that the experiential acquires not only cognitive but therapeutic value; participants state that AA meetings changed their lives, or in other terms, they state their quality of life improved. The cure through the word is and old and disputed issue, but what interests us here is the recognition that the so-called recovery movement has gained – a movement created by many groups of addicts and mentally ill patients who acknowledge in the AA an undoubted source of inspiration (FARRIS; KUTZ, 1990; WHITE, 2005).

There are thousands of AA groups all over the world, but the participants not always live nearby or can easily access the meeting places. Bringing together dispersed individuals has always been difficult and costly. The internet allows that to happen at nearly zero cost (SARASOHN-KAHN, 2008; FERGUSON, 2007). We have many examples of communities that have used the internet to meet and talk about what is going on. We are talking about groups disappointed with the response they have received from academic and public institutions. We refer to groups of diseased who have not found the expected comfort from formal therapies. There are many groups of diseased who have decided to adopt a critical posture in relation to medical practice and their canonical institutions (RODRÍGUEZ-GIRALT, 2010; BROWN, 2004).

There are two cases which we will examine in order to explore the breadth of these counter-hegemonic movements. The first are the electrosensitive (CHATEAURAYNAUD & DEBAZ, 2010), a condition which affects 3% to 5% of Europeans, with varying degrees of severity. The electrosensitive are patients who had to fight for their diagnosis, because without the acknowledgement of the disease they might lose their jobs or be treated as people without courage or will by their family circle. In practice, we know that a percentage of those affected could suffer the extreme fatigue syndrome and were too depleted to perform ordinarily in life. Without energy and proper diagnosis, their life was an ordeal full of incomprehension and misunderstandings, because frequently they were told in medical consultations that they suffered from some kind of post-traumatic shock originated from their lack of ability to adapt to the technological changes of our time. It was not waves that were killing them, but their resistance to adapt to the modern world. So they decided to get together to discuss what happened to them, with a view to elaborating a document that could represent them, which gave form to the diseased they were suffering from. They managed to convince authorities in Scandinavian countries. So much so that electrosensitivity was accepted as a new illness, which returned to patients the condition of full citizenship and the benefits that the sick enjoy in the so-called welfare societies.

The second case we would like to recount consists of a gigantic online group which brings together mentally sick patients tired of taking anxiolytics and antidepressants. Not only do they discuss whether the solution to problems they experience are the pills, but they are also committed to giving higher cognitive value to their own personal experience. They have decided to use chats to try to understand each other, and to check if there is anything in what they feel that respond to some shared pattern. What happens when people with mental disorders of the Brain Talk Communities (HOCH; FERGUSON, 2005) start to talk, in the same way that it happened with the electrosensitive, is that there are no words to refer to their condition. As the diagnosis or the treatment they are given is not satisfactory, they are forced to identify features which may be recognized as symptoms, which makes them create a shared and contrasted language. Shared because communication does not get interrupted and contrasted because they need to be sure that homemade, local or bizarre medicine which circulate on the chat are effective and not mere placebos. Not only do they contrast potions, but also ideas, sometimes heard in their consultations with their respective doctors, sometimes read in some free access academic repository. What we are saying is that those concerned, based both in their own experience (the proprioception as proposed by Merleau-Ponty) and in the experience they had access to (reading papers or listening to physicians), were capable of organizing a kind of gigantic critical essay in real time, where the diseased took control of their own bodies. Nobody would be more interested in finding good responses than those who are using their own lives while they look for those answers. They know they can only aspire to an improvement in their quality of life: at least for them, the healing paradigm was left behind.

The experiment is confirmed when they agree that they are better, although this improvement is a sustained commitment among all and not an individual solution, like with addicts. If the participants are being taken seriously by formal scientific institutions (the electrosensitive and those affected by the Gulf War syndrome, for example, fought to get a diagnosis) or experience some improvement (like those with mental disorders), there is no alternative but to admit that we are talking about knowledge produced by all. The community that sustains it is recognized insofar as the knowledge produced is validated for being functional. Finally, the affected community exists in/by this cognitive activity. It is a learning community which was able to give consistency to a collective of intergeneration nature and culturally heterogeneous, which means that they have acted as social brokers. Their role as social innovation vectors does not eclipse their importance as knowledge producers and as creators of other forms of sociability.

Let us recap the nature of your network activity: experimental, open, relational, distributed, horizontal, collaborative, inalienable and recursive. What talkers are doing is to reinvent a relational body based on experimentation; that is, in all that a scientist tends to qualify as collateral, irrelevant or useless. It is the same experience that we described before in relation to urbanism. From the abandoned lots and in view of social practices ignored for being characteristic of the poor, uneducated or marginal, we are reinventing the city. In the same way, we are creating a common body from the excess, from what is ignored for being irrelevant (LAFUENTE; IBANEZ-MARTIN, s/d). It is not that the scientists disdain what they do not know, but rather that their protocols and practices preclude them from considering the experiential as material from which to build contrasted knowledge.

COMMON SCIENCE

We already have everything we need to conclude. We call common science a form of producing knowledge that must happen amongst all. The condition of "amongst all" is different from the "for all" that is characteristic of public goods. Common science is not better or worse than public or private science, but different. It is built from other practices and different materials, and the way in which knowledge is validated is also different.

If it needs to be made amongst all, it is necessary that it does not require previous accredited knowledge. No titles are requested, nor previous experience. The entry rituals do not discriminate between those who know and those who do not know, or between those who are capable and those who are not. There are no exams, no competition. Nobody seeks the best or the better prepared. Common science is not conceived from the imaginary of the experts. They may be represented, it is expected that in the collectives referred there are people with some qualification or with more reading, or why not, with more dedication. Not all participants have the same degree of knowledge, or know it in the same way. It is exactly the opposite. Each one has arrived at the collective by their own means without any filtering process in order to produce a more connected group. So that it happens amongst all, so that nobody is left out and nobody dominates the situation, knowledge must be constructed from material which is both abundant and ordinary: experience. Something we all have. Moreover, something in which we are all experts, because we all know nuances, even if not verbalized, about that which happens around us and about what we can discuss with flexibility and our own criteria. We all know a lot about what happens to us and we can all participate in a process whose destination is the knowledge of what we have in common, or in other terms, to find the words with which to describe our shared experiences. The cases we have described, both in terms of the human body and the city, show that common science is part of a response that the communities of the diseased have found to give visibility to their own way of inhabiting the world, or their way of feeling it, of narrating and sharing it.

The search about which we talked is experimental in its shared, contrasted and public nature. The process is always open to the arrival of new interlocutors and other points of view. The process, being open, is not infinite, because it ends when the participants – as it happened at the AA – realize they are feeling better, when the signs of improvement in quality of life are undeniable. The truth about the experiment is contained in the goodness of its consequences for participants. It is the community of those concerned which certifies the credibility of the procedures. The community not only is constituted while experimenting and its members learn to live together solving the problems that affect them, but it is exemplary and sustainable, which is equivalent to saying it is replicable and hospitable.

Common science which is configured around the recovery of the experience of something that we were about to forget, the experience of a body and a common city, is not an alternative to academic science. Both need each other, although sometimes we will see them competing for public space and also for the public.

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3

Open science: revolution or continuity?

Alessandro Delfanti e Nico Pitrelli

Will scientific discovery become as quick and immediate as a tweet? For Michael Nielsen, quantum computing expert and open science advocate, we are in the middle of a transition towards a new scientific era, an era comparable to the 17th century Scientific Revolution and the transition to the modern age. According to Nielsen's book *Reinventing Discovery* (2012), thanks to the Internet we have a chance to radically transform the way in which knowledge is produced. The US scientist highlights two directions in which networks have impacted science: an acceleration in the speed of scientific discovery, and a profound change within science and society relationships. This increased epistemic and social efficiency is based on the impact of openness on the scientific enterprise.

"Open science" is a very broad concept that encompasses several different practices and tools linked to the use of collaborative digital technologies and alternative intellectual property tools. Some inclusive definitions propose that open science embraces practices as different as open access to scientific literature, digitally-mediated forms of open collaboration, as well as the use of copyleft licenses to foster reuse of scientific results and protocols. For example, FOSTER, a project recently funded by the

European Commission to set in place sustainable mechanisms for EU researchers to embrace open science practices, defines open science as "the conduction of science in a way that others can collaborate and contribute, where research data, lab notes and other research processes are freely available, with terms that allow reuse, redistribution and reproduction of the research."[1] The taxonomy tree of this concept branches into several directions (see also FECHER; FRIESIKE 2014). The website lists at least five different classes of issues or topics related to open science: Open Access, Open Data, Open Reproducible Research, Open Science Evaluation, and Open Science Policies. Each of these themes can be subdivided in many other subtopics that represent the whole spectrum of difficulties you face in an open science framework. Not to consider Research Data Management, and finally Ethics and Legal Issues.

This complexity might partially explain why, in spite of Internet apologists' emphatic tones, some scientists seem to be reluctant in the adoption of the opportunities networks offer. Twenty years after the birth of the World Wide Web at CERN, in Geneva, scientific research is embracing change at a slower pace than other fields of cultural production. For example, physics might seem to be one of the disciplines that have taken the most advantage of the opportunities offered by digital and connective technologies: since the dawn of the modern Internet physicists have inaugurated preprint archives in which any researcher can deposit and make freely available the draft versions of scientific articles before submitting them to an academic journal. Yet in recent initiatives in the field of physics that deploy huge organizational and financial efforts, as well as strong promises of innovation, the reproduction of traditional practices seems to prevail. On January

[1] Available on: https://www.fosteropenscience.eu/foster-taxonomy/open-science-definition. Access on: January 19, 2015

2014 physicists launched the SCOAP3 consortium (Sponsoring Consortium for Open Access Publishing in Particle Physics[2]), an unprecedented initiative towards an open access publishing model in particle physics. The consortium includes some of the most important scientific institutions of the field, CERN *in primis*. These institutions pool money that would normally be allocated to journal subscriptions or to "gold" open access journal fees. The SCOAP3 consortium then distributes those resources on a pay-per-article model, thus guaranteeing funding for the publishing cost of the most important particle physics journals. Thanks to SCOAP3, anyone with a computer connected to the Internet is able to access articles published in the field, which are made freely available online by publishers.

Obviously, the SCOAP3 model might be difficult to export to other disciplines: particle physics is a relatively small and cohesive field, with a limited number of journals and a strong culture of sharing. Also, while this switch to an open access model might be the first one involving an entire scientific field, the main change introduced by this initiative is at the level of the financial relation between publishing houses and universities, rather than the modalities of scientific knowledge production. SCOAP3's final goal is in fact the scientific paper, a form of knowledge exchange that hails back to the 17th Century. In this case the core phenomenon is re-mediation, i.e. the transposition of an old medium (the scientific paper published by a scholarly journal) onto a new technology (the scientific paper published online by web-based scientific journals) (BOLTER; GRUSIN, 2000). This is anything but a revolutionary process. But digital technologies offer a much broader spectrum of possibilities: collaborative writing and design (Wikipedia and Linux), distributed rating systems (Amazon and Yelp), trend automatic analysis based on big data (Twitter). While

[2] Available on: http://scoap3.org/ . Access on:January 19, 2015

some similar tools and technologies are being adopted by other scientific disciplines, especially biology, change seems to be slower than the disruptions lead by digital technologies in other cultural industries. Why does the field that invented the web appear so slow in adopting the opportunities it creates? Why is it not driving Internet's evolution anymore?

Some open science activists seem to be puzzled by the slow pace of change, as they take for granted that "science wants to be open." But considering all those variables and problems, it is difficult to support a position that portrays science as teleologically directed towards more openness. In our opinion, the transformations related to the emergence of digital media need to be put in a historical perspective. Open science is not necessary, but rather one among many possible evolutions that depend on several factors that include but go beyond technological evolution and adoption, and even cultural change. Understandably, most approaches to open science tend to highlight the dimension of novelty and change. While we do not deny the cultural importance and productivity of those vantage points, we would like to stress that other perspectives should be taken into account. Here we sketch out three issues that we believe should be acknowledged as core problems by any research agenda that analyzes open science and the impact of digital technologies on the production and circulation of scientific knowledge: the resilience of communication formats over time, in this case the scientific paper; the increased importance for science to maintain its social boundaries; and finally the broader social positioning of scientific research and its communication practices.

First of all we should consider that regardless of hegemonic descriptions of digital scholarly communication as "revolutionary," change in media (and thus in publishing systems) often maintains a balance between continuity and discontinuity (BORGMAN, 2007). The concept of re-mediation accounts for the evolution of new media technologies while explaining the persistence of communication formats: should this lesson be applied to the scientific paper? This is what the history of scholarly communication seems to reveal. This idea is put forward by scholars who have analyzed in detail the emergence and evolution of the scientific article, focusing on the changes in the style, organization, and argumentative structure of scientific communication over time. More interestingly for the scope of this paper, authors such as Gross et al. (2002) speculate on the currency of the scientific article in the digital age, showing also that there are historical and epistemic reasons to account for its lasting influence. In this scenario, the problem of establishing new forms of reward for practices such as data sharing or blog posting might be of secondary importance. The centrality of the peer reviewed paper as the final product of scientific research might respond to the need of communicating complex scientific information according to established reading and learning modalities. For example, the main effect of the digitization of books has not been the fragmentation or decomposition of reading, but rather the digital transposition of forms of linear and in-depth reading onto environments that make books easy to port, socialize or modify. Not surprisingly, then, old practices seem to fold into new technologies and shape them continuously. For example, physicists claim that the online preprint repository arXiv, which since its emergence in the early Nineties has become the main medium for scholarly content circulation in a number of disciplines such as physics and mathematics, mimics the traditional practice of shipping preprint articles to colleagues in other universities. Physical copies of the preprints were posted to a departmental bulletin board so that faculty and students could read them and hopefully send written comments or critiques back. Christopher Kelty makes a similar argument about open source synthetic biology by tracing the genealogy of its sharing practices back to newsletters for model organisms (KELTY, 2012).

Second, we would like to highlight the importance of the boundaries of the scientific enterprise. Over the three centuries since the birth of the first scientific journal, science has often confronted the need to construct and defend the boundary between inside and outside, between scientists and non-scientists, scientific and non-scientific knowledge (GIERYN, 1999). Today we are witnessing an unprecedented re-negotiation of the boundaries of science's cognitive authority, i.e. its ability to present itself as knowledge's depositary, hence the resistance to change. According to a growing body of scholarship, scientific knowledge and the 'experts' who represent it no longer command the unquestioned authority and public trust that was once bestowed upon them (MAASEN; WEINGART, 2006). Networked open science has the potential to foster a transformation similar to the one that followed the invention of printing. Yet this is a tortuous process which might need decades before a new equilibrium is found. In the 17th century, print has unveiled new characteristics of knowledge and has facilitated social and political transformations within the world of research. The same is happening with open science: like Galileo's telescope, it shows us that what we knew about knowledge and its dynamics might be wrong. As previously noted, the Gutenberg-era science was based on a final product, often in form of the peer-reviewed article published in a scholarly journal. Imagining the creative process as an open and collective enterprise might be one of the main obstacles behind the slow pace of the open science "revolution." Digital media and networks, for example, show scientific knowledge as being in a perennial beta version, never concluded and always open to modification, and its output as composed by a number of different objects that are characterized by their unclear status as publications, such as datasets, notebooks, software, etc. This is the opposite of the traditional scientific paper, which has one or more recognized authors, is stable, and can be deposited in libraries (or archives) where it will be discussed and contested, but not modified, incremented or improved, thus reinforcing the social boundaries of scientific research.

Finally, there are deeper reasons for the difficulties experienced by contemporary open science. The public dimension of science that emerged in the 17th century answers natural philosophers' expectations of economic success and reputation accumulation much better than "closed" models of information circulation. The price to pay is a loosened control over produced knowledge. But this side effect is accepted because, in exchange, natural scientists earn a new social role (and the corresponding benefits) accessing wealthy and powerful European patrons' courts (DAVID, 2001). The apparent irony of making widely available the results of one's work without any direct economic compensation can be explained with mathematics' and natural philosophy's growing sophistication in the 16th and 17th centuries. Patrons, anxious to embellish themselves with the best scholars, did not have the knowledge necessary for understanding and evaluating their quality and thus needed to root their choices upon a collective judgment expressed by the expert community. Thus natural philosophers needed to adopt new practices of knowledge exchange, circulation and validation. In order to be reliable and verifiable, knowledge must be transparent and visible. This happened through correspondence exchange, journal publishing, comments and critiques that were based upon the emerging print system. Technological innovation was the necessary precondition for the passage from a world of mysterious and secret knowledge about Nature to a new public and collective mode of scientific production. Yet today, as in the 17th century, technological change is not the only force behind an overall transformation of science communication practices. Through a survey about the obstacles to the adoption of open science practices, Scheliga and Friesike (2014) highlight how openness can be seen as a *social dilemma* where "what is in the collective best interest of the scientific community is not necessarily in the best interest of the individual scientist." While researchers seem to agree upon the positive repercussions of a more open scientific process, they also point out the need to overcome both individual and systemic obstacles. Among individual obstacles, the authors identify fear of free–riding and reluctance to disclose parts of the research process such as negative results. Systemic obstacles seem to be pinpointed as institutional constraints and limitations, for example lack of appropriate evaluation criteria to include open science practices or need of better standardization for new forms of publishing. Obstacles, in sum, seem to be related to a difficult integration of open science in the social contract of scientific research rather than to cultural resistance from individual scholars.

We would like to wrap up this chapter by looking especially at the crucial importance of both the boundaries that maintain scientific authority and the social and economic incentives that drive it. We propose that research on the scholarly communication system, and in particular on digitally-mediated open science, should incorporate more explicitly concerns related to power over scientific knowledge and to transformations of established social contracts of science. Through such a lens, the emergence of communication practices that renew the system of scholarly communication might be seen as attempts at confirming the boundaries of science while intervening to overcome problems related to the management of scientific communication – i.e. the problem of who controls and profits from it. For example, online preprint archives or open access initiatives such as new journals or new funding schemes for scholarly journals appear as ways to construct forms of public legitimation that are redeemed from the economic power of commercial publishers. These considerations are related to more comprehensive evaluations that support the idea of a *coevolution* of science, society, and communication systems. Scientism tends to represent society as lagging behind science, and non-experts as a possible obstacle to scientific and technological innovation. According to this view, science and society live in different domains and do not understand each other. Similar viewpoints mirror the ideal of tight and cohesive scientific communities, characterized by a strong cultural and ethical homogeneity. This model probably never reflected the reality of scientific practice, and it would be even more difficult to apply it to the profound changes that have pushed some scholars to describe a “new contract” between science and society. This new settlement, that has emerged after the end of the Cold War, is characterized by a social configuration that “affects modern science in its organization, division of labour and day-to-day practices, and also in epistemological cores” (GIBBONS, 1999). In this framework, today’s scientific innovation becomes a non-deterministic activity in which the relation between communication systems and practices of knowledge production is all but linear.

Nevertheless, any great discontinuity in scientific inquiry’s social organization goes hand in hand with an intellectual and cultural change which expresses the desire to share knowledge, often regardless of economic incentives. In order to produce the radical transformations prefigured by open science, both cultural and institutional change - in the 17th century as well as today - needed to be fed and stabilized. Interactive digital media are the precondition for a transformation of knowledge’s nature, as print was in the 17th century, as long as science will be able to define material and reputational incentives that could make their massive use significant. Often times today’s open science apologists focus on the desire for a more collective and productive scientific production while neglecting institutional economic logics (TYFIELD, 2013). The history of the Scientific Revolution teaches us that the two paths must converge if change is to emerge. For example, will new systems of evaluation and communication enable science to conserve current forms of social legitimization? Old problems might emerge in new forms: as in the past, open science shows a new facet of scientific knowledge. Yet its emergence might be a lengthy and painful process.

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4

The road less travelled: optimizing for the unknown and unexpected impacts of research

Cameron Neylon

Two roads diverged in a wood, and I—
I took the one less traveled by,
And that has made all the difference.

Robert Frost – from *The Road Not Taken*

THE PURPOSE OF THE ACADEMY

What is research for? What purpose does the academy, or the university, or the research institute, serve? These are questions we shy away from, both because it is difficult to reach consensus but also because it requires a level of self-examination that is uncomfortable. Probing our own motivations and the motivations of those who fund us can be unsettling.

There may be broad societal agreement that research is a generally good thing, but there is very little agreement on why that might be. Governments with a market orientation see an economic value in innovation. Campaigners look to academic experts to question the government's focus on markets. Patients and their families hope for new treatments, environmentalists may look for studies that show the damage that the factories producing those treatments can cause. Technologists might point to the value of science in helping us to understand and tame the natural world. Humanists point to the value of the humanities in helping us to understand ourselves so as to obviate the need to tame the outside world.

It may be difficult to reach agreement on what research should deliver. These are deep questions of values. But we should be able to reach agreement that there is a responsibility on the part of the academy to those who pay for research. That responsibility is to deliver well in accordance with those values. Delivering well might mean efficiency or it might mean effectiveness. Even that is not clear. But delivering well is a responsibility we should assume and talk about.

Testing the performance of institutions

We build institutions to carry out research. In a perfect world we would build these institutions based on clearly articulated shared values. We would use those values to craft an effective and useful statement of the mission of the institution and we would then assess performance against that mission.

Mission statements can be wooly aspirational statements, but the best are useful strategic decision making tools. Crafting a good mission statement is a substantial challenge. In particular crafting statements that assist in making objective performance assessments, while still reflecting the full set of shared values, is at best difficult and often impossible. Easily measured and instrumental goals support instrumental assessment, which drives instrumental behavior – performing against the measure, rather than performing against the mission.

In practice, we measure what we can, and that in turn becomes the *de facto* mission. Rather than asking whether we are doing well at generating new knowledge and how effectively we are transferring it to those who can use it we ask how many articles have been published and what journals they were published in. The problems of instrumentalism and naïve metrication of research assessment are well rehearsed. We will not spend significant time on it here but those criticisms should be borne in mind.

Instrumental strategies and institutional leadership

The issue with metrics is not the metrics themselves. These proxies or indicators measure what they measure. The problem arises when strategic decisions are made on the basis of the measures themselves, rather than assessment of performance against a well articulated mission. The problem is not that number of articles, or H-index, or grant income can't answer a question; it is that they cannot provide complete answers to the questions that *should* be asked – how *productive* is a researcher, what is their *influence* in the community, in what ways do they *contribute* to the institution.

These questions, and others that would follow from a well designed mission statement, are not straight forward to answer. They will not be addressed by any single indicator, nor any simple "basket of metrics". Indicators and metrics can only ever be data to support the strategic decision making. Too often, in a search for an illusory objectivity we reach for quantitative measures as a way of avoiding the responsibility to make those decisions.

The unique contribution of an effective institutional leader will be to make informed strategic decisions. Reliance on league tables and metrics, the posting of thresholds or performance targets is a sign of a lack of confidence in their ability to make those decisions. The best institutional leaders will use metrics and other indicators as data to assist in making decisions. They will not use quantitative measure *to* make decisions. They will have a diverse set of data at their fingertips and an understanding of how to integrate that to assess a wide diversity of research activities.

Diverse portfolios and delivering on mission

The future impact of research is unpredictable and investment in research is risky. The rational response to this is to hold a diverse portfolio. At each level of granularity; investigator, group, department, institution it makes sense to have a range of different activities that as a collection optimize the opportunity for delivering value.

The true cost of the instrumentalism described above has been homogenization. Institutions are all trying to climb the same league tables based on narrow criteria. Only a very small number of highly prestigious institutions have the self-confidence to carve out their own path. The irony is that institutions worldwide seek to rise up league tables so as to be like Harvard or Stanford or Cambridge, while those institutions do what they do largely because they ignore those same tables.

In the end what research is for is a question for institutions, communities, nations and global publics to answer for themselves. But when institutions address that question they should focus more on what makes them unique instead of what makes them a pale imitation of Princeton or Oxford. Diversity of mission and focus at the institutional level will aid in delivering on mission at the national and global levels by creating a portfolio of institutional profiles.

Diversity at the institutional level will also provide space for a more diverse range of researchers generating more diverse outputs and more diverse impacts. Clearly this creates challenges for institutional leaders and effective institutional leadership. Ultimately the challenge for assessment is developing a sufficiently diverse set of indicators to support the tracking and management of such a diverse portfolio. Perhaps even more challenging is to know how to combine those indicators to support effective decision-making.

IMPACTS AND INDICATORS

While we recognize that agreeing on the values and mission for the research enterprise is challenging it will nonetheless be useful to consider the different classes of results we might wish for and the extent to which they can be measured. "Impact" may be a dirty word in many research circles but it is nonetheless a useful technical term.

There are a range of different definitions in use, but in the current context I will use a meaning that expands on that used by the Australian Research Council[1], Research Councils UK[2] but including the scope described by the LSE Impact of Social Sciences project[3]: the change in the world that results from the dissemination of research outputs. We can speak of different forms of impact, including economic impacts such as job creation but certainly not stopping there. We can also consider impacts in the areas of policy, education, culture, environment and health. I explicitly include impacts on research activities as well as "wider impacts".

Again the prioritization of different classes of impacts is a matter for community discussion but we can recognize that these impacts depend on the outputs of research being disseminated to those places where they can be applied. The outputs might be concepts, skills, new technologies or approaches, or they may be people. There will be diversity in outputs, impacts and the paths that join them together.

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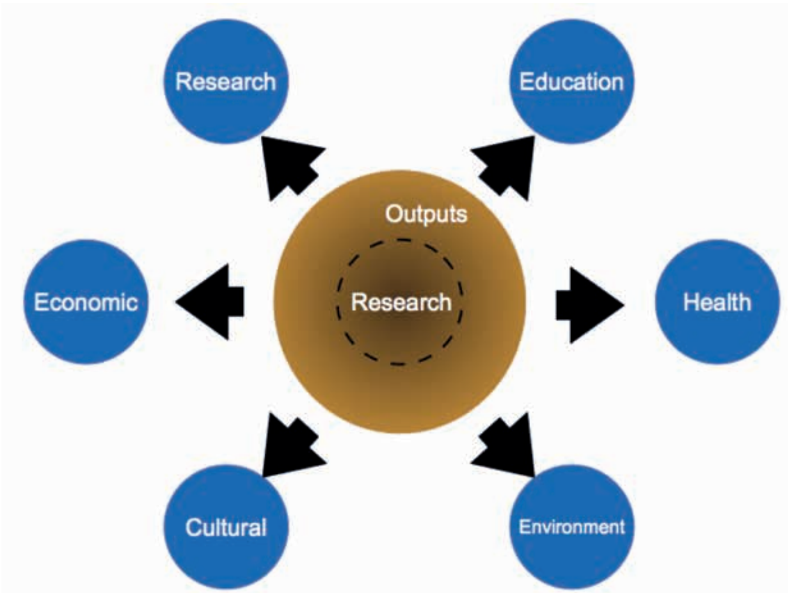
[1] Available on: http://www.arc.gov.au/research-impact-principles-and-framework#Definition. Access on: June 21, 2015

[2] Available on: http://www.esrc.ac.uk/funding-and-guidance/impact-toolkit/what-how-and-why/what-is-research-impact.aspx . Access on: June 21, 2015

[3] Available on: http://blogs.lse.ac.uk/impactofsocialsciences/introduction/ . Access on: June 21, 2015

Figure 1. Varying forms of research impact. These different categories of effect have little in common being linked only by the process of research which leads to them. Research is transmitted through outputs (although that distinction is becoming more porous, shown by the dotted line) and on through some process into outcomes and impacts.



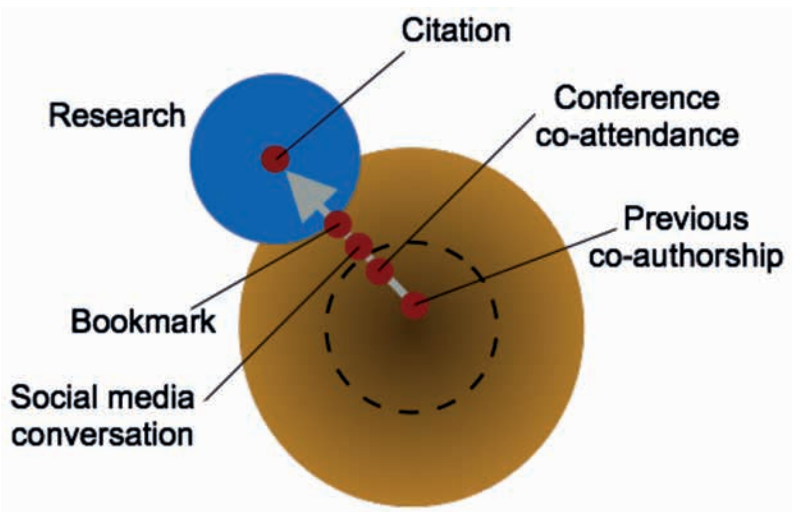
Proxies, indicators and their meaning

Impacts are what we ultimately seek to maximize, but in practice they can almost never be measured directly. Outputs by contrast tend to be easier to track and measure. Our traditional focus on research articles and their citation is driven at least in part by the ease of tracking and quantifying their number.

If we focus research impact as an example, our aim is to measure the change in future research that results from a given project, a given output, or the work of a given researcher. What we have traditionally measured is productivity in outputs and citations. For all the potential diversity of possible impacts and outputs our view has been restricted almost entirely to these two sets of proxies. It is not only that metrication and instrumentalism are problematic in and of themselves but that our field of view has been horribly limited.

The movement of research online and greater general availability of information about the research enterprise has provided new proxies that have the potential to provide a richer view (NEYLON; WU, 2009; PRIEM et al. 2010). We are able to track discussions and use of research in a much wider range of places, from social to mainstream media, through bookmarking services to secondary sources like Wikipedia and policy documents.

Figure 2. The growing set of indicators and proxies that might be useful in measuring pathways to the impact of research on further research. In the past we only had the publication and citation events to work with.



This richer variety of data has the potential to provide a much more diverse view of the flow of knowledge and to support assessment of a wider diversity of activities. At the same time there are often questions raised as to what these new measures *mean*. Can a tweet tell us as much as a citation. Do bookmarks in Mendeley really mean someone has read an article? Is it necessarily the case that mainstream media coverage means the research is good or useful or important?

Counting proxies or telling stories

An objection often raised for any quantitative measure, including citations is that counting is misleading. Often this appears in the form of a statement such as "citations can also be negative" or "popularity is not a sign of impact". These criticisms become stronger when we look at proxies such as downloads or social media mentions, where the numbers can be large and where popularity (appears as though it) might play a stronger role.

A more productive way to use these proxies can be to use them to discover and tell stories. With social media in particular the numbers can be misleading due to reinforcement effects. It is important to investigate who is talking about a given research output and what they are saying (as well as who to).

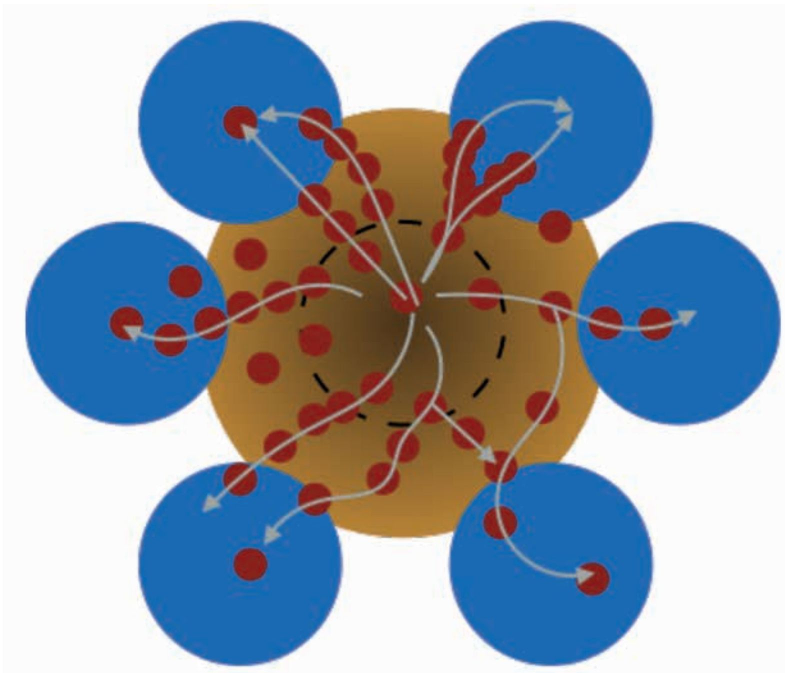
For example a story I often tell relates to Twitter. I was investigating papers published by the University of Cape Town with PLOS using data from the PLOS Article Level Metrics service and also the altmetric.com service, which provides information on the geolocation of tweets. There were very few tweets about this South African corpus of papers that originated in South Africa. However one paper (Jewkes et al. 2011) stood out as having some South African activity.

This was a paper on the relationship between HIV status and domestic violence. In particular the accounts talking about the paper were associated with women's crisis centres, sexual health clinics and support centres for minority sexual orientations. Furthermore I could identify the specific account and therefore the person that was disseminating this research to places where it might be directly applied. The counting of tweets was not very useful here, but identifying who was behind those tweets told a powerful story.

However there is a sense in which both the objection to quantitative metrics and the ability to tell stories expose a basic fallacy in the way we think about metrics old and new. Throughout this text I have been careful to refer to measures as "proxies" or "indicators". Too often the objections arise about either "meaning" or quantitation because of an assumption that a metric *itself* is what matters. Of course this is never the case, what matters is not citations but the influence they are a proxy for, not social media mentions but the way they inform us about communities using the research, not downloads but the usage that they signals.

All of these measures are merely proxies for things that we care about, but in many cases they are not even that. They are indicators of the flow of knowledge. It is more useful perhaps to think of them as flares that light up when knowledge flows past a point on a path. The same flares may result from many different pathways, and knowledge may flow through many different pathways to the same destination.

Figure 3. A figurative image of pathways of knowledge transfer (arrows) and the signals that arise (red dots). The observable word is only the red dots and the majority of our research assessment systems are based on only two of those dots, citations and publication events.



We can think of the pathway to impact as a set of knowledge flows, where the flow itself is invisible. All we have are indicators that signal parts of that flow. It becomes clear that it is only by combining multiple measures that we can pick out a specific path. The paucity of our traditional measures also becomes clear, one or two lights blinking on one single (assumed) pathway tells us little or nothing that is useful. Finally the question of "what does this metric means" falls away. The metric doesn't *mean* anything isolation, it is an indicator, mere data that in combination with other data may help us to understand the pathways through which a given piece of knowledge is disseminated.

We can also integrate the narrative view with a quantitative view. The stories are instances of knowledge flow down various pathways. Quantitative analysis of indicators can help us to understand the overall flows and their paths as well as helping us to identify specific instances of that flow. The story above is simply a very crude example of this form of analysis but more sophisticated approaches are certainly possible.

THE ROAD LESS TRAVELLED, THE ROAD UNKNOWN

This pathway model is potentially very powerful. Firstly it helps us to avoid the fallacy that a countable metric is itself what matters. Secondly it provides a route into more sophisticated analytical approaches that do not assume prior knowledge of what the pathways are. This brings the potential of "big data" analytics to bear on the problem of identifying and mapping the pathways.

This is superficially similar to many other models of how research leads to impacts. Most models describe, or aim to surface, some form of pathway or pathways. The Becker Model of Impact for biomedical sciences focuses on specific forms of impact and identifies indicators that lie on the path towards each of them (BERNARD BECKER MEDICAL LIBRARY, s/d). The Payback model and BRIDE tool developed from it (SCOBLE et al., 2010) have a similar conceptual framework. Many of these models build on diffusion of innovation theory, in itself a linear model (WALTER et al., 2013).

Even in those approaches where participants and stakeholders are engaged in defining desired impacts such as the Participatory Impact Pathways Analysis approach (STEPS CENTER, s/d) the focus is on defining *the* pathways that exist, or are desirable, for further monitoring. Overall, existing models and methodologies assume that the there are known (or discoverable) and generally linear pathways through which knowledge or insight flows to create impacts.

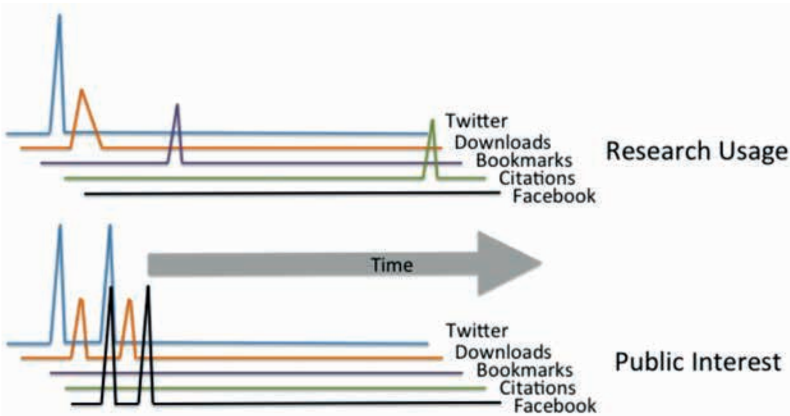
This leads to assessment frameworks in which various indicators are tied to specific impacts, and therefore specific pathways. They develop matrix approaches in which, by measuring the presence of specific indicators, sometimes through quantitative approaches, sometimes qualitative, evidence of specific impacts (or their future potential) is provided. In turn the same matrices can be used to optimize research dissemination so as to maximize those desired impacts.

A "Hidden Pathways" Model of Knowledge Flows to Research Impacts

In contrast to these linear and explicit models, the model developed in the previous section assumes that the pathways are unknown and probably high branched. There is an implicit focus on more granular indicators and to some extent to more quantifiable ones, as opposed to qualitative and narrative indicators or evidence. Finally there is an implicit requirement that indicators can be tied to *events*, that is, they can be fixed in time.

Formally, this hidden pathway model is described as a set of measurable channels (indicators) in which signals can be measured. These signals are indicative of processes (knowledge flows along defined pathways). The signals can be thought of as flares or blinking lights that show when some particular knowledge transfer is occurring along a pathway. Any given indicator may be attached to none, one, or many pathways. The pathways themselves are not observable, but can only be inferred.

Figure 4. Signal patterns from different underlying processes. Both processes lead to signals from twitter and download channels but a research use also shows later bookmarking and citation activity. Public interest shows greater correlation with Facebook and tighter time domain correlation. The signal patterns are hypothetical based on non-quantitative observation of specific data sets.



The means of inferring a pathway is through identifying patterns of signal activities that occur across sets of indicators (signal channels). For instance a hypothetical "scholarly knowledge transfer" pathway might involve a tweet (through which a scholar discovers a work), a download or view (reading the work), bookmarking and then citation in the formal literature. Impact on a patient group might start from the same place (a tweet, a download) and then branch off through a Facebook conversation and on to wall posts on a patient-focused service.

Of course, all these processes are occurring at the same time, leading to very complex signal patterns, which need to be disentangled. Broadly speaking this means using maximum likelihood methods to model the probability distributions of sets of possible processes that explain the observed patterns of signals. Essentially the aim is to embrace the larger sets of data we have available to us so as to cast the problem as one of time domain signal processing. There are strong analytical methods from engineering and other disciplines that are designed to tackle precisely this class of problems; trying to untangle the multiple underlying processes that are giving rise to a complex multichannel signal.

Mapping unknown pathways

The advantage of this conceptual approach is that it creates the potential not just to identify flows down the pathways we (think we) know about but also to surface new pathways. Instead of either assuming specific pathways exist, or seeking to surface them through conversations with stakeholders, it makes it possible to start from an assumption that there are knowledge flows that no-one is aware of and make an attempt to discover them.

Whether this is possible in practice is uncertain. Such approaches require large quantities of data with high quality time information. While the quantity of data we have is certainly increasing it is not clear that it is sufficient to surface unknown pathways. Even if we have the data the quality of the time information is generally rather poor. For tweets we can utilize a time stamp, but article download data has very variable time resolution, and is also collected differently by different organizations. In attempting this form of analysis we should identify the weaknesses in our data.

A side effect of analysis that seeks to identify the underlying processes occurring is that there is also the potential to detect signals that arise from processes not related to desired impacts. Such signals might include errors or problems in data collection or processing. Or they might reflect attempts to game metrics. We are already aware for instance that strong signals in a single channel (such as downloads) that do not correlate with signals in other channels (such as bookmarks or tweets) are indicative of gaming.

There are three broad weaknesses with this approach. The first, discussed above is the dependency on data scale and quality. In practice we may only be able to distinguish the strongest signal correlations and therefore not achieve the insight into the unknown pathways that we would desire. The second is that it is clear that the pathways themselves are rapidly changing at the moment. This complicates the analysis, and although not rendering it impossible, puts further demands on data scale and quality to obtain new insights. In an ideal world the best way in would be to have a set of data in a stable environment. The irony of course it that we are interested in the analysis precisely because the environment is not stable.

The final weakness is the most central. These approaches can not identify the actual pathways. We can only ever infer that a pathway we can qualitatively describe corresponds to a probabilistic model of signal correlations. More generally such an analysis can not provide direct evidence of impact itself. The signals indicate underlying processes, not change in the word. To use this analysis to help us understand or optimize impact we need to embed it in a social practice, which leads us back to the need for articulating values.

RESPONSIBLE MANAGEMENT AND ARCHITECTING OF THE RESEARCH ENTERPRISE

The focus of this hidden pathway model of knowledge transfer is to exploit a technical analytical capacity to better understand and optimize the pathways the lead to research impacts. It is fundamentally technological. Yet I started with what is fundamentally a social issue of responsibility and values. How do we bring these together?

The link for me is through leadership, management and institutional design. In practice the conversation about what the shared values for the research enterprise is an ongoing one. These values will evolve and change as communities' needs change and as our capacity to address them changes. I make an assumption that a way to address both this issue of change and uncertainty as well as the unpredictability of research outcomes is through embracing diversity at a range of levels. Diversity of goals, of skills, of outputs and of research agendas allows, potentially, for buffering of capacities as well as agility in response to changing needs, as well as providing many controls that can be tuned to optimize impacts.

The defining characteristic of research is its unpredictability. If we knew the answer we wouldn't need to do the research. Picking winners is near impossible. This makes it imperative that we design our institutions at the systems level. Decisions about individual projects, or appointments, or modes of dissemination will always be informed guesses. But we can tune the processes by which we make those decisions so as to optimize the *average* outcome. It is entirely possible to design an electrical circuit without needing to know what path an individual electron will take.

A central design challenge for such systems is to optimize for the possibility of unexpected outcomes and impacts, unexpected pathways to impact. It is a matter of faith amongst researchers that the most important insights arise from serendipity. Yet we focus almost exclusively on known modes of communication to specific, known audiences defined by specific journals. In truth we *do not even know* how much research impact arises in the expected places versus the unexpected. We try to measure *expected* impact (or more strictly progress towards it) through a horrendously narrow, albeit expanding, set of proxies that are totally inadequate to the task, yet I argue we have a responsibility to also seek to maximize the *unexpected*.

The hidden pathways model I have described here seeks to address the lack of data that should trouble a responsible institutional leader. But in addressing that issue it also takes away any comfort that can be derived from the measurement of progress against naïve and simplistic rankings that currently characterize institutional decision making.

Such simple rankings are comfortably normative; higher is "good", downward is "bad". Everyone agrees, even those who are violently opposed to the rankings themselves. In a model focused on pathways to diverse impacts there is no "up" or "down", there is no normative position on which impacts are better or more important. These are not even decisions that leaders can themselves take, involving as they do whole communities.

The responsibility for leaders therefore becomes greater, and in many senses the freedom to act becomes less. A leader is a curator of the conversations that articulate these values, the guardian and caretaker for a useful mission statement, and an engineer who must constantly seek to tweak a thousand settings to optimize importance.

This is perhaps not the skillset that characterizes today's generation of institutional leaders – it is however one that aligns closely with successful managers of online communities. This may require a generational change, but in turn the institutions of our future will be the ones that are successful in a world of online communication. It may indeed be the road less travelled, but with luck it will make all the difference for the future of a successful, community embedded and responsible research enterprise.

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5

What is open and collaborative science and what roles could it play in development?

Leslie Chan, Angela Okune e Nanjira Sambuli

INTRODUCTION

This chapter provides the contexts and rationale for the development of the Open and Collaborative Science in Development Network (OCSDNet), a three-year research and practice project co-funded by the International Development Research Centre in Canada and the Department of International Development, UK.

Launched in July 2014, the network is jointly coordinated by iHub - Nairobi's Innovation Hub based in Nairobi, Kenya, and the Centre for Critical Development Studies at the University of Toronto Scarborough, Canada, while supported by an international team of expert advisors who are well-known practitioners of open science and policy researchers. This chapter further describes the organizational framework of the OCSDNet and how it intends to mobilize and support researchers and practitioners from the Global South through a multi-stage network-building process to support the overarching goal of the project, which is to investigate whether, and the conditions under which, a set of open research practices could lead to new thinking and practices about development and their outcomes.

We further outline the strategies being undertaken by the OCSDNet team in realizing the more specific objectives of the project, which are to frame a series of research questions about the nature and assumptions of open science, and to support a community of open science practitioners in the Global South whose research and practices would deepen our understanding of the principles and impacts of open research and knowledge co-creation.

It is common in the literature to characterize open science as processes that involve sharing of research plans, data and publications, participatory citizen science, distributed "crowdsourced" forms of data collection (RIN/NESTA 2010, THE ROYAL SOCIETY, 2011; FRANZONI; SAUERMANN, 2014), and new forms of international scientific collaborations, enabled by networked technologies and peer-to-peer production (NIELSON 2011; KOCAREV; IN, 2010; BARTLING; FRIESIKE, 2013). Common examples include the Human Genome Project, in which open and rapid sharing of gene and protein sequence data over the Internet greatly facilitated the completion of this mega-project in record time with multiple downstream impact (WADMAN, 2013). Similarly, crowdsourcing has been used to monitor deforestation in Brazil and Indonesia[1], political violence in Kenya, natural disasters in Haiti and Pakistan, and gender violence in Egypt[2].

However, how these mechanisms challenge and enrich traditional research systems and how new network-enabled collaborations and institutions could lead to more equitable and inclusive change in knowledge production and sharing in the Global South, is still poorly understood. The intention of OCSDNet is to

[1] Available on: http://www.crowdsourcing.org/editorial/crowdsourcing-to-help-brazilian-ngo-monitor-deforestation/16207 e http://bigideas.berkeley.edu/wp-content/uploads/2014/11/Curtailing_Deforestation_in_Indonesia-Improving_Forest_Mapping_and_ Monitoring_using_Drones_Technology-.pdf . Access on: 19 June 2015.

[2] See Harass Map http://harassmap.org/en/ . Access: 19 June 2015.

critically examine some common assumptions about open science and its purported impact on development, and to begin to gather evidence on both the positive and unintended effects of network enabled knowledge making practices. In the longer term, the project intends to generate a richer conceptual framework about the complex interactions of open science in diverse institutional contexts, and to stimulate dialogues on policy thinking and formulation in support of emerging practices documented by the research projects within the network.

BACKGROUND AND RATIONALE

Convergence of Openness

The hallmark of science is that the results of scientific research are meant to be made "public" in order to enable future knowledge building. Indeed progress of science is dependent on access to prior understanding and contributions of scientists to a common pool of knowledge. In the Gutenberg era, making science public was primarily through the publication of research articles in scholarly journals. However, as the scientific publishing enterprise began to be dominated by commercial interests because of the high profit they could extract, the fruits of science became less and less public, and became enjoyable only to those organizations and individuals who were privileged enough to afford the increasingly high cost of access (CHAN; COSTA, 2005, CHAN et al. 2011).

The Internet has profoundly changed the public and open nature of scientific communication. Thus, the "Budapest Open Access Initiative" (2002) began with the statement that: "An old tradition and a new technology have converged to make possible an unprecedented public good."[3] The old tradition refers to the

[3] Available on: http://www.budapestopenaccessinitiative.org/read. Access on: June 19, 2015.

willingness of scholars and scientists to share the fruits of their research without payment for the sake of inquiry and knowledge building for the public good. The new technology is of course the Web, with its peer-to-peer architecture and the foundation of open technology. Over the last decade, open source tools and open networks have enabled the flourishing of "openness" movements across different domains, from Open Access to Open Educational Resources, from Open Data to Open Government, and from Open Innovation to Open Development initiatives around the world.[4]

While drawing on open source and peer production principles, these open initiatives also share the common historical trajectory of starting out as grass-root movements in localized context, but growing worldwide with increasingly diverse stakeholders and participants, and increasingly supported and indeed advocated by funders and policy makers at both the local and international level.[5]

In the case of Open Access, support by national and multilateral funders and policy makers are predicated on emerging evidence that opening up the results of funded research greatly enhances the return on research investment, not only in economic terms (HOUGHTON *et al*. 2009; HOUGHTON; SWAN, 2013), but also in the creation of new forms of social and political impact (JOSEPH, 2013). These may include new opportunities for entrepreneurship, citizen participation in political processes, and novel forms of

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[4] See for example the various chapters in the "living book" *Open Science* edited by Bartling and Friesike (2014), various chapters on "openness" in the book *Open Development* edited by Smith and Reilly (2014), an extensive essay on open innovation by Foray (2013).

[5] For a succinct history of the growth and convergence of the various grass-root open commons movements, see Bollier (2008). At the regional and national level, policies on Open Science are now being actively formulated by the European Commission as part of the Digital Agenda for Europe <http://ec.europa.eu/commission_2010-2014/kroes/en/blog/open-science>, the National Science Foundation in the US has a long history of supporting data sharing of publicly funded research <http://www.nsf.gov/bfa/dias/policy/dmp.jsp>. Access on: June 19, 2015.

inclusive collaboration, all are potential benefits beyond the original funding targets.

In a similar vein, across some low- and middle-income countries (LMICs), the rapid adoption and deep penetration of mobile technologies are providing access to banking, health services, learning resources, and important platforms for information sharing. These opportunities have the potential to empower citizens who did not previously enjoy such forms of access and participation (FUCHS; ELDER, 2013).

"Open Development"

Across these open initiatives, there is also growing consensus that traditional intellectual property (IP) regimes of maximum restriction and protection not only stifle innovation, but also restrict and limit participation from those with limited means and political power (DE BEER et. al. 2014). A number of scholars (e.g. BOYLE 2009; DRAHOS; BRAITHWAITE, 2002; SHAVER, 2015; KIRCHSCHLAEGER, 2013) suggest that "the right to science and culture" requires a public goods approach to knowledge innovation and diffusion rather than the current practice of IP protection, thus reframing the access to knowledge agenda as a demand for fulfillment of fundamental rights (DONDERS, 2011).

Excluding individuals from enjoying the fruits and benefits of scientific inquiry is also understood as a social justice issue, as it violates the fundamental rights of the individual as stated in the 1948 Universal Declaration of Human Rights[6] and the International Covenant on Economic, Social and Cultural Rights, adopted by the UN General Assembly in 1966[7]. Understanding access to scientific

[6] Available on: http://www.un.org/en/documents/udhr/ . Access on: Sept.1 , 2014

[7] Available on: http://www.ohchr.org/EN/ProfessionalInterest/Pages/CESCR.aspx. Access on: Sept. 1, 2014

knowledge and participation in science as a human right counters the tendency to view science and development primarily through a macro-economic lens and provides an important alternative to the econocentric paradigm of development with exclusive focus on economic growth of the past few decades (ESCOBAR, 1995; STIGLITZ et. al. 2010; STIGLITZ, 2012).

The growing discontent with the traditional development paradigm, coupled with the emerging observation that access to open technologies and equitable participation in knowledge production could improve the quality of lives and well-being of people in marginalized regions, has given rise to a new school of thinking known as "Open Development" (SMITH et. al. 2011; SMITH; REILLY, 2014).

"Open Development" is a broad proposition that open models and peer-based production, enabled by pervasive network technologies, non-market based incentive structures and alternative licensing regimes (such as Creative Commons licenses), can result in greater participation, access and collaboration across different social and economic sectors.

These interactions may in turn create new social benefits in areas as diverse as education, health, science and innovation, governance and citizen participation and small and medium enterprises.

A key understanding of "Open Development" is that while technologies are not the sole driver of social change, they are deeply embedded in our social, economic and political fabric. We therefore need to understand 'openness' within the context of a complex socio-technical framework and power structure (BUSKENS, 2014). This understanding about the need to understand the power dynamics of institutional structure and how individuals are often constraint by existing practices is central to the development of the conceptual framework that guides the development of OCSDNet.

Defining Open Science

Across the various open initiatives, we are also seeing boundaries of what can be made open being pushed further and further. This trend is most apparent in the emerging area of open science.

According to Michael Nielsen, author of *Reinventing Discovery* (NIELSEN, 2011), "Open science is the idea that scientific knowledge of all kinds should be openly shared as early as is practical in the discovery process." The British Research Information Network defined open science as "science carried out and communicated in a manner which allows others to contribute, collaborate and add to the research effort, with all kinds of data, results and protocols made freely available at different stages of the research process." (RIN / NESTA, 2010).

In the traditional research process, publications were only made publicly available as an end product, and not necessarily in an open fashion. On the other hand, in open science, not only are research articles openly accessible, but access is extended to other research objects such as data, software codes, protocols and workflows, such that people are free to use, re-use and distribute without legal, technological or social restrictions. In some cases, open science also entails the opening up of the entire research process from agenda-setting, data generation and data analysis, to dissemination and use with the aid of various emerging social platforms and tools (O'HARA; HALL, 2013).

Open science utilizes the prevalence of the Internet and associated digital tools to enable greater local and global research collaboration. Such collaboration need not be limited to traditional research communities but could also include the participation of citizen scientists, both in partnership with traditional research institutions as well as those in non-traditional research locations, often using open software, hardware and other open technologies (WOELFLE et al. 2011; BARTLING; FRIESIKE, 2014).

Fecher and Friesike (2013) surveyed the current landscape of open science and attempted a typology of the various activities under this broad umbrella. Not surprisingly, what they found was a diversity of activities involving different actors (though they often overlap), different actions and strategies, but most importantly, these activities are guided by different motivations, incentives, assumptions and end goals (Table 1).

Table 1 A simplified chart showing the different activities (involving different motivations and actors) that have been grouped under the term Open Science

	Knowledge as Public Goods	**Pragmatic**	**e-Infrastructure**	**Public Engagement**	**Value System**
Assumption	Access to knowledge is highly inequitable	Open Collaboration is more efficient for knowledge creation and discovery	Network Infrastructure and tools are essential for open collaboration	Science is a public enterprise and should be made publicly accessible	There is a need to create new metrics and incentive
Actions	Making scholary knowledge freely available to everyone	Opening up the process of knowledge discovery as early as possible	Creating open platforms, tools and services for scientists	Engaging citizens in design and conducting research	Developing Alternative metrics and more inclusive system of evaluation
Actors	Scientists, policy makers, funders, citizens	Scientists, tool developers	Scientists, platform designers and providers	Citizens, Scientists, Non-government Organizations	Scientists, Funders, Policy Makers
Tools and Strategies	Open Access, Open License, Open Data, Open Source	Open Data, Open Source, Crowdsourcing, Open Access, Open License	Defining Standards and Interoperable protocols for knowledge exchanges	Social media platforms (Facebook, Twitter, blogs ,etc.), Crowdsourcing	Altmetrics, open peer review, openness indices

Source: Modified from Fecher and Friesike, 2013

In trying to understand open science, it is important to go beyond the mechanisms of access and reuse, such as the statement that open science is “scientific knowledge that people are free to use, re-use and distribute without legal, technological or social restrictions."[8] If we take as a starting assumption that open science entails collaboration and participation of diverse actors in a wide variety of institutional contexts, with wide ranging motivations, values and intentions, then we must view open science as a conditional process, not a binary condition, operating within a highly complex socio-technical system that span the local and the global (HALFORD et. al. 2012).

Thus, understanding the principles and dynamics of collaboration and participation is central to the OCSD network activities as openness is more than simply about access (CHAN; GRAY, 2014). We therefore adopted "Open and Collaborative Science" (OCS) as an operating term for the research network to remind us of the central nature of network collaboration and participation (SHRUM et. al. 2007).

Open Science and Development

The OCSDNet is particularly timely given the increasing awareness of the integral role of science, technology and innovation (STI) in development activities on the one hand (WAGNER, 2009), and the growing interest in the role of openness in science as a transformative framework for both development thinking and practices on the other (CRIBB; HARTOMO, 2010).

In the book *The New Invisible College: Science for Development*, Caroline Wagner posits that:

> Like many parts of the knowledge system, the organization of scientific research is changing in fundamental ways. Self-organizing networks that span the globe are the most notable feature of science today. These networks constitute an invisible college of researchers: scientists who collaborate not because they are told to but because they want to, not because they work in the same laboratory or even in the same field but

[8] Available on: http://science.okfn.org/ Access on: June 19, 2015.

> because they have complementary insight, data, or skills. Networks can take on the role of institutions in some parts of the world that do not have a long history of building scientific infrastructure. (WAGNER, 2009, p. 2)

By mapping the emergence of global science networks and tracing the dynamics driving their growth, Wagner argues that the shift from "big science" to global networks creates unprecedented opportunities for developing countries to harness science and the potential of innovation. Rather than wasting resources in mimicking scientific establishments and policies of the pre-digital age, policy makers in developing countries should leverage networks by creating incentives for scientists to focus on research that addresses their concerns, and by finding ways to tie knowledge to local problem solving (WOLKOVICH et. al. 2012).

This approach is highly appropriate because many of the "grand" challenges facing humanities today, such as climate change, environmental degradation, emerging infectious diseases, inadequate access to clean drinking water and food insecurity, are global in nature but are disproportionately harmful to developing economies. Meeting these challenges requires not only appropriate local solutions but also requires rapid and sustainable deployment of new tools and approaches that draw from the global scientific and knowledge commons.

The dramatically falling cost of computing and the increasing access to the Internet as well as associated digital networks by researchers around the world hold great promises for solving some of these development challenges through open sharing of data, methods, infrastructure and other open approaches to knowledge discovery and problem solving (SMITH *et al.*, 2011; SMITH; REILLY, 2014). The emerging practice of Open Source Drug Discovery for neglected diseases (MASUM; HARRIS, 2011; WOELFLE, 2011; ROBERTSON et al. 2014); the incorporation of citizen science in a wide variety of environmental monitoring and climate change related research (VITOS et. al. 2013; SUZUKI, 2014; SEE et al. 2013), and the increasing use of social networks for scientific collaboration among scientists in the Global South (e.g. GUERRERO-MEDINA et al. 2013) are but the tip of the iceberg.

In addition to addressing these Global level problems, which require long term interventions, OCS also promises to increase visibility and impact of research at the local level, facilitate participation of researchers in local and international collaborations, encourage public engagement with science through activities such as citizen science, and promote the culture of knowledge sharing and new thinking on social innovations. These are considered to be short term outcomes that have direct development benefits and could contribute to the strengthening of local research capacity through education and participation.

In the longer term, these results will potentially lead to more equitable participation of researchers from the Global South, who are often marginalized in the traditional research competition process driven by Northern agendas (YNALVEZ; SHRUM, 2011; DUQUE et. al. 2012).

This has the further potential of leading to expanded and more inclusive ways of knowing, and is in keeping with our assumption that 'collaboration' entails equitable contribution in both the framing and the search for solutions to relevant problems, and not simply about following the norms set by those in power or in charge of resources (HAVERKORT et. al. 2012).

In this regard, openness is not simply about gaining access to knowledge, but also about the right to participate in the knowledge production process, driven by issues that are of local relevance, rather than research agendas set elsewhere or from the top down.

However, while open science is lauded by many as a goal to stride for, the practice is far from universal in the Global North (GRUBB; EASTERBROOK, 2011; PIWOWAR 2011; WHYTE; PRYOR, 2011) and awareness of its benefits and practices are even less prominent in the Global South. Indeed many researchers in established organizations are actively resisting the disruptive changes brought on by open practices, as they simultaneously call into question long held notions of scientific authority, trust, quality, recognition as well as incentives (MASUM; TOVEY, 2011; PRIEM et al. 2012; BERNAL, 2013).

And while many of the purported development benefits of Open and Collaborative Science (some of which were outlined earlier) are highly attractive, there is little empirical evidence at the moment to support or refute these claims.

Indeed, as discussed above, the notion of OCS is an umbrella term that encompasses a diversity of activities, actors, assumptions, motivations, and institutional contexts and the outcomes of these complex interactions are often uncertain. Such outcomes may also turn out to be negative in nature, and could further exacerbate problems of inequitable participation, gender disparity, and further exclusion of researchers who do not have the capacity to take advantage of the network tools and resources (POWELL et. al. 2012).

Questions have also been raised about potential conflict between open approaches to science and the interests of privacy, safety and security of citizens (CHANDRAMOHAN *et al.*, 2008; CHURCH *et al.*, 2009; PISANI; ABOU ZAHR, 2010).

In short, we have very limited understanding of the social, political and institutional contexts and the value and incentive framework within which open approaches to science take place (DELFANTI 2013), and equally little about the mechanisms (causal and others) that link open science practices with potential development outcomes. The OCSDNet research program and network is designed to address these gaps in our understanding through a multi-stage data collection and theory building process.

GOALS AND SPECIFIC OBJECTIVES OF OCSDNET

To tackle the rather broad and ambitious goal of OCSDNet described above, there needs to be a set of more specific objectives and strategies to guide the generation of observations, data gathering, and theory building. At the same time, we need to construct a "Theory of Change" (ToC) to guide the design and implementation of the research problems. The ToC is intended to make explicit the assumptions of the problem situation, potential mechanisms of change, the institutional contexts and the actors of OCS, the short and long-term outcomes, and the processes that need to take place in order for the desired changes to occur.

To these ends, the key objectives of OCSDNet include:

1) Support (both funding and intellectual) of new sub-projects and activities so as to generate evidence on whether, and if so, under what conditions open approaches to science can enable research that contributes to development goals in the Global South.
2) Build a community of open science practitioners and leaders in different contexts, by nurturing an interactive research network and providing an enabling platform and needed resources.
3) Identify the structural, technical, policy and cultural barriers for individuals and organizations to participate in OCS and determine how these barriers could be addressed. This will be accomplished through a synthesis of the research results generated by the various sub-projects.
4) Contribute to the building of a new and vibrant area of study (OCS for Development), producing guidelines and knowledge synthesis to inform policy and practice.

Objectives 1 and 2 constitute shorter term goals and they require substantial financial input and coordination. While 3 and 4 are medium and longer term goals. iHub, Nairobi's innovation space for the technology community, has taken on the role of network coordination, administrating the funding support for the network sub-projects provided by IDRC (International Development Research Centre) and DFID (Department for International Development), and providing network and resource support for researchers within the network. The Centre for Critical Development Studies at the University of Toronto assumed the role of research coordination, responsible for synthesizing the findings from across the sub-projects, and generating a conceptual framework that would guide future debates and research in the area of open science and development.

OCSDNET RESEARCH APPROACH

Funding and Support of Sub-projects

For the first stage of the network project, OCSDNet issued an international call for concept papers on potential research projects. The call targeted case studies that employ innovative open processes in generating knowledge and actions intended to address a range of development challenges in various Global South contexts, and the concept papers must address one or more of the four key themes central to the research objectives of the network. These themes were identified from two IDRC funded scoping workshops that were held prior to the launch of the OCSDNet project. The themes are:

1) Motivations (incentives and ideologies)
2) Infrastructures & Technologies
3) Communities of practice in open and collaborative Science
4) Potential Impacts (positive and negative) of open & collaborative science

Detailed descriptions of each theme and associated research questions, and how these themes fit with the proposed conceptual framework, are provided on http://ocsdnet.org/thematic-areas/.

In addition, we were seeking a mix of projects that include scientific research in different domains aimed at producing new knowledge, as well as critical research on ongoing initiatives, focusing on the behaviours, contexts, challenges and opportunities enabled by OCS.

The call resulted in 91 concept note applications from across the Global South, from which 14 applicants were invited to the full proposal development workshop held in mid-October, 2014 in Nairobi. The selection process was undertaken by the OCSDNet advisors and the coordinating team, as well as appropriate external reviewers. The selection criteria were made known to the applicants through the call, and extensive background materials were provided to the applicants to help with preparation of the concept paper[9].

Community and Theory Building

The workshop was the first step of the community building process, providing a venue for applicants to get to know each other and the OCSDNet team and advisors.

At the workshop, the applicants received detailed feedback on their concept note from the OCSDNet advisors and coordinators, as well as other peer applicants. The workshop provided important face-to-face time and space for the applicants to refine their papers and to ensure that it became a fundable proposal, with a detailed budget that met the funders' requirements. The workshop also provided opportunities to share common research problems, methodologies, monitoring and evaluation protocols, and more important, to establish how the various projects could contribute to the common goals of open and collaborative science to address diverse development challenges.

[9] For details of the Call and background materials, see http://ocsdnet.org/application-2/ . Access on: June 19, 2015.

The workshop was a clear move toward achieving Objectives 1, 2 & 4 as workshop participants represented a broad range of disciplines, domains and activities, from open hardware in various South East Asia countries to climate change adaptation with indigenous peoples in South Africa, with common elements of using open approaches and collaboration to look at development opportunities and challenges.

The workshop attendees represented 11 Global South countries, with 3 proposed projects from Sub-Saharan Africa, 1 from the Middle East, 1 from the Caribbean, 5 from Latin America, and 4 from South, East and Central Asia. The workshop attendees also represented a diversity of disciplinary background, from environmental scientists to sociologists of science, and from policy studies scholars to citizen science practitioner in open hardware. The attendees had therefore varying experience, knowledge and conception of development, and different perceptions of open and collaborative science, making the event an important opportunity for applicants to share common challenges, and to debate differences in their approaches, priority setting, and ways of knowing.

The diversity of participants underscore the importance of OCS as a multi and interdisciplinary enterprise, with the need to draw and integrate ideas and research methods and analytical frameworks from disciplines that do not traditionally cross boundaries. This is particularly important for researchers and practitioners from the Global South, who could bring important though often neglected perspectives from diverse institutional settings.

Importantly, one of the key consensus that emerged from the workshop was the need to consider OCS from the perspective of "cognitive justice", the notion that OCS should seek to empower local actors, including researchers and citizens, by taking into consideration the plurality of knowledge systems and to give priority to development challenges that are of local relevance

(SANTOS, 1987; VISVANATHAN, 2005; REILLY, 2014; BARRETO, 2014). The assumption is that by supporting capacity development through research participation, local communities are empowered with greater autonomy and ability to create better and more sustainable livelihoods. "Researchers need to work with society and the grassroots because they are the people who are suffering and know what the problems are," noted OCSDNet Advisor Hebe Vessuri[10]. This has become an important cross-cutting theme for several of the proposed subprojects, and we anticipate emergence of more cross-cutting themes as the various projects develop and learn from each other.

CURRENT AND FUTURE ACTIVITES

After further online dialogue with the advisors, peer applicants, and external reviewers, the applicants submitted their final proposals in late December 2014. All the proposals were subsequently approved for funding in early January 2015 and all the final proposals are posted on the OCSDNet site[11]. The projects applicants and the host organizations also went through the due diligent process required by the funders, and all projects were scheduled to begin in February 2015 and last a duration of 24 months.

Through these projects the network expects to be better placed to begin working towards Objective 3 "Identify the structural, technical, policy and cultural barriers for individuals and organizations to participate in OCS and determine how these barriers could be addressed", and towards building the Theory of Change.

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[10] Cited on http://www.scidev.net/Global/networks/news/network-open-access-research-development-impact.html . Access on: June 19, 2015.

[11] Available on: http://ocsdnet.org/projects/ . Access on: June 28, 2015.

In addition to the development of OCSDNet subprojects, the OCSDNet team has created and launched a network website[12]. The website includes a blog as well as topical forums, providing space for network participants and interested parties to (1) share and access resources, (2) engage in discussions about issues related to openness and development, and (3) stay informed about the network activities.

The creation of the website is a foundational step towards Objective 2 "Build a Community of Open Science Practitioners and Leaders in different contexts, by nurturing an interactive research network." In the following months, the OCSDNet team will continue to encourage widespread participation on the website by preparing relevant blog content, stimulating discussions in the various forums, providing resources on networking tools and research approaches, and by increasing the visibility of the OCSDNet's activities through social media. OCSDNet grant recipients will also be hosting and participating in a variety of conferences and workshops related to OCS and development, and these activities will be reported and shared on the web site to broaden debate and participation.

Each funded projects will also be providing regular updates to the network, and the coordinators will be sharing these widely. These reportings will also form the basis of the ongoing synthesis work that constitutes the theory building phase of the project. At the same time OCSDNet will be engaging in regular monitoring and evaluation exercises with the sub-projects, as well as with the network as a whole. These evaluation outcomes will also be made widely available to interested communities.

12 Available on: http://ocsdnet.org/. Access on: June 19, 2015.

FINAL REMARKS

Given the burgeoning and converging interests on "openness" and open science around the world, it is not surprising to see a flourishing of projects designed to investigate the nature and potential impact of "openness" on scientific practices and discourse. The OCSDNet is part of this growing trend, though the network's focus on the Global South and on development discourse is different from many of the initiatives based in the North. As the network project develops, we also begin to map the diverse actors, agencies and policy dialogues around the world and identify areas of common interests and approaches.

We are also cognizant of the need to be cautious of the strong enthusiasm for open science and its utilitarian claims on efficiencies, return on investment, and economic growth (MANSELL; TREMBLAY, 2013). While cautiously optimistic of the potential of OCS to reshape development practices and discourse, we want to raise critical questions about what real benefits OCS could bring to the Global South, where persistence asymmetries in power structure and deep inequalities in access to resources persist.

Clearly many questions remain open and call for investigation and data gathering. At the same time, as Hebe Vessuri noted (2015, p. 298), there is a strong need to create a "comparative frame that would foster organic interconnections between multiple voices and nourish a diversity of approaches". Creating rich dialogues between different ways of knowing in a complex networked environment is indeed one of the key challenges for the OCSDNet, and we warmly welcome this challenge.

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6

Citizen science: modes of participation and informational activism

Henrique Z.M. Parra

TECHNOLOGIES OF KNOWLEDGE AND CONTROL

The leap from the so-called information society to the world of "smart technologies" was so quick that we find it difficult to grasp the extreme transformations and continuities at stake. *SmartPhone*, *SmartCity*, *SmartGrid*, *SmartHome*, *SmartTV*, *SmartCitizen*... different technologies that promise the efficient management of life in a world without friction (to use a term dear to enthusiasts of the accelerated technological succession). The *smart* world, only present beforehand in the corporative and advertising discourse, begins to penetrate, in subtle ways, new spheres of daily life with the dissemination of new technical artefacts. In all of them, the common element is the digital informatisation of technically mediated processes combined with the continuous production of a new flow of information generated by the effects of cybernetic coordination.

The expansion of the codifiable promoted by informatisation and by the digital convergence of innumerable technically mediated human activities generates new tension between dynamics that lie next to each other. These are: the emergence of new forms of knowledge production resulting from the broadened access to information through interactions on cybernetic networks and, simultaneously, the modulation of our lives, the emergence of a society of control and the expansion of informational capitalism.

The expanding use of digital communication technologies generates a large amount of data, traces and indications of our existence mediated by these gadgets. Consciously or unconsciously, we make each action, interaction or thought expressed on the network into a new recordable and quantifiable piece of information. This becomes possible because the interactivity/ feedback between communicating entities is an imperative of the socio-technical design of networks, a characteristic that is fundamental to the working of cybernetic technologies. It underlies collaborative processes on digital networks, extended forms of scientific production, various expressions of cyberpolitics and digital activism, but it is also one of the conditions that allow the expansion of the production and extraction of economic value from our interactions on the network while modifying the ways in which power is exercised in contemporary societies.

Simultaneous to the emergence of new knowledge and cognitive actors, the diffusion of new forms of creation and political resistance can be observed, together with initiatives of citizen participation or public management based on new mechanisms of interaction between citizens and governments (citizenship 2.0; cyber democracy, experiences of online participation and citizen consultation). Through transverse pathways, words such as participation, collaboration, transparency and access to information have entered the vocabulary of activists, scientists, governmental managers and non-governmental organisations. However, what do “participation” and “transparency” mean when access to information, mutations on the public-private divide or between work time and non-work time become fluid and technically regulated?

Amy Kapczynski (2010), taking up the Foucauldian thesis according to which the production of new knowledge participates in the emergence of new forms of government (governmentality and biopolitics) asks the question of whether we are living in an analogous period as we face the ways of knowing inaugurated by the expansion of digital technology. Indexicality, traceability, computational simulation, *crowd sourcing*, data mining, emergence phenomena, pattern analysis among others are some of the elements that make up a new methodological and epistemological repertoire. Some authors refer to them as silicon sciences, cybersciences among other names (PARRA, 2014a). However, what are the characteristics and the problems presented by these new forms of knowing inaugurated by digital technologies?

We analysed similar issues in previous papers[1]. In this chapter, we focus on some empirical Brazilian cases, calling attention to ways of participation and collaboration among scientists involved in these ways of knowing as well as to the challenges resulting from digital mediation in the investigative process. More specifically, the chapter discusses how certain experiences of citizen science are challenged to place scientific practice closer to the borders of political and informational activism. Indirectly, we intend to interrogate the possibilities and the limits for the production of knowledge in the field of human sciences through digital technology: how can we delineate the tenuous border between digital humanities, social engineering, cognitive capitalism and the shaping of a society of control?

[1] In previous papers, we have discussed the relationship between the expansion of digital communication technology, emerging ways of exercising power and the new configurations of contemporary capitalism (PARRA, 2009; 2014a).

CITIZEN SCIENCE AND MODES OF PARTICIPATION

We have observed, along the last decade, a diversification in the forms of collaboration among scientists, citizens and non-academic researchers that re-invents the public dimension of science and transforms both relations between amateurs and professionals as well as the very dynamics of production, validation, diffusion and appropriation of the resulting knowledge. The work of Antonio Lafuente (2010; 2011; 2013) constitutes an excellent survey of these experiences, analysing the plurality of ways of knowing that are currently in place. The multiplication of cognitive-political actors that come onto the stage (affected communities, patients, social movements, etc.); of the places and institutions for production and diffusion of new knowledge (associations, open universities, online collectives); of new communities and epistemic practices can be observed. A universe of knowledge that at times ignores its own diversity, at others lives together peacefully and at yet others, comes into violent conflict. We believe that it is not just the case of a quantitative change in the production of information and knowledge, but that we are witnessing the emergence of new ways of knowing whose characteristics (episteme, methodologies and cosmologies) are under dispute.

Several of these experiences of collaboration between professional scientists and interested citizens (who are, in some cases, acknowledged as amateur researchers) have come together under the term *citizen science*. In 2013 the *Green Paper on Citizen Science* – a research report that presents a number of evaluations and suggestions for future elaboration of public policies – was produced by the Socientize Consortium[2] for the European Commission for the Unity of Digital Science, an initiative within the scope of "*Europe 2020: strategies towards smart, sustainable and inclusive*

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[2] The site for the Consortium is available on: http://www.socientize.eu/?q=eu . Access on: June 11, 2015.

growth"[3]. The document provides an interesting compilation of experiences of citizen science in Europe, spells out the conditions for its development as well as the challenges to its promotion aiming at policies of scientific and technological innovation. These objectives were established by *Europe 2020* as part of a broader political strategy towards economic and social development. As stated in the report, there is still no consolidated definition for the notion of citizen science:

> Different definitions can be found for Citizen Science, where some take up more traditional aspects, understanding Citizen Science as an approach, which involves volunteers from the general public in scientific investigations during data collection and analysis. Others define it more broadly, as the public participating in scientific research, which includes also scientific activities like the asking of questions, formulation of hypotheses, interpretation of results. Current discussions around the definition of citizen science not only focus on the scope of activities but also what to understand under "volunteers" and how to composite citizen science teams. What we cannot find is one generally accepted definition of citizen science yet. (SOCIENTIZE CONSORTIUM, 2013, p. 22).

Nevertheless, the same document points out a number of elements that might help us in circumscribing these experiences:

> Citizen Science refers to the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources. Participants provide experimental data and facilities for researchers, raise new questions and co-create a new scientific culture.

[3] The site (with a Portuguese version) for the initiative *Europe 2020* is available on: http://ec.europa.eu/europe2020/europe-2020-in-a-nutshell/index_pt.htm. Access on: June 11, 2015.

> While adding value, volunteers acquire new learning and skills, and deeper understanding of the scientific work in an appealing way. As a result of this open, networked and trans-disciplinary scenario, science-society-policy interactions are improved leading to a more democratic research based on evidence-informed decision making" (SOCIENTIZE CONSORTIUM, 2013, p. 6).

To further detail the different expressions of citizen science, we will use a typology elaborated by Alexander Hallavais (2013). In his work, as well as in the Socientize Consortium, the production of scientific knowledge is analysed at the crossroads between the following phenomena: the expansion of digital communication technology, *crowd sourcing* and the use of *big data*. It is perceived, therefore, from the perspective of new opportunities for collaboration between scientists, citizens and scientific institutions, but also from that of broadening the possibilities of production, gathering, sharing and analysing data. Thus, it integrates the perspective of the application of scientific knowledge within a model of development whose premises will not be analysed here.

Hallavais points out that several of these experiences share a public conception of science understood in the following ways: (1) it involves scientific literacy and diffusion; (2) it is made up of practices that create forms of public participation in carrying out research or that seek legitimating through public consultation on scientific decisions; (3) it allows for the voicing of opinions on the subject of *undone science*, laying claim to themes and problems that are not investigated and that should be approached by institutionalised science.

Based on these three approaches, Hallevais (2013) proposes four models for typifying citizen science. Even though the formal framework is insufficient to encompass the complexity of cases, it contributes to the understanding of the main vectors to be found in the organisation of the field. Alongside the framework proposed by the author, I will develop complementary arguments, and, as often as possible, provide examples from Brazil in the footnotes, particularly those related to the fields of human, socio-environmental and communication sciences [4].

In the first situation – Model A – experiences of collaboration between the scientists themselves and their institutions are found. Informatisation and digital convergence have created new possibilities for research and the sharing of data[5]. Both in the human sciences – that have now gone down the path of *digital humanities* – as well as with the other sciences, new forms of sharing resources, methodologies and produced knowledge have arisen that demand the creation of new protocols at different stages of scientific activity.

In this case, it is important to call attention to the fact that one of the conditions for this model to operate is the degree of "openness" adopted by the scientist. There are different ways of understanding the concept of "open science". On its site, the Brazilian work group Ciência Aberta (Open Science)[6] employs an all-encompassing definition proposed by Michael Nielsen: "the

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[4] The choice of these areas is justifiable given the following reasons: they are the areas of knowledge I am most familiar with and interested in; they are less known, due to the fact that, in the areas of the exact and biological sciences, such initiatives have greater visibility. For a broader perspective on this topic in the Brazilian context, please refer to the collaborative mapping (in process) on open science. Available on: https://pt.wikiversity.org/wiki/Pesquisa:Ci%C3%AAncia_aberta_no_Brasil . Access on: June 11, 2015.

[5] Some examples to which we can refer: Grupo de Pesquisa em Humanidades Digitais - https://humanidadesdigitais.wordpress.com/2014/03/15/humanidades-digitais-em-hypotheses-org/ ; Associação de HumanidadesDigitais (Lusófona) - http://ahdig.org ; Grupo de Pesquisa História, Mapas e Computadores (HÍMACO) that carries out historical research with tools and methodologies taken from geographic informational systems (SIGs) http://www2.unifesp.br/himaco/; Projeto Arquigrafia that shares an important collection of images of Brazilian architecture - http://www.arquigrafia.org.br . Access on: June 11, 2015..

[6] Platform for the work group Ciência Aberta - http://www.cienciaaberta.net/ Access on: June 11, 2015.

idea that scientific knowledge of all kinds must be openly shared as soon as practicable in the process of discovery". *Based on information available on the site of the same group, we can add other characteristics that would also define open science such as:the* "development of research standards, software, hardware, input, methodologies and instruments as a shared resource"; or the "development of the scientific process immediately, permanently and publicly recorded, with collaboration open to all "[7]. In practice, however, these definitions will fan out into different experiences, within which the very notions of "openness", "shared", "transparency", "public" will acquire new meanings.

In another situation – Model B – the public is present as producer or data collector. As described above, informatisation and digital convergence have extended the universe of the digitally codifiable. The presence of digital gadgets in objects and processes has benefited from miniaturisation and from the drop in costs of production. There are sensors everywhere producing varied data (temperature in a particular environment, number of people going across a certain area, etc.); our communication gadgets generate and capture a number of other bits of information (speed of displacement, GPS coordinates, volume of surrounding sound etc.). In a certain way, as described by Latour (2004), the laboratory is everywhere and we all participate, willingly or not, of new collective experiments[8]. According

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[7] CiênciaAberta on the Wikiversity platform (in Portuguese): https://pt.wikiversity.org/wiki/Portal:Ciência_Aberta Access on: June 11, 2015.

[8] Collaborative research on climatic condition is a good example. In the project "Estação Meteorológica Modular"(Modular Metereological Station), the authors are interested both in the fostering of a network for the production and collection of data as in their possible application to primary and secondary education. Available on: http://cta.if.ufrgs.br/projects/estacao-meteorologica-modular/wiki/Wiki#Sobre-o-projeto . Another interesting example is the InfoAmazonia platform: a combination of citizen investigation, environmental and investigative journalism with open data made available - http://infoamazonia.org/#!/map=49 . Access on: June 11, 2015.

to this model, as proposed by Hallaveais, we have degrees of situations. In some cases citizens simply provide data (filling in forms, tables, etc.) that feed databases[9]; or they make personal information available through the daily use of digital gadgets (their daily displacement or the graph of their relationships on a digital network); but there are also situations in which citizens operate in the filtering, selection and identification of cases[10]. The relationship between scientists and the public in this model encompasses different ways of sharing the work within the process of producing knowledge. However, scientists are responsible for the final analysis, the systematisation and formalisation of the produced knowledge.

In a third situation – Model C – it is the public that analyses the data produced or made available by professional scientist, scientific or governmental institutions. Hallavais includes within this framework different initiatives related to the practice of *open data,* whereby citizens can freely use information made available by institutions. In this case, experiences of public use of governmental or scientific data should be mentioned[11]. Also, initiatives based on the opening of governmental data, allowing

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[9] Interesting examples of social and environmental problems: collaborative mapping of water shortage in the great São Paulo (Available on: https://www.facebook.com/faltouagua); data collection on fires in São Paulo shanty towns and their likely relation to other urban dynamics (http://blog.fogonobarraco.laboratorio.us/sobre-o-projeto-como-ajudar/); collaborative platform for the monitoring of social-environmental situations on the Northern coast of São Paul - http://www.simapln.com.br . Access on: June 11, 2015.

[10] FlorestWatchers Project carried out by the Federal University of São Paulo in conjunction with different partners in civil society. Available on: http://forestwatchers.net/pt-br/ . Access on: June 11, 2015.

[11] The project *Cuidando do Meu Bairro* (Looking after My Neighbourhood), coordinated by professors from the University of São Paulo, analyses official data from governmental budgets and produces collaborative maps and contextualised analyses in conjunction with civil society organisations. Available on: http://cuidando.org.br/ . Access on: June 11, 2015.

citizens to carry out new analyses of such data[12] as well as practices of data-based[13] or investigative[14] journalism could be included in this typology.

In order to ensure that these practices become more efficient and robust, it is necessary that open data keep to certain specifications. Unfortunately, this does not seem to happen in some cases. In a nutshell, it is the case of abiding by protocols that define the possibilities of use, modification, interoperability, diffusion and re-appropriation. After all, it is not enough to make information available: it is necessary that it be available for different purposes and for different forms of using it.

The definition of open data is an area ridden by controversy just as is the notion of open science. As we will see in the final part of this text, the way digital information becomes open evidently has consequences for the way knowledge is produced, for its economy (pecuniary or symbolic) as well as for the distribution of power related to the use of information. The definition proposed by the initiative

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[12] In 2011, the *Lei de Acesso à Informação* (Lei 12527) (the Access to Information Law) was passed in Brazil, setting out a number of important guidelines for making governmental data available to the public - http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2011/lei/l12527.htm. See also the Brazilian government portal that makes this data available - http://dados.gov.br/ .Simultaneously, there are several civil society initiatives that aim at both bringing about wider accessibility to this data as well as ensuring it is analysed in order to produce new information: http://databr.io/; http://www.infopatrimonio.org; http://escoladedados.org/ . Access on: June 11, 2015.

[13] There is a varied number of experiences of data journalism as practiced by both major Brazilian papers(see the case of the newspaper O Estado de S.Paulo - http://blog.estadaodados.com) and by initiatives of associative and independent journalists (see the case of the collective Hacks Hackers - http://hackshackers.com/ or the project Jornalismo Digital (Digital Journalism) -http://www.jornalismodigital.org/). Access on: June 11, 2015.

[14] There are some interesting initiatives of investigative journalism in Brazil that combine innovative communication strategies and visibility of narratives with rigorous investigative procedures as well as with making research data available at a later stage. See the cases of *APública* (Agência de Reportagem e Jornalismo Investigativo) - http://apublica.org/, and*Repórter Brasil* - http://reporterbrasil.org.br/ Access on: June 11, 2015.

Open Data[15]may serve as an initial point of reference: "*open means anyone can freely access, use, modify, and share for any purpose (subject, at most, to requirements that preserve provenance and openness)*" or, alternatively, "*open data and content can be freely used, modified, and shared by anyone for any purpose*". Within this proposition, it is necessary that a number of more specific requirements be met because the conditions for effectively opening data depend on socio-cultural (practices), legal (regulations and laws), economic (systems of property and use) and socio-technical (standards, specifications and formats for machine processing) factors[16].

Finally, in Model D, citizens participate in all stages of the production, systematisation and diffusion of new knowledge. The public acts as producer and collector of data, analyses results and may elaborate new research questions. Hallavais includes in this framework some experiences of individuals or groups that act as independent researchers as in the case of self-supervised investigations[17] or in *crowd sourcing* initiatives such as *Wikipedia* and *Open Street Maps*[18].

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15 Site of the initiative Open Data available at: http://opendefinition.org. Access on: June 11, 2015.

16 A presentation with 11 topics encompassing the complete description of open data in Portuguese is available at: http://opendefinition.org/od/1.1/pt-br/ Access on: June 11, 2015.

17 According to Hallavais, examples of this particular case can be observed in the different practices of personal self-monitoring in the areas of health and life style. The project *Quantified Self - Self Knowledge Through Number* - http://quantifiedself.com/ Access on: June 11, 2015. - is directed to the investigation and dissemination of several experiences of using digital gadgets for self-knowledge. Many of these practices make use of online platforms to share individual data and to make it available to new investigations, particularly in the area of health. The social and political implications of the possible use of this information are controversial and deserve more detailed analysis. However, this lies beyond the scope of this article.

18 Wikipedia - http://www.wikipedia.org/ ; Open Street Maps - http://www.openstreetmap.org Access on: June 11, 2015.

Adopting the same typology, we could include in this model other initiatives of citizen science developed by researchers in participatory investigations organised in conjunction with social movements, affected communities or activist groups in the production of "situated knowledge" (HARAWAY, 1995). These will produce a counter-expertise that will contest the analysis of particular phenomena with institutional actors. However, differently from the cases discussed up to now, the use of digital technologies – either as a research instrument or as a resource promoting the integration between scientists and amateurs - does not come up as the main feature characterising these experiences, but as an internal component of methodologies for which socially oriented collaboration is the fundamental element[19].

Participative research is not new in human sciences and a lot has been written about methodologies of action research, participatory observation among other denominations in the fields of sociology, anthropology and socio-environmental sciences, for example. There are, however, important practices that will pick up these methodological trends and merge them with new use of digital technology, generating other possibilities of investigation and of

[19] An interesting movement that congregates different initiatives guided by the democratisation of scientific production is the network *Movimento de Ciência Cidadã (Citizen Science Movement)*. The objectives of this initiative are: "(1) To congregate researchers, critical scientists and engaged citizens motivated by the social struggle on agriculture, housing, health and the environment (2) To bring together the most capable actors who, at the moment, are isolated by the compartimentalised organisation of science and technology. This can be achieved through transverse reflection and action, aimed at the democratisation of science and expertise as well as the empowerment of civil society (3) To elaborate, propose, promote new democratic ways of doing science with the participation of subjects (Citizen Conventions, participative research, popular forums for scientific education, science shops, social technology…) and submit them to law makers at the appropriate occasion". Available on: http://www.movimentocienciacidada.org/. Access on: June 11, 2015.

knowledge production[20]. In the field of social sciences, we can also refer to some experiences in visual anthropology and sociology in which different participating agents and groups operate at the different stages of the elaboration of a project of visual investigation and production (photographic, audiovisual, cartographic)[21]. But, perhaps, the cases in which digital technologies go beyond their instrumental use are those where we observe an appropriation that intensifies their technical-political specificities[22].

Despite the increase of citizen participation in the production of and access to knowledge, there are dimensions that remain underexplored in the models described above: the different conditions of access to information between citizens and scientists; the unequal possibilities of appropriation, application and reframing of produced knowledge; the unequal effects of

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[20] The *Instituto Socioambiental* (The Socio-Environmental Institute) - http://www.socioambiental.org/pt-br - has been active for 20 years in research and promotion projects on socio-environmental rights, working with native communities, *quilombolas* (communities of descendants from Afro-Brazilian slaves) and other traditional communities. In many of these works, the use of new tools for the production of participative cartography, for the creation of alternative multimedia communication and documentation networks is a fundamental resource. Another relevant experience on related topics that we would like to point out is the project *Nova*Cartografia Social da Amazônia (New Social Cartography of the Amazon Region) - http://novacartografiasocial.com . For both experiences, it is worth calling attention to the effort of creating programmes focused on the production of knowledge and on continuous education at the crossroads of different types of knowledge. See: https://ensinosuperiorindigena.wordpress.com/ http://novacartografiasocial.com/quadro-de-projetos/#cienciasesaberes. Access on: June 11, 2015.

[21] A good example of multimedia research and documentation on Cidade Tiradentes, a neighbourhood in the city of São Paulo - http://www.fabricadecultura.org.br/cidadetiradentes/ ; the photography and video work carried out by VisurbISURB – Grupo de Pesquisas Visuais e Urbanas (Visual and Urban Research Group) - http://visurb-unifesp.wix.com/visurb-unifesp. Access on: June 11, 2015.

[22] The work of the RedeMocambos (Mocambo Network), related to the topic of the *quilombolas* is a good example of the experimental use of digital communication technology l - http://www.mocambos.org/wiki/P%C3%A1gina_principal Access on: June 11, 2015.

the circulation of this knowledge; or even the effects related to the characteristics of the layers (physical and logic; *hardware* and *software*) that carry out digital mediation.

In connection with the latter, as communication through digital networks becomes more reticular and ubiquitous, it tends to become invisible or "natural". Here, both the position occupied within the structure of the network as the capacity of control over the software and hardware in use become highly strategic. In this sense, if, on the one hand, we can observe the opening of new opportunities for citizen participation in scientific production, on the other it is necessary to explore the difficulties that arise so that the collaboration between scientists and non-scientists may in fact create relationships and knowledge guided by more democratic principles.

ACCESS TO KNOWLEDGE AND INFORMATIONAL ACTIVISM

The importance of the objectives and values of citizen science is inseparable from the issue of the means and processes required for its achievement. To the extent whereby the characteristics and effects of the digital technologies employed in the investigative process result from complex socio-technical dynamics (PARRA, 2014b), open and citizen science practices, in their most radical versions, become part of a technical-political phenomena.

One of the challenges most frequently faced is that related to the conditions of access and use of information. It is present both in the case of direct collaboration between scientists as in the cases of collaboration between scientists and non-scientists. To whom does the data belong? How can it be used? Which are the possibilities of interoperability and access to other research? What are the rules of property?

In this sphere, the possibilities of sharing brought about by digital technologies collide with tendencies of commoditisation and privatisation of knowledge. The new "*enclosures*" (to use a term coined by James Boyle) of what is produced in common (information, knowledge and culture) come into being both through the expansion of the legal system of intellectual property as through the technological adoption of proprietary software and hardware that limit the possibilities of use, modification and re-appropriation of information.

Beyond access to new information, the same problem applies to the use of research software and hardware. It is expected that the investigation carried out through digital technologies become, as well as all scientific research, open to the scrutiny of interested people. In this sense, how can one analyse the effects of the algorithms, software and hardware in the course of data collection, processing and analysis when these are inaccessible either as a result of intellectual property laws ors by the adoption of technological blockades?

Thus, the public and citizen dimension of science achieved through the use of digital technologies acquires a compelling and up-to-date meaning. An interesting controversy has recently taken place when Princeton University researchers, in partnership with Facebook, carried out an experiment of emotional contagion on digital networks[23]. The controversy resulting from this paper published in the prestigious PNAS (Proceedings of the National Academy of Sciences of the United States) journal focused on ethical issues related to the informed consent and privacy of participants[24]. However, an unexplored aspect of this event concerns the lack of knowledge of how Facebook's algorithm operation responsible for the modes of interaction between users and published information functions. How can we ensure the public dimension of science

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[23] The article "Experimental evidence of massive-scale emotional contagion through social networks", by Adam D. I. Kramer, Jamie E. Guillory e Jeffrey T. Hancock is available on: http://www.pnas.org/content/111/24/8788.full Access on: June 11, 2015.

[24] Confronted with the dispute the journal published an editorial about the new ethical issues implicit to the work with *bigdata*. Available on: http://www.pnas.org/content/111/29/10779.1.full Access on: June 11, 2015.

when we ignore the way many of the proprietary technology used by the research works? In this sense, scientists interested in open or citizen science[25] become allied with activists in favour of free access to information and knowledge[26] and with technical-activists in favour of free software and hardware[27].

To acknowledge the non-semantic (abstract-formal) character of digital information and the way whereby this understanding integrates a model of scientific production promoted at the convergence of NBIC – nanotechnology-biotechnology-information technology-cognitive science – is important to critically contextualise some research based on *big data*. Often enough, we are confronted with the risk of de-contextualisation of the initial process of generating digital indicators. The very definition of what is chosen as an "indicial" element that will generate digital information is, in itself, an area of political confrontation. Such a claim is expressed in more simple and direct

[25] At the Federal University of Rio Grande do Sul, there is a Centro de Tecnologia Acadêmica (Centre of Academic Technology) - http://cta.if.ufrgs.br/ - that develops free software and hardware for scientific application; at University of São Paulo we can refer to the Grupo de Pesquisa em Políticas Públicas para o Acesso à Informação (Research Group on Public Policies for Access to Information) - http://www.gpopai.usp.br/wiki/index.php/P%C3%A1gina_principal ; at the Federal University of São Paulo we refer to the Pimentalab - Laboratório de Tecnologia, Política e Conhecimento (Pimentalab – Laboratory for Technology, Politics and Knowledge)- http://blog.pimentalab.net Access on: June 11, 2015.

[26] The initiative Transparência Hacker (Hacker Transparency) is possibly the widest network, encompassing a wide diversity of projects related to practices of access to information, transparency and critical appropriation of data in Brazil - http://thacker.com.br . Access on: June 11, 2015.

[27] Claims in favour of free access to information and for the adoption of free technologies are voiced by various Brazilian groups. There is a powerful community for the promotion of free software in the country - http://softwarelivre.org – as well as a growing movement of *do-it-yourself* inspired on hacker culture: Garoa Hacker Club - https://garoa.net.br/wiki/P%C3%A1gina_principal ; and Metareciclagem http://rede.metareciclagem.org/ . The Brazilian government also supports some specific projects in favour of free software as a strategy for economic and technological development - http://www.softwarelivre.gov.br/ and https://portal.softwarepublico.gov.br/social/ Access on: June 11, 2015.

arguments in the struggle of social movements and techno-activist groups that question the use of digital technologies for social control. This seems to be the case when, based on *profiling,* they define managerial actions (public policies) for citizens that fit a profile of potential threat. In this context, problems regarding privacy and the protection of personal data and of freedom of speech acquire new political relevance[28].

From another perspective, scientists also face problems related to the political economy of information. As discussed by Amy Kapczynski (2010), is open science based, after all, on the promotion of the intellectual *commons* or on a market of flexible permissions supported by a concept of intellectual property? The pun "*free from market*" or "*free for market*" provides a good summary of this ambiguity. At some Brazilian universities where the model of privatisatison of knowledge (patents, brands and copyright) is the dominant one, to practice open science in an anti-market direction becomes an action of political resistance, since it fights for making public and allowing free access to the scientific knowledge produced most of the time with public funding[29].

Digital mediation also introduces an issue regarding the ownership and access to sensitive data. In such cases, how can we regulate the border between public and private data? How can we ensure privacy? How can we avoid sensitive data, even when kept anonymous, from being used by governments or businesses in simulations aimed at obtaining advantages in the (political,

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[28] In Brazil we can refer to some techno- activist groups that work with topic regarding the promotion of privacy, safety, freedom of speech: Actantes - http://actantes.org.br ; Saravá - https://www.sarava.org/ Access on: June 11, 2015. .

[29] Na interesting example was the elaboration of a collective proposal presented at the Conference of the Federal University of São Paulo, where topics guiding university organisation were discussed. See the proposal "*Deve o conhecimento ser livre? Sim!*" ("Must knowledge be free? Yes!") Available on: http://pimentalab.milharal.org/2014/08/28/deve-o-conhecimento-ser-livre-sim/ Access on: June 11, 2015.

social or economic) control over citizens? Given that both the State and several private corporations hold large databases with information on different aspects of people's lives, how can we avoid the emergence of a tyrannical power based on the asymmetric control of such information? This is a difficult problem to face considering that digital technology in cybernetic networks produce a new volume of data that, when is aggregate, becomes extremely valuable for science, for the State and for corporations. To sum up, the possibility of new knowledge comes hand in hand with new possibilities of power and control.

When the Brazilian Civil Rights Framework for the Internet (Marco Civil da Internet) was passed in 2014, the demand for new legal regulations for the protection of personal data surfaced as the current frontiers of the public debate on the management of computarised data in digital networks. At a recent seminar, the director in charge of the database on Brazilian citizens of the Central Health System (Sistema Único de Saúde – SUS) declared: "the data belongs to citizens"[30]. However, what does this "belongs" mean when the data is generated, transmitted, stored and analysed through so many technological mediations that it becomes impossible to know who, under which conditions, can have access to the information? Therefore, it is necessary to ask questions about the likely degree of autonomy of the average citizen regarding the control of his/her own data, particularly in relation to future and still undetermined uses.

Finally, perhaps this is the moment to take up again the discussion on technological sovereignty beyond the conception of the sovereignty of the nation-state. Hacktivists and techno-activists argue that both individual and collective autonomy depends on the capacity of users

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[30] According to the article published on the site Convergência Digital: "Marco Civil: Saúde decide que o dado pertence ao cidadão". (Brazilian Civil Rights Framework for the Internet: health system decides that thedata belongs to citizens") Available on : http://convergenciadigital.uol.com.br/cgi/cgilua.exe/sys/start.htm?amp%253bpost%255Fdata=&infoid=37483&sid=21/ Access on: June 11, 2015.

to have full control of technological mediations implicated in their lives[31]. If this proposal is taken in a sense that differs from the liberal or communitarian techno-utopia, perhaps we can advance it towards a new sovereignty (LATOUR, 2004) set up by a community capable of acknowledging simultaneously the political dimension of social life and of technical artefacts. It is no longer possible to neglect the socio-technical specificities and the political-cultural horizon that shape up the technological environment surrounding our lives. In this sense, the production of knowledge guided by the promotion of freer and more solidary life styles places, shoulder to shoulder, scientists, hacktivists, librarians, citizens and cypherpunks!

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[31] There is an excellent dossier dedicated to the discussion on technological sovereignty edited by Alex Haché (2014). Besides examining the different technological requirements and characteristics of the different levels implicated in communication through digital networks, the dossier presents practical experiences of the application of the concept of technological sovereignty.

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7

Open source hardware (OSHW) for open science in the global south: geek diplomacy?

Denisa Kera

INTRODUCTION

The Do-It-Youself biology (DIYbio) movement originated in the U.S. in approximately 2009 around student iGEM synthetic biology competitions (DURRETT; FIELD 2011; KUZNETSOV et al. 2012) as well as parallel open biology efforts in Europe and Asia with their connections to bioart and critical science practices in the late 1990s (BUREAUD; MALINA; WHITELEY, 2014). This movement merged in recent years with other movements coming from professional scientists advocating eScience, Open Science, Open Access and Open Data (NEYLON; WU, 2009; MOLLOY, 2011; UHLIR; SCHRÖDER, 2007). The calls for changing the publishing model and opening the datasets while supporting online collaboration and crowdsourcing are starting to merge with attempts to reduce the cost of experimental research and increase reproducibility by building low cost customizable laboratory equipment (PEARCE, 2014; LANDRAIN et al. 2013).

This convergence of hackerspace and makerspace OSHW interests with open science goals (open data, open access, online collaboration) created some unique opportunities to involve citizen scientists, but also scientists from the developing countries in alternative global research networks (KERA, 2012A; KERA, 2013). In this paper we want to reflect upon the critical role of open hardware in forming these unique South to South and South to North networks and research cooperation. We will analyse the issue as a form of "geek diplomacy" over open science.

Geek diplomacy is a citizen, grassroots involvement in science which bridges various knowledge and infrastructural divides to create a more inclusive R&D response to challenging international political, social and scientific issues. It is a form of citizen and scientific diplomacy (FLINK; SCHREITERER 2010; BURNS, 2014; GILBOA, 2008; MAKHEMA, 2010) that emphasises the important role of R&D based on open-source technologies in creating conditions for peace and cooperation while acknowledging the importance of indigenous, local and vernacular cosmopolitan knowledge and cultures, crafts and sources of experience. In this sense, geek diplomacy offers unique opportunities for global cooperation around science, but also for R&D with a more participatory, inclusive, but also reflective and socially responsible agenda.

Examples of geek diplomacy include projects such as the Hackteria network for open biology[1] or the Safecast[2] radiation monitoring network and the Open Technology forever network[3]. Both networks show an international grassroots innovation effort around OSHW that mobilised citizens into taking an active role in solving problems in their communities while rethinking the role of science and technology globally. The DIY radiation monitoring by Safecast created an active global network of citizens concerned with environmental monitoring

1 Available on: http://hackteria.org/. Access on: June 7, 2015.

2 Available on: http://blog.safecast.org/. Access on: June 7, 2015.

3 Available on: https://opentechco.co/. Access on: June 7, 2015.

after Fukushima. This network improved the standards in environmental sensing by cooperating with industry actors (KERA; ROD; PETEROVA, 2013). The Hackteria network specialises in building OSHW laboratory tools used for various artistic, educational and research efforts around the world mainly in microbiology and nanotechnologies. The network has been very active in Indonesia since 2009 where the OSHW tools increased science literacy, artistic expression, but also helped the local research community to develop their own R&D goals (KERA, 2012B; KERA, 2013).

Due to their global and international scope, but, at the same time, their sensitivity to local and cultural contexts, these networks support democratic goals and resilience. We can describe them as an emerging "open science diaspora" with reference to the term "science diaspora" proposed by the AAAS (American Association for the Advancement of Science) Center for Science Diplomacy. They embody the emerging "new architecture of cooperation" enabling countries to "invent, create, innovate, and solve problems together" (BURNS, 2014) while using open source hardware. The reason we emphasise the role of OSHW and the related groups of geeks, makers and hackers is that they represent informal and independent knowledge and technology transfer institutions that are more adaptable to the developing context.

Geek diplomacy based on open science and open hardware efforts democratises the R&D process by making it more inclusive: it encourages the participation of various stakeholders and citizens from around the world that inspire each other by sharing data, protocols or schematics of hardware and design. R&D becomes less about diffusion and technology transfer, which perpetuate the various forms of science "divide", and more about the value of cooperation and unique niche interests. The emerging "open science diaspora networks" cooperate over open source technologies to test surprising geopolitical, but also scientific, networks and define new ideas of what the role of science is in the Global South:

> The near monopoly of governments in the management of international affairs has certainly been broken. Diaspora networks, like nongovernmental organizations, civil society groups, and multinational corporations, are increasingly important and influential actors in international relations. Science diaspora are vital to a new architecture of cooperation that will allow us to invent, create, innovate, and solve problems together.... There is no single formula for developing and growing a science diaspora network as a platform for cooperation. Each will be a unique outcome of a country's culture, history, international relations, political system, economic development, and geography. (BURNS, 2014)

This DIY and maker approaches to building laboratory equipment with open source hardware tools democratise infrastructure and involve more people in reflecting and defining the role of science in their communities. The specific DIY tools such as microscopes, PCR (polymerase chain reaction) thermocyclers, laminar flow cabinets and centrifuges support science literacy. They also lead to better management of expectations, fantasies, fears and risks by demystifying how science facts and data are measured and by opening these practices to design and artistic pursuits. By building laboratory equipment, individuals and communities are empowered to define their own scientific and developmental challenges and goals in their local context outside the technology transfer and various rhetoric about divides (BOUDOURIDES, 2002; HOLMGREN; SCHNITZER, 2004; PACKER; MENEGHINI, 2007). These individuals and communities can also decide how much and what type of risk they want to take; this supports resilience along with sustainability and simple agency.

OPEN SCIENCE DIASPORA NETWORKS

The open science diaspora networks and projects such as Hackteria, Safecast or Open Technology Forever defy the geopolitical stereotypes about North-South divisions in particular the various discourses on some form of “divide”. The latter are inspired by the deficit model in science communication and theories of digital divide etc. (BYERLEE; FISCHER, 2002; FORERO-PINEDA, 2006).

These networks and projects refuse to perceive the Global South as a place of deficit and lack that simply need to be bridged in order for progress to be achieved. The projects and workshops by Hackteria bring together members from Indonesia, Singapore, India, Switzerland, UK, Germany and Slovenia from various disciplinary and cultural backgrounds to share their common interests in OSHW approaches to science. These approaches encompass, for example, building microscopes or spectrometers, turbidity sensors etc. used for scientific, but also artistic pursuits. The participants exchange their knowledge and interests on equal grounds by helping and teaching each other; the work on a project goes hand in hand with a series of workshops, performances and informal networking. The legal entity – Hackteria - is registered in Switzerland as a nonprofit organization that can access local grants, but acts more like a fractal or meta-organisation whose members are not only individuals, but often parts and representatives of other organisations. This horizontal and decentralised structure, which supports mutual crosspollination rather than linear transfer, is also visible in the case of Safecast and Open Technology Forever networks. The latter present complex global meta-institutions that do not make a difference between an individual member or another organisation if they are willing to share open science protocols and open hardware tools.

The networks congregate around Open Source Hardware (OSHW), which supports such hybrid and fractal organisational structure by its own nature. OSHW presents an assemblage of technologies, design principles and licenses that connect innovation with concerns about (open) infrastructure and protocols, issues of social justice and economic sustainability. This allows geeks and makers to work on all these levels while prototyping (WEISS, 2008; GACEK; ARIEF 2004; DAVIDSON, 2004). OSHW includes attempts to democratise electronics specially microcontrollers, but also experiments with digital fabrication (3D printers) that promise to more people around the world the possibility of building anything they want. The main goal remains to make these tools affordable by "opening" their design, but also often by simply repurposing existing tools. This means opening them for learning, but also for further improvements and individual appropriations.

OSHW also defines a whole new set of places and institutions where R&D happens in an alternative and holistic way such as Maker Fairs, niche centres or libraries of tools such as hackerspaces, makerspaces and FabLabs. The global network or "open science diaspora" is, in this sense, a continuation of such existing efforts and their extension into the intergovernmental or supranational institutions.

The OSHW efforts are part of other open design related trends that in recent years have defined an emerging public of makers or even DIY citizens (RATTO; BOLER, 2014; PAULOS, 2009) who connect political deliberation with prototyping. Citizens join efforts to democratise and build better tools around the world to influence their local communities, but also to challenge the geopolitical division. This type of "geek diplomacy" over prototyping supports R&D in unexpected places.

The value of customisation, openness and cooperation in these projects is "deontological" rather than purely pragmatic and utilitarian. With OSHW, we can define what technology and science could and should mean rather than looking for more efficient and better "diffused" solutions to various divides that support the existing patent and profit driven R&D. The value of OSHW prototypes is that they are neither "invented" nor "adopted" or "disseminated" by clearly defined actors; they are neither imposed nor protected or regulated by any governments or industries. They are simply forms of technological "folklore" that is inclusive and open to the local context, while leading to global interactions that are political and design related at the same time.

Open Source Hardware (OSHW) supports decentralised and participatory approaches to innovation that make technology accessible to various niche communities. The kits, which are often used as a form of distribution, lead to further development of OSHW by providing the components and instructions needed to learn how to build the first prototype. They, then, inspire various groups to create their own clones and further develop it. These kits define this new relation between experts and amateurs, innovators and producers, technologies and contexts (niches). We claim they can also form unique geopolitical research networks that ignore the prevailing North-South stereotypes to enable R&D in new places.

Pragmatic and utopian at the same time, the OSHW tools are becoming both a product and a medium for self-reliant and independent communities around the world seeking their own version of technological progress. Examples of such communities include projects such as the Open Source Ecology[4] village in Missouri, US; the Micro/Macornation[5] villages by HONF around Yogyakarta and the emerging projects in Nepal. The latter include projects such as the Karkhana collective[6] that is working with a local farm, but also with a social entrepreneurship venture company, Biruwa.[7]

4 Available on: http://opensourceecology.org/. Access on: June 7, 2015.

5 Available on: http://vimeo.com/45452898. Access on: June 7, 2015.

6 Available on: http://www.karkhana.asia/. Access on: June 7, 2015.

7 Available on: http://www.biruwa.net/. Access on: June 7, 2015.

OPEN HARDWARE MICROSCOPE IN INDONESIA

One object that summarises well the possibilities behind the OSHW for science efforts is the low cost DIY microscope in Indonesia. This was tested in 2009 and developed into a professional tool supporting various artistic and scientific efforts and co-operation over the years. It is based on a flipped lens of a repurposed webcam whose price can start at USD2.00 and whose image sensors (CMOS of CCD) convert light captured by the lens into a digital image. While the lens typically captures a wide-angle view and focuses it onto the small sensor, by flipping the sensor we can achieve a 200x-magnification of a microscope. More importantly, such microscope can connect to a computer over a USB cable. This enables analyses of the captured images with various open source software, such as the open CFU[8]. The open CFU is a bacterial/yeast colony counting software that can analyse agar plates and support a common microbiology protocol. The enumeration of colony forming units (CFUs) can then be shared as open data over Wikimedia, Figshare or other image data repositories and transform the microbiology practices into a minor open science revolution.

The critical part for any DIY microscope build from a repurposed webcam is the stage which needs to be mobile, but also stable enough to capture and hold the image on the plate. While the lens and sensors of the repurposed webcam are closed and patented technology, the design of the DIY kits for the stage became an open source hardware project connecting Indonesia and Switzerland between 2009 and 2014. The open source collaborative development of the "stage kit"[9] for the webcam microscope captures the complex networks around open biology. It

8 Available on: http://opencfu.sourceforge.net/ . Access on: June 7, 2015.

9 DIY microscopy resources, available on: http://hackteria.org/?cat=15 Access on: June 7, 2015.

forms an original case of knowledge transfer and alternative R&D cycle connecting the citizen and open science efforts in Yogyakarta with Luzern and other places around Switzerland where Hackteria members work.

The original 2009 prototype was developed during a visit by Marc Dusseiller from the then newly established network of scientists, artists and designers for open biology called Hackteria.org during a Media Art festival “Cellsbutton” organized by a local nonprofit organization “House of Natural Fibre” in Yogyakarta, Indonesia. Marc Dusseiller offered a workshop on building DIY microscopes in the Microbiology Lab of the Faculty of Agriculture, University of Gadjah Mada. There, he observed attempts to build low cost equipment for microbiology, for example, the laminar flow cabinet built by Professor Irfan D. Prijambada. After some experimentation, the final model of the microscope used a PS3eye webcam because it was capable of working with low light intensity, one of the requirements of the project.

These original Playstation webcams turned into microscopes were precise enough to be useful for the needs of the students from UGM Microbiology Lab. The critical component - the stage - was developed much later in 2012 after many frustrating attempts and improvisations with microscopes in educational, artistic and research projects.

In 2012 one of the Hackteria members, Urs Gaudenz, familiar with the efforts in Indonesia, but also with various workshops in Europe decided to standardise the stage for such DIY microscopes. He worked in cooperation with Fablab Luzern in Switzerland where he was working part-time. There, he designed the first laser-cut microscopy stage and sent the design together with two of his kits to the UGM Microbiology Lab in Indonesia and to their affiliated, nonprofit organization of citizen scientists, Lifepatch.

Lifepatch used the microscopes for open science workshops with disadvantaged children in Yogyakarta, but also with artistic performances and educational activities that required a simplified stage. Since it was expensive to ship the kits from Switzerland, a Lifepatch member copied the original laser-cut stage from Fablab Luzern and crafted it into a handmade acrylic stage[10]. After this initial prototype, which paradoxically combines the traditional crafts with digital fabrication, Lifepatch was able to find a laser cutter and eventually improve the original design of the stage.

This open hardware "dialogue" between Switzerland and Indonesia not only enabled science infrastructure (open hardware microscopy), which can support both citizen and open science projects, but it also envisioned an interesting interaction between traditional (glassmaking) crafts in Indonesia and a Fablab-style digital fabrication object. The unique handmade microscopy stage paradoxically copied the digitally fabricated design from the Fablab Luzern only to return a better design that was then laser-cut back in Luzern. The handmade copy in Yogyakarta actually used acrylic leftover material from laser cutting that was lying around the Lifepatch studio.[11]

This unique handmade stage for a hacked webcam was built by Radix Nugroho from Otakatik Creative Workshop that up-cycles glass and collaborates with Lifepatch and other citizen science organization. This first Lifepatch and Otatik kit for a microscopy stage was "cloned" manually, but the later laser-cut versions improved the Hackteria's stage design. In the short period of two months, Lifepatch members designed their own Indonesian clone and created a microscopy stage kit (SIAGIAN, 2015). They also

10 DIY microscopy stage kit – Indonesian clone, available on: http://hackteria.org/?p=2082. Access on: June 7, 2015.

11 Documentation of the whole process in photos: https://www.facebook.com/photo.php?fbid=299885063470577&set=a.182960105163074.37706.144301485695603&-type=1&relevant_count=1 , also https://www.facebook.com/media/set/?set=a.549545511747116.131034.284578538243816&type= 1 and http://www.flickr.com/photos/92698778@N04/8447886916/in/photostream/ Access on: June 7, 2015.

explored the possibilities of using recycled local materials in order to make it cheaper, but also to enhance its value as an artwork.

The open hardware laboratory infrastructure in Indonesia was always part of such artistic, design and community oriented activities. They show that the OSHW model of R&D is not only about efficiency and low cost, but also about interdisciplinary collaboration and niches that generate unique appropriations and interactions between old and new technologies and materials, North and South while supporting the pragmatic needs for infrastructure and capabilities.

The dialogue between traditional crafts and digital mass production shows the potential of OSHW for science as a critical practice capable of questioning its role in society. The low cost and affordable laboratory efforts go hand in hand with the search for a more creative and better integrated science in society in the context of maker activities, educational and artistic interests. OSHW simply enables socially inclusive science that involves and inspires rather than only solving problems.

The artisan “kit”, which cloned the original microscopy stage, influenced a project in 2014 that is trying to connect Indonesian Wayang Kulit (shadow puppet) theatre with a microfludic (lab on a chip) interface.-It also tries to perform with zooplankton by using both OSHW laboratory equipment and traditional material (coconut, but even bamboo, that are commonly used for gamelan music instruments). The early experiments, which partially happened out of necessity, evolved into aesthetic interests of the citizen scientists in Yogyakarta and elsewhere and inspired a whole branch of design research (Ausareny et al. 2014).

OSHW prototypes, kits and clones often make up such “hardware dialogues” and improvisations between various countries, disciplines and institutions. In 2012, the Lifepatch members from Indonesia cloned not only the microscopy kit, but also the simplified microcontroller on a USB stick called GNUSbuino which is used among other things for controlling a diode on a turbidity sensor to gather simple data for water analysis. This Swiss microcontroller was introduced in a workshop in Yogyakarta in January 2012 and then transformed by Indonesian geeks into a cheaper, BabyGnusbuino Tropical DIL version v0.3 that uses electronic parts available in Yogyakarta.[12]

Both, the microscope stage as well as the microcontroller were later used at a workshop during the Shanghai Maker Fair in October 2013. There, they attracted the attention of Eric Pan - a CEO of Seeed Studio[13] in Shenzhen, an important online open hardware marketplace which supports hardware developers around the world. Seeed Studio invited the Lifepatch members and Hackteria to introduce a new line of DIYbio kits that will support open science and DIYbio efforts by mass-producing such open science kits in Shenzhen. The interaction between a homemade prototype object and the DIY, mass-produced kit has created a large number of unexpected innovation networks between Switzerland, Indonesia and China. The first Indonesian DIY microscopy kit offered to the global geekdom by Seeed Studio could show how the North-South divide is irrelevant when it comes to R&D supported by OSHW.

OPEN SCIENCE DIASPORAS AND RESILIENCE

The scientific, technological, but also political empowerment of individuals and communities by OSHW is often achieved through various Do-It-Yourself (DIY) kits such as the microscopy stage or the famous case of radiation monitoring devices developed by

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12 Documentation of Baby GNUSbuino Tropical, available on: https://www.facebook.com/photo.php?fbid=10200667640320218&set=a.10200400213394712.201694.1437047270&-type=1&relevant_count=1. Access on: June 7, 2015.

13 Available on: http://www.seeedstudio.com/ . Access on: June 7, 2015.

Safecast. The cycle starts with a group prototype that is developed into a kit by involving citizens through crowdfunding campaigns, but also through workshops in which people learn how to use it or how to further develop it. At the same time, the prototype is professionalised by the engagement with existing companies, such as in the case of the Safecast which engaged with companies producing Geiger counters. Later, they helped to improve the quality while complying with standards.

The DIY Geiger counters during this whole cycle of prototyping, testing and reiterating enabled citizens to gather and share independent data on radiation and to take an active part in policy related to the future of nuclear energy (KERA; ROD; PETEROVA, 2013). The latest prototypes - bGeigie nano - even received more than USD100.000 in 2012, through the crowdfunding platform Kickstarter from anonymous and global communities of "backers" keen to invest and support the quest for independent and accurate data. Another project - Bike 2.0 - is taking the idea of citizens' monitoring of the atmosphere a step further by creating a sensor platform for radiation and air quality for bicycles, innovating the function of this everyday transportation vehicle and, as a result, rethinking the future.

Over a period of two years, the initial ad hoc network for radiation monitoring evolved into a global nonprofit organisation supporting open measurement and publication of various atmospheric data, but also the cooperation of citizen-tinkers with various regulatory bodies in charge of their environment. The OSHW, in this case, supported the interactions between stakeholders by enabling efforts for independent measurement of data through custom-built DIY tools as well as the discussion about their accuracy and calibration. This brought geeks into contact with regulatory bodies and established industry players.

A similar strategy can be observed in environmental sensing projects around the world such as the Czech-based platform

Kanarci,[14] or the sensors and tools for monitoring offered by the OSHW marketplaces such as Libelium[15] or Seeed Studio (KLOSOWSKI, 2015).

While similar "humanitarian" hardware projects (AKIBA, 2011) demonstrate the social and political possibilities of the emergent tinkering public, numerous other OSHW projects are less specific in terms of their agenda. Prototypes and kits provided by services such as Adafruit[16] and Sparkfun Electronics[17] in the US, Seeed Studio in China and various hackerspaces around the world often serve educational and entertainment purposes. Indirectly, however, they connect politics with design by creating conditions for the public of tinkers to take on new challenges. OSHW tools and kits help amateurs learn how sensors and basic electronic components work, in order to customise existing products and to eventually build prototypes that tackle various issues - from health to environmental monitoring, prospecting and building independent infrastructure.

That is the case of the "Open Source Ecology" (OSE) project – a network of farmers, engineers, and supporters building the Global Village Construction Set. Their "Global Village Construction Set" (GVCS) prototype applies open source hardware to support sustainable and autonomous communities anywhere around the world: a "modular, DIY, low-cost, high-performance platform that allows for the easy fabrication of the 50 different Industrial Machines that it takes to build a small, sustainable civilisation with modern comforts."[18] The GVCS prototype is an object, but also a medium for rethinking the future of agriculture and sustainable communities. It helps tinkers and farmers around the

[14] Available on: http://www.kanarci.cz/ . Access on: June 7, 2015.

[15] Available on: http://www.libelium.com/ . Access on: June 7, 2015.

[16] Available on: http://www.adafruit.com/ . Access on: June 7, 2015.

[17] Available on: https://www.sparkfun.com/ . Access on: June 7, 2015.

[18] Available on: http://opensourceecology.org/ . Access on: June 7, 2015.

world to discuss and deliberate upon the future of their own local communities, but also the global society.

OSE is building the tools and the community and, in parallel, it is also testing them at their "Factor e Farm" (FeF) in rural Missouri. The FeF site is an experiment that "aims to take everything that civilization has learned to date, to create a working blueprint for communities that work" (Ibid.). The whole project has split up into parallel efforts that have become an international network or "science diaspora". The Open Technology Forever project combines a Spanish-based mapping app for sharing environmental data with a US-based open hardware factory to include a patented pesticide sensor from Singapore. It aims at integrating them in a crowd-sourced open beehives project responding to yet another global crisis.

OSHW assists the technologically savvy global public in tackling local and global challenges and in testing potential futures rather than simply discussing issues or delegating decisions. OSHW is a technological platform for collaboration and prototyping that influences both policy and design, politics and technology. It enables public participation and global engagement in various issues through collective tinkering that is not bound to any immediate patent rules or geopolitical interests. The informal collaboration between a global group of hackers, makers and experts together with citizens and amateurs takes place both online and offline through workshops and its main function seems to be to involve more actors at such grassroots level.

The radiation monitoring efforts showed that, by teaching volunteers to connect Arduino boards with sensors and electronic components and, later, by simplifying this through custom-made PCBs and kits, we could empower various groups to obtain independent data and to make decisions and engage with politics on this infrastructural and material level. The whole OSHW process of design, distribution, customisation, learning and prototyping, encourages citizens and amateurs in projects such as Open Technology Forever to take an active part in and interact at every step of the R&D process with experts, policy makers and industry players.

GEEK DIPLOMACY

OSHW presents an interesting challenge to the idea of the public sphere because it enables people to use and build new tools, apps, and hardware as well as change the social and technical conditions and limits while discussing the issues that are important to them (environmental, monitoring, sustainability, cheaper energy, etc.) Action and reflection, deliberation and transformation are closely tied and normative regulations are formed while building and testing the tools. The public sphere built on OSHW is not just a condition for free deliberation, but something literally "built" and formed through tinkering with tools. The ability of hardware to create such assemblages through which people collaboratively resolve matters of mutual interest and insist on further opening various patented technologies while working on the rules of their use is clearly expressed in the "statement of principles" of OSHW: "Open source hardware is hardware whose design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design. The hardware's source, the design from which it is made, is available in the preferred format for making modifications to it."[19]

These calls for open source technologies as tools of empowerment go back to the famous slogan "Access to Tools" of the "Whole Earth Catalog" (WEC) published by Stewart Brand between 1968 and 1972 to define radical politics through a set of products and tools that enable autonomy, self-sufficiency, ecology and a "do it yourself"

19 Available on: http://www.oshwa.org/faq . Access on: June 7, 2015.

(DIY) approach to resolving various local and global problems. This famous slogan of the American counterculture inspired not only the emergent technological entrepreneurship in the Silicon valley, but even development efforts in the 70s Papua, where a famous "clone" of the catalogue was published under the name Liklik Buk and inspired the permaculture movement which is now global. With the current OSHW tools, we are in some sense repeating this cycle of rethinking technological and political empowerment with Stuart Brand. What is specific about today's efforts is that they involve science more directly such as DIYbio (Do-It-Yourself biology) efforts (KERA, 2012; KERA, 2014)

Community-based science and technology efforts such as DIYbio embody a variety of definitions regarding "open" and "collaborative" science (GACEK; ARIEF, 2004; LERNER; TIROLE, 2005) and sometimes relate to tools, community rules, norms and licenses or simply to the participants described as "geeks, "hackers" and "makers". This simply includes any citizen-scientists, designers, engineers, activists willing to engage, share, learn, and teach in an "open" environment. The unavailability of laboratory equipment in the Global South perpetuates stereotypes related to knowledge production which we view as centred in the North. The "development decades" following World War II supporting the idea of technology transfer only embraced the neoliberal policy and created even worse inequality and dependence on the West for scientific knowledge and research (MOORE et al. 2011; KIHARA, 2010). With the OSHW model for open science, we can finally question the deficit model of science communication and the whole idea of technology transfer rooted in the unreflected colonial views of the Global South as recipient of science knowledge leading to development (BYERLEE; FISCHER, 2002; FORERO-PINEDA, 2006).

The discussions about science in the Global South perpetuate a form of "epistemic violence" (SPIVAK, 1998) that defines technologies and science as things that are always transferred and applied in the developing countries with the help of various donors, corporate responsibility programmes or other innovators from the "west." The efforts around building open laboratory equipment in Yogyakarta support and recognize the agency of actors at the local level who can question the technology transfer rhetoric. Community-based and open science involve a variety of actors within unique open science networks (HOLMGREN; SCHNITZER, 2004) and explore the possibility of open science in a postcolonial context. While agreeing with Spivak that the "subaltern" maybe cannot research and innovate (speak), we still see evidence that they dare question what research and innovation mean in the present economic and political crises and in the postcolonial context.

Discussions about the "public sphere" in Media studies (LUNT; LIVINGSTONE, 2013) or about "public participation and deliberation" (CANINI, 1994) in Science, Technology and Society studies (STS) are important points of reference for formulating the emerging geek diplomacy and the aspirations of a postcolonial open science. They contrast two very different views of the political role and governance of technologies, which we can question in the case of OSHW. In the STS field, we are discussing how to support the public on deliberating upon various technologies which are seen as an object of policy decisions.

In communication and media studies, technologies are means rather than objects of public deliberation. The public of tinkers and the geek diplomats have elements of both. They relate to technologies as objects and as means of citizen participation and deliberation. To this we can add a third function - "hacking" and modifying technology to support communities. They are not only objects or media, but also something that is designed by citizens themselves to empower them to define the role of technology in their society.

The ontology behind this attitude is close to recent materialist positions that claim that non-human agency should be defined not as a pure fact or an objective reality, but in terms of actors with whom we negotiate interests and relations, and actively co-create our future (HARMAN, 2009; HARMAN, 2002).

The intricate connections between society and technology based on these new materialist and realist positions lead us to define regulation and policy as experimental design. Technologies as new actors with agency need to be integrated as much as deliberated over and negotiated with. In this sense, the OSHW enables technological empowerment which is material, discursive and social. It produces a new metaphysics, but also a politics of prototypes whereby we express our political values and insights by building and cooperating over new tools. The emergent public of tinkers and geek diplomats view the political ideal as something we need to co-create and design rather than embody like some true nature of our soul or society.

CONCLUSION

We are at a moment in history when we are opening and democratising not only public discourse and political processes, but also technical protocols, standards and, even, technology. This enables science and further R&D. This opening is discursive and material at the same time, because we are building open hardware laboratory infrastructure while discussing the role of science in the Global South and the value of open science as a reform in the North. The public of tinkers and geek diplomats who are already using these tools for various interventions in microbiology, but also in agriculture and environmental monitoring, form their own global networks and "science diasporas". The challenge for the future is to support more citizens in building OSHW tools as a way of self-regulation or deliberation or even testing of a certain technology. The well-known examples of OSHW such as Arduino boards (a microcontroller development platform) or the original MakerBot Replicator (a 3D printer) enable individuals and communities to design, deliberate, and negotiate their needs and interact with various stakeholders over an issue. OSHW is a symptom of our changing attitudes towards technologies which involve questioning and rethinking the relations between producers and consumers, citizens and regulators, and the emergence of a new type of technologically savvy public. OSHW encourages individual and collective involvement with technologies combining political and ontological commitments. In this respect, it is close to some recent views of agency in Actor Network Theory (ANT), cosmopolitics, speculative realism, new materialism and object-oriented ontology which rethink politics in relation to objects and processes outside the narrowly defined social sphere and human agency.

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8

Open science: from hypertexts to hyperobjects

Rafael Peretti Pezzi

INTRODUCTION

Participants of the open science movement argue that for science to function appropriately and result in due benefits for the whole human population, it is essential to guarantee free access to operational details of scientific practice, such as free access to open scientific journals (open notebook science), open data, publishing of font codes of scientific software (open code manifesto) and universal access to scientific publications and corresponding data (open access, Panton Principles). The thesis defended here states that there are additional elements of scientific practice which may be shared in more detail in order to achieve the presumed benefits. These elements correspond to the operation, use and construction of scientific apparatus and the tools used for their creation and development, that is, the documentation related to the development and use of scientific equipment and its applications. The availability of this documentation seeks to encourage and in some cases even enable the reproduction of scientific experiments, improving the mechanisms for dissemination of scientific knowledge and its applications. One of the mechanisms for this dissemination will be the use and study of those equipment in technical and higher education.

In order to sustain the suggestions presented in this chapter, some parallels will be drawn between the free infrastructure that led to the advent of the World Wide Web for the creation and communication of multimedia content and the creation and communication of content which results in the conception of material elements, specifically scientific instruments. This analogy is convenient because the WWW appeared as a set of standards and tools made available for the public domain by a major scientific laboratory[1], the European Organization for Nuclear Research, known as CERN (former acronym for the Conseil Européen pour la Recherche Nucléaire), which enabled the construction, publication and access to hypertexts for purposes of optimizing scientific communication. That proved to be important not only for science in isolation, but also for society as a whole, taking us to a new information era.

Informatics, besides increasing access to data, texts and graphs, enabled the sharing of codes so that numerical analysis and scientific simulations could be carried out. Following this tendency, one may think about the next step in informatics as a structure to facilitate the conception, sharing and production of material objects, such as scientific apparatus. With that, we get to the conception of an open infrastructure for the construction of scientific hyperobjects. Such infrastructure encompasses free tools for digital design, study and production such as CAD (Computer Aided Design, CAMs (Computer Aided Manufacturing) and CNC (Computer Numerical Control) machines.

Henceforth conceptual aspects which fundamented the WWW will be approached, taking the hypertext as the basis for the construction of the concept of hyperobjects. Next, the technical

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1 The software that drives the WWW was put into public domain by CERN on April 30th 1993. Available on: http://home.web.cern.ch/about/updates/2013/04/twenty-years-free-open-web. Access on: April 2nd, 2014.

and legal aspects which enable the free flow and use of traditional scientific content and how they may be extended to hyperobjects are explored. Finally, elements of an ideal infrastructure for the creation, sharing, modification and materialization of scientific hyperobjects and their applications will be proposed.

Non-rivalry of knowledge

Non-rivalry is one of the basic properties of knowledge and its representations which are effectively and successfully explored in many hypertexts on the WWW.

> The term comes from economics: a rival is that asset or resource whose use by someone prevents (or competes with) its use by someone else. Material assets are always rival: my use of a chair, an apple or a book prevents (or competes with) the use of those same objects by another person.
>
> A non-rival asset or resource, on the other hand, is that which admits simultaneous uses which do not compete among themselves." ... "like ideas, computer programs, works of art and scientific or cultural work – are, in general, non-rival. (SIMON, 2008, p. 16)

It is this non-rivalry which permits that hyperlinks which are present in hypertexts and their contents may be used simultaneously by a large number of people. Different from material assets and objects, knowledge or digital objects does not require exclusive use and their availability is not diminished by use. In practice, their use is non-rival.

When we deal with physical objects like scientific instruments, their uses are evidently rival. Two people cannot use the same scientific instrument in order to carry out two experiments simultaneously. However, the knowledge and digital representations related to any physical object, like scientific instruments, are non-rival and may be used for the construction of two similar pieces of equipment. The thesis presented here suggests qualifying and systematizing the organization and publication of digital information related to scientific objects in order to obtain the full advantage of their non-rival aspects. This potential may be effectively used not only for purposes of reproduction and study of instruments, but also for their development and adaptation. The full use of this potential is becoming evident through the advances and cost reduction of personalized manufacturing equipment, such as 3D printers and open source milling machines (PEARCE, 2012). The same non-rival characteristics are also enjoyed by scientific free software, generally based on free and open source compilers and programing language, enabling the free sharing of codes and their use and reuse.

COGNITIVE ECOLOGY: FROM ORAL COMMUNICATION TO HYPEROBJECTS

Throughout history, the appearance of new forms of communication has been observed: oral tradition, written language, printing, informatics. The appearance of each one of them alters human culture significantly by altering the forms of knowing and learning. With respect to science, the reflexes of writing up to the printing age can be well identified; however, the implications of informatics are still being assimilated (LEVY, 1993; NIELSEN, 2012).

Informatics, through the largest hypertext system existing nowadays, the World Wide Web, and of other computer programs, has made available a means of support and transmission of knowledge whose properties are closest to those of human cognition, of our intellectual potential: the thinking, the ideas, language and communication are fluid, they transform and adapt themselves, and propagate with or without modifications, naturally. Pierre Lévy presents the hypertext as a symbol of the connectivity between the representations in the context of the informational era. Besides that, Lévy describes the potential of communication tools according to the concept of cognitive ecology:

> The ecological environment in which representations propagate is composed of two big groups: the human minds and the technical networks for storage, transformation and transmission of representations. The appearance of intellectual technologies like writing or informatics transforms the environment in which representations propagate. (LEVY, 1993, p. 84)

It is clear that the success of the propagation of representations of knowledge is directly dependent on intelligible standards of representation for the parties concerned, of which a language is an example: the existence of a common language is the essential standard for the efficient direct propagation of knowledge among individuals, be it through written or spoken words. When the exchange of information is mediated by instruments such as computers, digital standards which specify electric signals and binary codes must be precisely defined and implemented so that information may be exchanged between devices. In addition, the fact that technical implementation is associated with permissive licensing practices, establishes the fundamentals of cognitive ecology based on the dissemination and use of knowledge, its representations, its applications and its evolution (see the *Legal and technical issues* section of this chapter). In other words, the true potential of the WWW cognitive ecology is revealed when legal and technical aspects are orchestrated in such a way as to permit new forms of information generation and access like, for example, Wikipedia. We will then search for something similar which shall be used as a referential for the construction of objects whose information and potential for materialization and use are organized and accessible in analogous form to hypertexts – here referred to as hyperobjects.

Hypertexts

> *Hypertext* is a term which refers to a text to which other groups of information are added, in the form of blocks of text, words, images or sounds, to which access is granted through specific references called – in digital media – hyperlinks, or simply, links. These links appear in the form of identifiers highlighted in the body of texts, graphic icons or images, and have the function of interconnecting the different groups of information, offering on demand access to information which extends or complement the main text. (WIKIPEDIA, s/d).

Hyperlinks have the function of "offering on demand access to information..." That is to say, it is expected that the path of a hyperlink provides access to the desired information. In case the information is not available or is unintelligible, the link may be considered to be broken, and has then little or no value. If the pointed content is codified in a nonstandard manner, it will not be legible for users. On the other hand, if it is available under permissive licensing terms, such as some Creative Commons licenses, which is the case of Wikipedia, the value of that content is even higher to whoever may access it, given the possibilities of reuse.

In relation to scientific research, the World Wide Web had its origin in the need to find a means of speeding up the way in which information was shared among scientists, that is, to bring more dynamism to scientific collaboration. In 1993, the CERN put the WWW programs in the public domain[2] in order to maximize their dissemination, given that Tim Barners-Lee, project leader,

[2] Available on: http://home.web.cern.ch/about/updates/2013/04/twenty-years-free-open-web. Access on: April 2nd, 2014.

had conceived it to meet the demand for exchange of information among scientists, universities and institutions all over the world[3].

Applying the concept of cognitive ecology to the case of hypertexts, not only is language needed for the efficient propagation of representations: additional WWW standards are also essential, and must be implemented with precision among hypertext editors, web servers, browsers and network communication protocols so that browsing hyperlinks is possible, with the guarantee of "on demand access to information which extend or complement the text". The merit of CERN was to have created and integrated basic elements necessary for make such browsing possible, and acknowledging its value, to launch them publicly and permit their universal adoption, like any language. Nowadays we live in a highly connected society where the hypertext is a familiar representation thanks to the popularity of the World Wide Web.

Hyperobjects

Having realized that the hypertext transcended text in its forms of representation of knowledge, we may use the concept to understand the transformation of objects into hyperobjects:

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[3] In this context, it is easy to perceive that broken links in hypertexts are an impediment to the advancing of research or studies. In a current scientific article, these hyperlinks indicate supplementary materials as well as bibliographical references – other scientific articles – all of them essential for the evaluation, validation and reproduction of the research objects of the scientific article. We notice then that inaccessible references, indicated by hyperlinks in scientific hypertexts, are indicative of broken hyperlinks. In many cases, the scientific hypertext will only be valid (without broken hyperlinks) for those who subscribe to the scientific journals mentioned or have the means to purchase individual references. The purchasing of individual references may easily reach hundreds of thousands of dollars, to cover all references of a single scientific article. Thus, the open access move may be understood as a natural reaction of a society which acknowledges the advantages of hypertexts in relation to conventional texts and considers the systematic existence of broken links in scientific hypertexts not only frustrating but damaging.

> Hyperobject is the term which describes an object to which are added actions and/or sets of information in the form of code blocks, texts, words, images, sounds, functions and actions, to which access is granted through specific references called, in the digital media, hyperlinks, or simply links. These links appear in the form of identifiers highlighted in the object or in its representations in the form of texts (tags), graphic icons or images, and have the function of interconnecting the different groups of information, offering on-demand access to information which extend or complement the hyperobject. (Adaptation of Wikipedia, s/d)

In fact, an object my become a hyperobject by making available hyperlinks which provide more dynamic access to what is known or is relevant about that object in each context. For example, a domestic appliance may be considered a hyperobject when information such as a users' manual, the technical support network or spare parts and accessories vendors may be easily accessed, either through hyperlinks present in the physical object, like a bar code, QR codes, or through digital interactive representations like augmented reality.

In the scientific and educational spheres, the interest resides in hyperobjects whose links show information such as theoretical, digital or mathematical models of the object, use and maintenance instructions, applications, codes and software and firmwares (programs embarked in the object). Actionable hyperlinks may also be used, giving access to functions or actions of the object, or hyperlinks to digital representations which facilitate its materialization, physical or mechanical simulations and their transformations. Hyperobjects may contain different levels of detail according to their objective and context. Scientific and educational applications of hyperobjects are ideal models given that for those the omission or clouding of information are not desired, on the contrary, can be accompanied by all known information that facilitates the reproduction of the object, its study and its transformation.

HYPERINSTRUMENTS IN PRACTICE

The development of hyperinstruments, as proposed here, requires the consolidation of technical and legal aspects, and good practices which allow those to enjoy the non-rival possibilities analogously to those of hypertexts. The models of development of free software and free content, such as respectively, Kernel GNU/Linux and Wikipedia, are the starting points for the construction of hyperobjects, where technical and legal aspects already stablished enlarge their possibilities of use, but also considering new material characteristics.

Technical and legal issues

In order to guarantee the sustainability and broad adoption of the cognitive ecology of hyperobjects, technical and legal elements must be satisfied. It is expected of this cognitive ecology that access to the contents shown by the hyperlinks is free, and that these contents in turn, enjoy the non-rival properties of knowledge so that they may be used, studied, modified and distributed. Thus, hyperobjects may be modelled and transformed with the full potential of digital tools and of the human minds.

Data format, computer programs and digital manufacturing machines

The action of navigating through hyperobjects and the action of transforming them, even if digitally, be it by the creation of new hyperlinks or by the alteration of existing ones, requires the integration of two aspects: i) the implementation of open standards for data stored in computer files and communication protocols and ii) the use of free and open source tools, software and digital manufacturing devices which allow access and modification of the content of hyperlinks through the interpretation of computer files and of communication protocols and their execution/materialization. In relation to the first category: "An open format is a published specification to store digital data, usually kept by a non-proprietary standards organization, and free from legal limitations for its use."[4].

Some open formats are already well defined for texts, multimedia materials, programming languages, data storage and data banks, allowing the sharing and use of good part of the content with scientific interest. However, there is still a big gap in terms of the format of pertinent data for hyperobjects which have not been defined as open standards or which need validation for technical and scientific precision applications. Among those, it must be highlighted the lack of at least one open format for the description of tri-dimensional objects and their properties for purposes of study, design, construction and simulation or scientific instruments[5]. The materialization of objects in digital representation will be covered in the section on *Infrastructure for hyperobjects*, next in this chapter.

In relation to software, their use corresponds to the operational part of the scientific methodology implemented through the use of computers. The use and evolution of these programs are essential for the advancement of science and the access to software source-code is considered, by adepts of open science, a premise for the process of validation of scientific publications which use them[6].

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4 Available on: https://pt.wikipedia.org/wiki/Formato_aberto. Access on: October 26, 2014.

5 There are open standards for 3D objects like the AMF (Additive Manufacturing File Format) and X3D, however their applications for scientific precision CAD and implementation in free CAD software for use in hyperobjects is still open. Available on: https://en.wikipedia.org/wiki/X3D and https://en.wikipedia.org/wiki/Additive_Manufacturing_File_Format. Access on: October 26, 2014.

6 Available on: http://sciencecodemanifesto.org/. Access on: October 26, 2014.

To the same effect, CERN, in technical communication on Technology of Information drawn by a task force for the licensing of software, recommends that:

- whenever possible, software under CERN property, in the whole or in part, must be made available as free software;
- all free software licensed by CERN must use licenses approved by the Open Source Initiative (OSI) [7].

Following those principles, CERN and Fermilab, another high-energy physics laboratory, contribute for the development and maintenance of an operational system and support programmes for scientific research called Scientific Linux[8]. Similar initiatives may be found in Nasa (the National Aeronautics and Space Administration)[9].

On the other hand, there are also scientific media where scientist's routine tasks, such as arithmetic operations, numerical calculations, creation of plots and graphics and text editing are carried out in large part by proprietary software despite the fact that there are a number of quality free software available for the same purposes. The use of proprietary software creates barriers for the dissemination of scientific practice through society, for example, limiting the scope of university teaching and extension activities. As a consequence, the use of proprietary software in the academic sphere reduces the offer or the relevance of teaching and extension activities which involve the use of computers. Thus, the dissemination of academic knowledge and its application outside research groups, be it in schools, popular communities of in the

7 Final Report of the Open Source Software Licence Task Force CERN; CERN-IT-Note-2012-029; Jan, 2012.

8 Available on: https://www.scientificlinux.org/

9 Available on: http://ti.arc.nasa.gov/opensource/ The NASA free software license cannot be considered free software, given that it does not allow the integration of these programmes with codes/programmes from third parties.

industrial/technological environment is limited to those who have access to the software used[10].

Licensing of hyperobjects

So that we may enjoy the non-rival aspects of hyperobjects, according to the intellectual human abilities associated to the possibilities of digital technologies, it is necessary that, in addition to the access to the content pointed by each hyperlink and the availability of the necessary tools to access them, we need the authorization which allows their use, study, modification and distribution. For that, the content must be available in accordance with the definition of open knowledge[11], the definition of free software[12], and the definition of free hardware[13], for each type of category of information to be used.

Nowadays legal issues are fundamental aspects of scientific and educational practice. The diversity of regulations and jurisdictions result in great difficulty for scientists and educators. They encompass elements of intellectual property laws which fall into two categories: i) copyright and ii) industrial property, and merit some clarification.

The first aspect comprehends intellectual, artistic and literary work, and software. They may be classified as Software Licenses and Content Licenses. Over the last decades, specialists and organizations have distinguished forms of licensing for the different licensing categories, creating a legal framework for the creation of

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10 It must be pointed out that,unfortunately, access to proprietary software frequently happens illegal copies, propagating a concealed habit of undue use of proprietary software through piracy.

11 Available on: http://opendefinition.org/od/1.1/pt/. Access on: October 14, 2014.

12 Available on: https://www.gnu.org/philosophy/free-sw.html. Access on: October 14, 2014.

13 Available on: http://www.oshwa.org/definition/portuguese/. Access on: October 14, 2014.

hyperobjects[14], allowing for an intelligible licensing ecosystem and also allowing the remixing and combination of objects. Table 1 presents a timeline of the first licenses of free software, content and hardware and their authorship.

Table 1: Timeline of free software licenses, free content and open hardware and their copyright

Year	License target	License name	Origin / Author
1989	Free Software	General Public Licence (GPL)	Free Software Foundation Richard Stallman
2002	Content in general	Creative Commons	Creative Commons / Lawrence Lessig
2007	Open Hardware	TAPR Open Hardware Licence	Tucson Amateur Packet Radio / John R. Ackermann

Source: Author's creation.

Software and content licensing are part of cognitive ecosystems which encompass the technical and legal aspects which allow their sustainability, like the examples taken from Wikipedia and the operational systems GNU/Linux. Free and open hardware projects started out being licensed with the same kinds of licenses for software and content as Arduino's. However, as equipment manufacturing is ruled by the industrial property regime, free software and content licenses like Creative Commons are not entirely appropriate for those. Thus, open hardware merits specific licenses.

[14] The FSF – Free Software Foundation keeps a page with comments on several software licenses and other types of content. Available on: https://www.gnu.org/licenses/license-list.html. Access on: October 14, 2014.

Open hardware licenses

Recently there have been discussions on hardware which offer users the freedom of use, study, modification and distribution – the freedoms defined to free software. The debate on open hardware started among hobbyists [Ackermann 2009] and resulted in the publication of the Open Hardware License TAPR in 2007[15]. Nowadays, the main market for open hardware is that of amateurs and DIY (do it yourself). Science and education may benefit from the adoption of these principles, given that these are aligned with their purposes of advancing and disseminating knowledge. This movement received a big push with the launch of CERN's Open Hardware License.

CERN's Open Hardware License.

In March 2011, CERN launched version 1.0 of CERN's Open Hardware License, and the latest version – 1.2 – was published in September 2013. At the initial launch, CERN's public communication reveals the following:

> In the spirit of knowledge and technology dissemination, CERN's Open Hardware License was created to govern the use, copying, modification and distribution of hardware design documentation and manufacture and distribution of products. Hardware design documentation includes schematic diagrams, designs, circuits or circuit-board layouts, mechanical drawings, flowcharts and descriptive texts, as well as other explanatory material. [16]

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[15] TARP OHL- Tucson Amateur Packet Radio Open Hardware Licence. Available on: http://www.tapr.org/OHL. Access on: October 24, 2014.

[16] Available on: http://press.web.cern.ch/press-releases/2011/07/cern-launches-open-hardware-initiative. Access on: October 24, 2014.

Nowadays, CERN's Open Hardware License has been used for the publication of several scientific, educational and industrial instruments. A good sample of these equipment and their applications can be found in the open hardware repository[17] and in projects from the Public Laboratory for Open Technology and Science (PLOTS)[18].

Good practices

In addition to the technical and legal issues mentioned, success in the dissemination of hyperobjects depends on practical elements that may facilitate or even allow their utilization: the quality of their documentation. We may draw a parallel between the navigability of a website and its layout, its organization. The content may have been covered, and its license may be appropriate, but the presentation of content and its hyperlinks affect the experience of someone who uses a website. The need for special software to grant access to elements which do not follow predefined standards is also impeditive for the adequate use of content. This is the reason for the existence of organizations which define standards, like the W3C (World Wide Web Consortium), responsible for maintaining the HTML – Hypertext Markup Language standard.

Likewise, the navigability of a hyperobject is affected by the disposition of hyperlinks, by the content they refer to, by the way content evolves through time, and by the ease of participation in this evolution. This is a question of organization and documentation of hyperobjects, in short, of good practices.

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17 Available on: http://www.ohwr.org – Open Hardware Repository. Access on: October 24, 2014.

18 Available on: http://publiclab.org/. Access on: March 31st, 2014.

Good examples of these good practices, which serve as a reference, are the free software and open content and hardware projects which use methodologies in which the concept of hyperobjects may be immediately applied, and which are inspired by them. These projects usually use:

- free and open development tools;
- version control;
- public access repositories;
- documentation wikis;
- users and developers' forums and e-mail lists;
- bug tracking systems.

The development of the GNU/Linux kernel[19], Wikipedia[20] and the self-replicating RepRap[21] printer are exemplary cases. Familiarization with the tools used in these initiatives for the use and recycling of codes, data and scientific instruments is of growing importance to scientific practice. Scientific practice in collaborative methodologies should be stimulated in the new generations of scientists, engineers, technicians and teachers[22]. With that aim, participants in the Academic Technology Centre of the UFRGS (Federal University of Rio Grande do Sul) have created and maintain a standard model for project documentation which suggests specific sections on documentation for development and use, in addition to educational applications[23].

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19 Available on: https://www.kernel.org/. Access on: October 24, 2014.

20 Available on: https://www.wikipedia.org. Access on: October 24, 2014.

21 Available on: http://reprap.org/. Access on: October 24, 2014.

22 Version control with git, wiki texts with Media Wiki or others must be highlighted.

23 Available on: http://cta.if.ufrgs.br/projects/suporte-cta/wiki/Modelo_de_Documentação_Padrão. Access on: February 20, 2015.

Infrastructure for hyperobjects

New cognitive ecologies appear when the elements for support to storage, transmission and processing of knowledge and its representations are adopted by a critical mass capable of using and benefitting from them. The infrastructure of cognitive ecology, beyond merely existing, must be available and be adaptable in order to be disseminated, and so as to be sustainable and of benefit to humankind as a whole.

We have mentioned the issue of the infrastructure made available by CERN for the creation of the www: means capable of creation of hypertexts, their publication and navigation. Within a simplified approach, we may say that the technical infrastructure that made viable the cognitive ecology of the free software was a combination of a free text editor and a software compiler which was also free. Those enabled the development and dissemination of computer codes which evolved to become the operational system GNU/Linux and many of their software.

Free software are essential for the creation of free hyperobjects. However, because they are intangible or non-rival, they are not sufficient to base the cognitive ecology of hyperobjects, which include their materialization through instruments of personalized manufacturing. We will call a basic infrastructure prototype for the creation and navigation of hyperobjects an OpenSource Workbench.

Open Workbench

The Open Workbench presented here consists of a group of minimum low cost instruments capable of creating scientific and educational hyperobjects. These open hardware and free software tools make viable the creation of workflows from the conceptual description of the project to the materialization of instruments by digital manufacturing machines[24]. The workbench itself is composed of hyperobjects.

The Open Workbench also aims at contributing to the educational qualification, and may be used in two ways. More directly, by its application to the reproduction of scientific and educational instruments available in online repositories. A set of files ready to be sent to digital manufacturing machines of the workbench is obtained on the internet and used for the manufacturing of parts of the instrument at stake, which is then assembled and used. The second form of utilization of the machines consists in the very study of the machine and its evolution. Professors and students in the areas of engineering, science and other technological areas are able to know the basic elements of machines, the parts of machines and their programming. In both cases, besides cultivating the curiosity and interest of students of all ages, the creative potential boosted by familiarization with digital manufacturing demystifies technological development and empowers individuals who change from a passive role (consumers of finished products) to that of active agents, of technology developers.

Digital Manufacturing

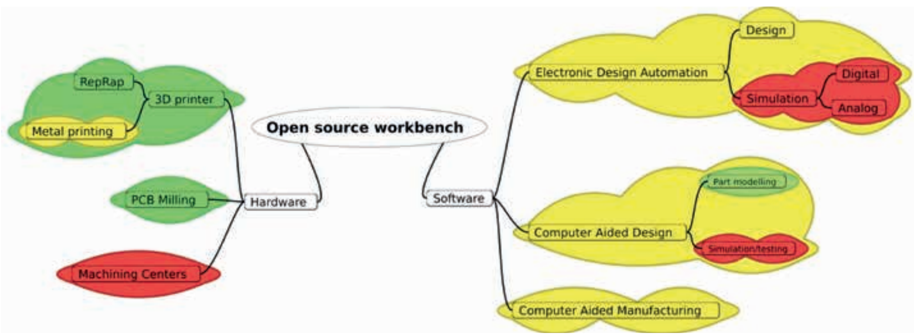
Digital manufacturing or *personalized manufacturing* consists of the materialization of objects from drawings and digital representations using computer numerical controlled (CNC) addition or subtraction of materials with a view to obtaining a

[24] There is a complementary initiative to the Open Workbench called Replab, created by Open Source Ecology. The open workbench does not compete with Replab given that the latter aims at creating instruments which are heavier than those proposed for the Open Workbench. Both share similar values and complement each other. Available on: http://opensourceecology.org/wiki/RepLab. Access on: October 24, 2014.

material object with the desired characteristics. The following methods of digital manufacturing may be mentioned:

- Additive manufacturing (3D printing):
  - Thermoplastics (polymers) printing
  - Metals printing
  - Printing from powder (ceramics and metals)
- Subtractive manufacturing:
  - CNC milling machines and lathes
  - Electrical Discharge Machining – EDM
  - Laser and plasma cutting machines
  - Machining centres

Figure 1 - Map of the Open Workbench in March 2015.



Green: available as open source technology; yellow: open project under development; red: inexistent open tool or needs important elements for spread of its use: lacks user-friendly interface or documentation.

Digital manufacturing became popular with the launch of the RepRap project, initiated in 2004 by Adrian Bowyer, in England (JONES et al., 2011). RepRap started a series of open source 3D printers (CANO, 2011) which proved to be capable of reducing in up to 8 times the cost of scientific instrumentation (PEARCE, 2012), not only demonstrating new potential for the creation of scientific experiments, but also extending access to laboratory equipment and facilitating their adaptation and maintenance. The works of Jones and Pearce (JONES et al. 2011; PEARCE, 2012) showed the potential of digital manufacturing for the cognitive ecology of hyperobjects and their application for open science and education. However, given the limitations of open and low cost machines currently available, it can be said that open source digital manufacturing is still in its infancy, but in full development, thanks to the enthusiasm of academics and non-academics.

One of the bottlenecks for digital manufacturing lies with the limitations of free and open tools available for computer-aided design (CAD) and for hardware manufacturing, the latter practically limited to plastic objects. Another limitation is associated to the physical-chemical and mechanical properties of polymer plastic parts, given that for them to be appropriate for use in the most diverse contexts, be it by force of temperature, pressure or wear and tear, there is also a need for the creation of specialized instruments using metals, minerals and special ceramics.

As important as low cost digital manufacturing equipment are the free software tools for the design, visualization, electronic simulation, mechanical and geometric assembling of the parts and instruments to be constructed with these devices[25], as shown in the yellow and red regions of Figure 1.

One of the most recent elements added to the list of low cost digital manufacturing machines consists of a milling machine for printed circuit boards.

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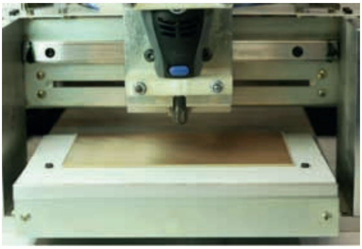
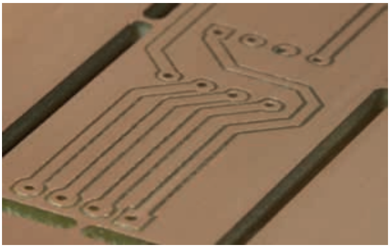
25 Many advanced functionalities may be found already implemented in free software. However, the quality of these software is way below those proprietary equivalents, given that the first lack integration, present non-intuitive user interfaces, high bug rates and difficulties for learning how to operate.

Furnarius rufus Milling Machine

The Academic Technology Centre of the Physics Institute of the UFRGS (Federal University of Rio Grande do Sul), is engaged in the development of elements for the Open Workbench. Their first contribution consists of the creation of an open machine for the prototyping of printed circuit boards, the Furnarius Rufus Milling Machine, created by engineer Germano Postal. Their first functional prototype was launched in September 2014 under the terms of the Open Hardware License from CERN version 1.2[26] (see Figure 2). This initiative aims at reducing the cost and the barrier for the prototyping of printed circuit boards for scientific and educational purposes, through an instrument which is easy to manufacture and adapt. The project got its name after the bird *João-de-barro, or Rufus Hornero*, with scientific denomination Furnarius rufus, which builds its nest using clay, in a very similar manner to modern additive digital manufacturing machines, like 3D printers.

Figure 2 – Furnarius rufus milling machine – ready for machining (left) and the result of machining for the construction of a shield engraver for microcontroller AVR ATtiny for Arduino (right).





[26] Available on: http://ohwr.org/cernohl. Access on: September 24, 2014.

The Furnarius rufus Milling Machine project has the following aims:

- Low cost (~US$1000) for the parts;
- High precision: able to prototype conventional circuit boards (through-hole) and SMD circuits;
- Easy to assemble: most parts may be assembled with workbench drills, metal sheets cutting and bending, available as services in major cities.

Project documentation

In order to guarantee wide dissemination through a community of users and developers, the Furnarius rufus Milling Machine project is being documented in detail to include information on each one of the parts of the machine, in printing formats (pdf) and CAD (dxf) [27]. The repository also contains descriptions of how each part was constructed in the first prototype. The project documentation may be found on the site of the Academic Technology Centre[28] and its version in English for the international community, in the CERN[29] Open Hardware repository. At the time this article was written, the first prototype of the PCI Furnarius rufus Milling Machine had been created and the repository already contains the diagrams of each one of the mechanical parts of the machine, in addition to a step-by-step guide for its use, based entirely on free software.

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27 Given the lack of appropriate free software, the milling machine was projected on low cost proprietary CAD.

28 Available on: http://cta.if.ufrgs.br/projects/fresadora-pci-joao-de-barro/wiki. Access on: September 24, 2014.

29 Available on: http://www.ohwr.org/projects/fr_pcb_mm/wiki. Access on: September 26, 2014.

Free software

The scientific and educational community already uses several free tools for the creation of texts, images and software, but lacks free CAD software for the creation and sharing of 3D objects and projects. An efficient intangible digital infrastructure is needed so that scientific and educational projects may reach their aims more easily, through the collaboration for the creation of instruments shared by all.

Some CAD software of scientific interest, divided into three categories are listed below:

- AEC – Architecture, Engineering and Construction
  - Software to aid the design of two or three-dimensional objects, of interest to architecture, engineering and construction. FreeCAD, LibreCAD, OpenSCAD, BRLCAD are some examples.
- EDA – Electronic Design Automation
  - Software to aid schematic design and electronic circuit boards. gEDA, KiCAD are examples of free software.
- CAM – Computer Aided Manufacturing

Software that codify the digital representation of parts created from a CAD for the control of additive manufacturing machines or machining. Printrun[30] and FlatCAM[31] are examples of CAMs for 3D printing and machining of printed circuit boards, respectively.

CAD – Computer Aided Design for AEC and EDA.

There is a variety of tools for computer-aided design (CAD) which are available as free software. The objective of this work is

30 Available on: http://www.pronterface.com/. Access on: October 28, 2014.

31 Available on: http://flatcam.org/. Access on: October 28, 2014.

not that of making a comparison of different tools[32], but it must be said that free CAD software available nowadays lacks advanced functionalities commonly found in proprietary equivalents. As a result of the gap between the level of usability and functionalities of free options and proprietary CAD tools, the use of proprietary software for the design of scientific instruments is current practice, including those considered to be open hardware[33]. Thus, open collaboration and sharing of scientific instruments design are rather limited, given that the cost of CAD tools may easily reach tens of thousands dollars per license. Universities and research centres invest millions every year in software licenses, an investment that could be directed to the development of free alternatives made available to everyone.

Electronic Design Automation (EDA)

There are a variety of free software for Electronic Design Automation – EDA. One of the options is Fritzing, an excellent starting point for beginners, since it presents a protoboard view in which the representation of components are identical to those, facilitating the familiarization with electronics, not to mention most usual visualizations such as circuit designs, in which components are represented by symbols, and circuit boards for the construction of connection trails between components. However, Fritzing is rather limited for advanced applications.

[32] There is na open initiative at Wikiversity for the collaborative evaluation of existing free CAD tools and for the inventory of essential functionalities in order to promote its development. Available in English and Portuguese. Available on: https://pt.wikiversity.org/wiki/Pesquisa:Ferramentas_livres:Desenvolvimento_de_CAD_Livre. Access on: September 1st, 2014.

[33] Like the electronic instrumentation design of the open hardware repositor maintained by CERN. Available on: http://www.ohwr.org. Access on: October 28, 2014.

The CAD software for EDA which is ideal for the cognitive ecology of hyperobjects must have advanced functionalities, at the same time in which it is easy to install and appropriate for beginners to start their learning of electronics given its simple circuit design and simulation facilities.

The current most promising CAD tool for advanced EDA is KiCAD. It is being developed by a community of collaborators, including researchers and developers linked to CERN, who noticed the importance of free software for collaboration in scientific instruments design[34].

One of the important functionalities still existing in CAD and EDA refers to the possibility of conducting circuit simulations in an integrated mode with users' interface. The simulation allows for the estimate of the circuit behaviour before its manufacturing/prototyping, reducing development time and waste of materials.

Potential of Open Workbench

Science and education share many of their fundamentals. Both efforts have the aim of improving and disseminating human knowledge in order to benefit society. The frontier between science and education is rather subtle. Postgraduate programmes, or of scientific initiation which involve undergraduate students or those in vocational education, or even initiatives of citizen science in the regular school, are examples of situations in which both areas are directly intertwined.

The adoption of scientific practices, methods and tools in the educational context has a clear benefit, given that it substantiates the application of that which is presented in the classroom

[34] Available on: https://giving.web.cern.ch/civicrm/contribute/transact?reset=1&id=6 . Access on: October 28, 2014.

and its developments. Tools for the creation, navigation and adaptation of scientific hyperinstruments may be immediately applied to the educational context. They enrich the concept of Open Educational Resources adopted by the United Nations Organization for Education, Science and Culture (Unesco) [35] in 2002. Open Educational Resources are "the teaching, learning and investigation materials in any kind of support - digital or others - which can be found in public domain or that have been disseminated under a free license which allows access, use, adaptation and redistribution"[36].

Access to a wide non-rival scientific infrastructure also reduces barriers for entrepreneurship, which are inspired in business models based on free software: consultancy, support, training, personalized development, as well as emerging business models for open hardware[37] (RAASCH, 2009; MERKEL, 2012), making the integration between science, education and entrepreneurship more natural.

Scientific and educational hyperinstruments

A scientific or educational hyperinstrument is a tool whose digital representations contain details which allow any interested person to increase their knowledge in the different aspects of the instrument, so as to guarantee its use, study, reproduction, adaptation and dissemination. In principle, information about scientific objects is not deliberately omitted, so that hyperlinks in

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35 Unesco adopted the concept of Open Educational Resources in 2002. Available on: http://www.unesco.org/new/en/communication-and-information/access-to-knowledge/open-educational-resources/. Access on: October 25, 2014.

36 Available on: http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/CI/WPFD2009/Portuguese_Declaration.html. Access on: October 25, 2014

37 Available on: http://www.openp2pdesign.org/2011/open-design/business-models-for-open-hardware/. Access on: October 26, 2014.

hyperobjects may point to theories, articles, findings and their data banks, manuals, user cases, repositories of parts and suppliers, manufacturing methods, maintenance guides, wikis, user groups, manufacturing tools. Table 2 presents a comparison between the use of hyperlinks in hypertexts and for scientific hyperobjects.

Table 2: Typical uses of hyperlinks in scientific hypertexts and hyperobjects.

	Scientific hypertexts	Scientific hyperobjects
Hyperlinks for	• Blocks of text: ▪ Bibliographical references ▪ Supplementary materials • Images (graphs, diagrams, photos and videos) • Software and scientific codes • Databases	• Digital representations ▪ CAD drawings ▪ Models: STL (3D), Gerber (2D) • Models, theories and manuals • Software, firmwares • Repositories of parts and suppliers • Instructions for manufacturing and assembling • Manufacturing tools • Use, maintenance and teaching guides • User groups: ▪ Wikis ▪ Applications

Source: Author's creation.

The hyperlinks of a hyperobject may be made available in different ways, such as:

- texts explicitly included in the material object. Example: the URL of a webpage;
- codes identifiable by image recognition software;
- html image map about one or more images in the object;
- hyperlink lists on html pages.

Examples of scientific and educational hyperinstruments

Scientific hyperinstruments are those which integrate the virtual and the non-virtual so as to facilitate their use, study, modification and distribution. There are several examples of instruments of scientific and/or educational interest which may be considered hyperobjects. Two examples will be mentioned here which contain elements of interest in several curriculum areas or transdisciplinary fields: the 3D RepRap printer from the University of Bath, and the Modular Meteorological Stations from the Academic Technology Centre of the IF/UFRGS.

☐ *The 3D RepRap printer*

The 3D RepRap printer is a project which originated in an English mechanical engineering school of the University of Bath [Jones 2011] whose repercussions go beyond the field of engineering, reaching diverse aspects of science and education, as well as of economics.

The RepRap is considered a hyperinstrument when we perceive that its hyperlinks allow its use, fabrication and modification. The RepRap and its derivations may be used for the creation of educational objects for children, for the study of geometry, mechanics and programming, as well as for materials science. It is a machine that allows for specialization in several areas of the curriculum, according to the interests and context of each person.

☐ *Open Source Modular Weather Stations*

The project of Open Source Modular Weather Stations of the Academic Technology Centre of the Federal University of Rio Grande do Sul[38] aims at integrating a network of climate and

[38] Academic Technology Center. Available on: http://cta.if.ufrgs.br. Access on: October 28, 2014.

environmental monitoring maintained and operated by citizens. However, the objective is not only the accumulation of data collected by citizens[39], but also the promotion of scientific and technological education so that the very construction of instruments, their programming, maintenance, development and calibration may be carried out by citizen scientists.

The project develops actions to integrate citizens to activities of scientific initiation and technological initiation based on free technologies [Silva 2014], including them in the process of measuring scientific quantities, sharing data and discussions on their repercussion. It invites each citizen to navigate in the scientific hyperinstrument and to better understand the environment in which they live.

This project seeks the consolidation of a teaching programme in science and technology based on a cognitive ecology in which tools are, as far as it is possible nowadays, free to be used, studied, modified and distributed. In this context, introductory courses to meteorology, analogical and digital electronics and microcomputer programming, digital manufacturing of electronic circuit boards and 3D parts are offered, besides the acquisition, visualization and interpretation of data.

FINAL CONSIDERATIONS

This chapter presented the concept of hyperobject and the proposal for the conceptualization of scientific instrumentation based on it. This concept aims at creating a cognitive ecology which promotes the dissemination of knowledge related to

39 There are several citizen initiatives for climatic and environmental monitoring such http://www.smartcitizen.me/ and http://www.wunderground.com/ . Access on: October 28, 2014. The initiative of the Academic Technology Centre also aims at educating citizens involved in data acquisition, in relation to scientific and technological aspects.

scientific instruments and their applications, providing elements for the expansion of the infrastructure of creation, construction, dissemination, application and materialization of these objects. The concept of hyperobject becomes the ideal model for the scientific and educational application, given that in these areas there is no reason for omitting or obfuscating information on hyperobjects.

Finally, it is suggested that a small fraction of the investment in research and infrastructure is directed to the support and development of the infrastructure of hyperobjects, with a view to bringing more dynamism in the sharing of project information and the manufacturing of scientific instruments, widening their access and reducing redundant efforts as well as costs. This infrastructure is also valuable for an education aligned with the principles of open science and open educational resources.

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9

Open data and open science

Jorge Machado

INTRODUCTION

Sharing research data via electronic media is not new. More than 40 years ago, computer scientists already shared files anonymously through an ftp[1], which was the standard network protocol used for transferring files from a host computer to another within a network. The arXiv.org, which nowadays houses almost 1 million papers mainly in the areas of physics, mathematics, computer Science and statistics, appeared 23 years ago. The term "open access" was launched with the "Budapest Declaration of Open Access Initiative", a 2002 document of great political relevance. In 2007, the definition of open data with eight principles strengthened the data opening process and widened the scope for the use and reuse of information, with impact on science as well.

Information and knowledge are basic inputs in the scientific and intellectual work process. For this reason, researchers need to have free access to scientific knowledge in their area. Quality and productivity gains are greater if a large amount of information can be selected or filtered, analysed, processed and recombined. Information and communication technologies have made all this process increasingly more powerful.

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[1] FTP - File Transfer Protocol.

The current debate on open access to scientific knowledge intersects with open data. Nowadays, protocols, formats and platforms which allow greater interoperability, processing, crossing and reusing of information are widespread. The traditional open access, as discussed in the last 10 or 15 years is now outdated and insufficient to account for advancements in the use and reuse of an open database.

The aim of this article is to show the evolution of access to scientific information up to open data, showing some of the challenges to be faced for its expansion.

This text is divided into five parts. The first is a brief introduction to the subject. In the second, we discuss briefly the evolution of the data opening process in electronic media. The third part describes the open access to knowledge and its relationship with international documents that aim to guarantee access to information and their relationship to human development. In the fourth part we discuss the different forms of open knowledge, presenting some of its concepts and their relationship with open data. In the fifth, we discuss the principles of open data and their application to science. Finally, we present the main conclusions in a critical manner.

EVOLUTION OF ONLINE SCIENTIFIC DATA

Considering their "embryos", the development of open access to digital content over the web merges with the history of the Internet, which was created with the purpose of sharing resources involving information processing, storage and traffic band between research centres.

The first initiative to create a database of electronic bibliography of open access data was the Educational Resources Information Center (ERIC - http://www.eric.ed.gov) in 1966. In the same year, Medline was created - a free access online database managed by the

National Library of Medicine and the National Institute of Health (both in the USA) with bibliographical citations from journals in the biomedical area, which later would be called PubMed (http://www.pubmed.gov), currently with over 14 million complete articles[2]. In 1971, the Gutenberg Project (http://www.gutenberg.org/) was created by Michel Hart, in order to encourage the production and distribution of e-books (HART, 2004). The goal was to make publicly available books which could be read or printed from a great number of computers and programs. In 1974, the Stanford Linear Accelerator Center (SLAC) (http://www.slac.stanford.edu) and the Deutsches Elektronen Synchrotron (http://www.desy.de) started to catalogue electronic literature in physics.

However, it was in the 1990s, with the global expansion of the Internet, that databases of freely accessible scientific articles began to proliferate. In 1991 came the repository of physics, mathematics and computer science texts ArXiv (http://arxiv.org). In 1992, the genetic research database Genbank (http://www.ncbi.nlm.nih.gov/genbank) was created. In 1996, under the auspices of the University of Virginia, the Networked Digital Library of Theses and Dissertations (NDLTD) (http://www.ndltd.org) was created and became the world's largest bank of dissertations and theses. In March 1997, Bireme - Latin American and Caribbean Centre of Information on Health Sciences - with support from Fapesp (State of São Paulo Research Foundation), created the periodicals database SciELO (Scientific Electronic Library Online) (http://www.scielo.org). In the following years the BioMed Central (http://www.biomedcentral.com) and the PloS (Public Library of Science), (https://www.plos.org/) came about, and would soon become references in the areas of biology and medicine, together with the PubMed.

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[2] See http://en.wikipedia.org/wiki/PubMed. Access on: June 11, 2015.

Scientific repositories also played a key role in open access, allowing the availability of articles, papers and research documents produced in universities and research centres. Some of the pioneers were the California Digital Library of the University of California (http://repositories.cdlib.org), the Papyrus of the University of Montreal (https://papyrus.bib.umontreal.ca) and the E-Prints Soton, of the University of Southampton (http://eprints.soton.ac.uk). The SHERPA project - Securing a Hybrid Environment for Research Preservation and Access (http://www.sherpa.ac.uk), the result of a consortium of 20 British university libraries, whose goal was to establish repositories at participating institutions, is also worth mentioning.

OPEN ACCESS TO KNOWLEDGE AND ITS RELATIONSHIP WITH DEVELOPMENT

From a political point of view, the publication of the Declaration of Budapest, in February 2002 and the Berlin Declaration - an improvement on the first document - launched on 22 October 2003, laid the foundations for the open access movement worldwide.

The Directory of Open Access Journals is also worth mentioning. Emerging from the First Nordic Conference on Scholarly Communication, held in 2002, and maintained by the University of Lund, Sweden, its aim was "to increase visibility and ease of use of academic and scientific publications by promoting their dissemination and impact" (DOAJ, 2014th). This directory offers free access to 10,000 journals from all areas of knowledge, including about 1.7 million papers (DOAJ, 2014b).

In Latin America, there is the RedALyC - Journals Network of Latin America, the Caribbean, Spain and Portugal, which brings together 916 electronic publications and 352 thousand full papers (RedALyC, 2014) and the SciELO, cited above, which brings together some 1187 journals and about 507 thousand articles (SCIELO, 2014). The latter has not established a commitment to the open access movement, but its expansion drew the attention of Brazil's journal publishers to the advantages of Internet publication.

In 2010, a group of scientists and activists launched the so-called Panton Principles for Open Data in Science. Going far beyond the Berlin Declaration, those principles focus on licensing content which clearly ensure the sharing, distribution, reuse, and the production of derivative works according to a general ethos of "sharing and reuse" of information by the scientific community (PANTON PRINCIPLES, 2010).

From a broader perspective, a key milestone for information access policies is the document produced by the World Summit on Information Society, sponsored by the United Nations in 2003, held with the participation of 173 countries. The so-called "Declaration of Principles", subtitled "Building the Information Society: a global challenge for the new millennium", so begins:

> We, the representatives of the peoples of the world, assembled in Geneva from 10-12 December 2003 for the first phase of the World Summit on the Information Society, declare our common desire and commitment to build a people-centred, inclusive and development-oriented Information Society, where everyone can create, access, utilize and share information and knowledge, enabling individuals, communities and peoples to achieve their full potential in promoting their sustainable development and improving their quality of life, premised on the purposes and principles of the Charter of the United Nations and respecting fully and upholding the Universal Declaration of Human Rights. (WSIS, 2014, art 1).

The text of the Declaration links access to information and knowledge as well as their sharing, to the development of peoples, in accordance with the United Nations Charter of Human Rights.

The second article of the Principles Declaration links the access to information and knowledge to the UN[3] Millennium Development Goals[4].

> Our challenge is to harness the potential of information and communication technology to promote the development goals of the Millennium Declaration, namely the eradication of extreme poverty and hunger; achievement of universal primary education; promotion of gender equality and empowerment of women; reduction of child mortality; improvement of maternal health; to combat HIV/AIDS, malaria and other diseases; ensuring environmental sustainability; and development of global partnerships for development for the attainment of a more peaceful, just and prosperous world. We also reiterate our commitment to the achievement of sustainable development and agreed development goals, as contained in the Johannesburg Declaration and Plan of Implementation and the Monterrey Consensus, and other outcomes of relevant United Nations Summits. (WSIS, 2014, art. 2).

Access to knowledge and to information is essential to human, social and economic development. This is already widely recognized through documents such as the Declaration of Human Rights (UDHR, 2014), World Summit on Information Society (WSIS, 2014), International Covenant on Civil and Political Rights (ICCPR, 2014), American Convention on Human Rights (ACHR,

[3] See http://www.objetivosdomilenio.org.br/ . Access on: June 11, 2015.

[4] The document also recognizes that "education, knowledge, information and communication are at the core of human progress, endeavour and well-being" and that "the rapid progress of these technologies opens completely new opportunities to attain higher levels of development. The capacity of these technologies to reduce many traditional obstacles, especially those of time and distance, for the first time in history makes it possible to use the potential of these technologies for the benefit of millions of people in all corners of the world." (WSIS, 2014: art 8).

2014) and statements of Brisbane (UNESCO, 2010) and Maputo (UNESCO, 2008), besides the already mentioned World Summit on Information Society (WSIS, 2014).

No doubt, the opening of scientific data represents enormous benefits to humanity. Politically, there is a strong consensus to strengthen the convergence towards the right of access to information as a fundamental human right. This concept meets the increase in "open" initiatives in science, which has led to the emergence of new paradigms for the production and distribution of knowledge.

Benkler, in The Wealth of Networks (2006), states that there is a new "information network economy", based on the Internet logic. Distributed, decentralized and self-organized, its development is based on collaborative practices. The author cites the example of distributed computing projects, collaborative platforms of biological innovation, open access repositories and open learning materials in addition to the free software collaboration and development model. Benkler highlights the importance of information for development, reflected in the components that make up the human development index (HDI): life expectancy, literacy and education, and per capita income, as shown in table 1 (BENKLER, 2006, p. 322-3).

Table 1: Importance of Information for the HDI components

HDI Component	Importance of information and knowledge
Life expectancy	Agricultural innovations, farming techniques, drug research, access to products, health care (access to research, publication and dissemination of information)
Literacy and education	Easy access to texts, libraries, computers and communication systems; access to educational materials for teachers and academic centres.

HDI Component	Importance of information and knowledge
Per capita income	Depends on access to innovation / development of advanced technologies - especially for developing countries, which need to adapt to new technological platforms

Source: Adapted from BENKLER, 2006, pp. 322-323.

The new practices of collaboration and sharing of information play an important role in the dissemination of information, culture and knowledge, which are fundamental to human development. In the information society, the opening of accumulated human knowledge becomes a possible reality, thus taking a priority role in any policy that aims to promote improvement in the living conditions of citizens and the reduction of large global inequalities. At this point, movements in defence of open access, access to public information, open technologies and protocols, open education and other "open" converge, as will be seen below.

OPEN DATA AND OTHER "OPEN"

The word "open" has been increasingly used to refer to alternatives to the "proprietary" models - with restrictions for copying, distribution and reuse of information. Thus arise the terms "open science[5]",

[5] The project called "Open Science" (openscience.org/blog), coordinated by chemistry professor of the Notre Dame University Dan Gezelter since 2006, is one of the pioneers in the use of this concept. Gezelter defines the meaning of "open science" from the achievement of four goals: i) transparency in methodology, in the observation and data collection; ii) public access and the possibility of reusing of scientific data; iii) public access and transparency in scientific communication; and the iv) use of web tools to facilitate scientific collaboration (GEZELTER, 2009).

"open access", "open research[6]", "open education", "open contents", "open source", "open notebook", "open licenses", "open courses", etc. .

There is also the concept of Science 2.0. Inspired by web 2.0, it suggests a new approach to the use of information science based on sharing and collaboration through the web, which includes the use of tools such as wikis, blogs, video to share findings, raw data and new theories, as shown in table 2 (WIKIPEDIA, 2014a).

Table 2: Differences between traditional science and "Science 2.0"

Current model	Emergent model (Science 2.0)
Research done in private, then submitted to journals; peer reviewed (guardians) of periodicals; publication	Data sharing at all stages of the research; scientists collaborate and findings are disseminated online
Scientific literature under payment barriers	Online scientific discoveries at no cost
Reputation established by the prestige of the journal or impact factors	Established reputation from quotes, page views or downloads.
Data is private until it is published	Data is shared before publication
Papers have generic copyright protection	Different licenses are possible: copyright, Creative Commons 3.0, public domain, etc.
Publishers earn by charging access	Publishers use new business models
Paper summary is available after publication.	Sharing data, methods and findings via blogs, social networks, wikis, Internet.

Source: Aadapted from WIKIPEDIA (2014a).

6 The central element in open research is to make methodological components freely accessible on the web, as well as data and results obtained or derivated. This allows for large-scale collaboration, where anyone can participate at any level of the project (WIKIPEDIA 2014b).

In order to establish the "open" concept, the Open Knowledge Foundation developed a very broad definition, which has become an important reference for the movements which advocate the opening of knowledge. Consisting of 11 items, this definition covers technical, legal and procedural aspects for the use and distribution of information, as shown in table 3 (OKF, 2014):

Table 3: Items to be considered "Open", according to the OKF

1. Access	The work should be made available in full at a price not exceeding the reasonable cost of reproduction, preferably free on the Internet. The work should also be made available in a usable and editable form.
2. Redistribution	The license must not restrict the possibility of sales or distribution of the work itself or as part of a package with works from various sources. The license shall not require payment of rights or fees for sale or distribution.
3. Reuse	The license must allow modifications and derived works; it should allow them to be distributed under the same conditions of the original work.
4. Absence of technological constraints	There should be no technological restrictions. The availability of the work should be in a format whose specification is freely and publicly available and whose use is not subject to financial or other restrictions.
5. Assignment	As a condition for redistribution and re-use, the license may require attribution – though not in a costly way - designed by the authors of the work.
6. Integrity	It is accepted that, as a condition for the distribution of the work, in case of modification a version name or number different from the original work is requested.

7. No discrimination against persons or groups	The license will not discriminate individuals or groups of individuals.
8. No discrimination of activity domains	The license must not restrict the use of the work in a specific area of activity.
9. Distribution of License	The rights to the work should be applied in its redistribution, without the need for an additional license.
10. License must not be specific to a package	The rights to the work should not depend on its insertion in a given package. Each work should have the same rights as the total package.
11. The license must not restrict the distribution of other works	The license must not restrict other works that are distributed along with the licensed work. For example, the license must not impose that all works distributed by the same means are open.

Source: Summarised by the author based on the definition of "Open" from Open Knowledge Foundation (OKF, 2014).

The concept of "open" of Open Knowledge covers the main obstacles to the access to knowledge. However, it admits the possibility of payment as a condition for access. That makes it differ from the classical definition of Open Access Initiative (OAI), according to which open access is access which is "digital, online, free of charge, and free of most copyright and licensing restrictions" (SUBER, 2013). Although the definition of OAI is too simplistic and general to serve as a practical reference, it is very clear with respect to the condition of free of charge access to be considered "open".

OPEN DATA IN SCIENCE

Open data are defined by a group of principles established in a meeting held in December 2007[7] in Sebastopol, California,

[7] Open Government Data (OGD): http://www.opengovdata.org/home/8principles

which brought together a group of researchers, representatives of civil society organizations and North-American activists. Among them were Lawrence Lessig, Tim O'Reilly, Ethan Zuckermann, Joseph Hall, Aaron Schwartz, Carl Mamamud and the creators of the Sunlight Foundation, My Society e GovTrack – pioneering organizations in the use of open data for the promotion of transparency. The focus of the meeting was the opening of governmental information. However, in subsequent years, the concept had its use extended, to include scientific data or even those from private organizations. Their principles state that any data, in order to be "open" must be used by anyone for any purpose. Such definition aims at orienting the data opening process so that it may be considered "open". Those are:

Table 4: The 8 principles of Open Data

The 8 principles of Open Data	
Complete	All public data must be made available. Public data are those which are not subject to privacy, safety or access privilege restrictions.
Primary	Data must be collected at the source, with the highest possible level of detail, and not in an aggregated or modified manner.
Opportunity	Availability must be provided as quickly as possible to preserve the value of data.
Accessibility	Data must be made available for the widest possible number of users and for the most diverse objectives.
Machine processing	Data must be reasonably structured so as to allow automatic processing.
Non-discriminatory	Data must be made available for everyone, without the need for registration.

The 8 principles of Open Data	
Non-proprietary	Data must be made available in a format upon which no entity has exclusive control.
Free licensing	Data must not be subject to any copyright, patent, commercial brands or secret regulations. Some reasonable privacy and restrictions of privilege and safety may be admitted.

Source: Open Data Government Working Group (2007)

Discussion: application of open data to science

The application of such principles to science implies the overcoming of a number of technical, legal and cultural barriers. As mentioned before, such principles have been thought in the context of the opening of governmental data. However, they are in principle applicable to any context with digital information. The widening of its scope results from the adherence of public and private organizations to open data, even at an international and multilateral level, in relation to Open Government Partnership (OGP)[8] and in G8[9] with the publication of *G8 Open Data Charter*. In this part, we analyse each one of the requirements for a piece of data to be open in light of its challenges for application in the field of science. The objective is not to go through the details and particulars in each area, but to raise some relevant aspects in a more general application of principles.

[8] Open data are present in many action plans of the 65 countries which subscribed to the OGP. See http://www.opengovpartnership.org/countries . Access on: June 11, 2015.

[9] *See G8 Open Data Charter,* available on: https://www.gov.uk/government/publications/open-data-charter/g8-open-data-charter-and-technical-annex and *G8 Open Data Charter and Technical Annex*. Available on: https://www.gov.uk/government/publications/ open-data-charter/g8-open-data-charter-and-technical-annex. Access on: June 11, 2015.

Principle 1 – Complete. All public data must be made available. Public data are those which are not subject to privacy, safety or access privilege restrictions.

The first principle of open data is that all data be made available. This means that the availability must apply to a complete dataset. The availability of complete datasets allows research to be conducted, allows the verification of whether findings are compatible with the data used and, above all, may allow errors to be found or new findings to be arrived at.

The traditional scientific model is very competitive. The public availability of data takes good part of the competitive edge of an author or group of authors. The only variable which may attenuate this "threat" to the author is the purposeful delay in the availability of information. This does not impair the verification of errors and new findings a posteriori, based on the same data, but guarantees that authors obtain the first credit for the use of data.

However, many authors object to having their data disclosed, even after the closing and publication of the research. A study conducted in the area of economics by Andreoli-Verbacha *et al* (2013), based on a random sample of 488 academic works published on websites, showed that in 89% of cases there was no information as to the availability of collected data on the web. In only 8.8% of cases part of the data was made available. In only 2% of cases all data was available (ANDREOLI-VERBACHA *et al*, 2013).

There are not many conclusive studies and each area of knowledge has their own reality. However, in general there is still lack of stimulus to the availability of complete data – especially until the research findings are published. If there is no policy or benefit for the author, he/she is unlikely to do it voluntarily.

Principle 2 – Primary. Data must be collected at the source, with the highest possible level of detail, and not in an aggregated or modified manner.

Documents in open formats allow for various uses of information which include crossing, automatic processing, data treatment and the implementation of studies and more detailed analyses of the available databases. For their characteristics, open format data offer great advantages for reuse. However, aggregated data restrict possibilities for the use of the database. Worse than that, they may prejudice verification and mask results.

An example of that is the aggregated socioeconomic data of cities which hide inequalities of districts and zones of a given municipality. The aggregation of geographic data imposes limitations to the researcher, which could be avoided.

In that sense, aggregating data is equivalent to "hiding data". It is understandable that, in a small scale, aggregating data is a way of keeping in anonymity a census base so as to prevent some citizen to be identified by his/her characteristics. Apart from some exceptions, the offer of primary data may be made without any problems to the benefit of reuse of information.

In summary: data may be published and offered in a non-primary manner, provided that complete information is made available to other users, preserving the data for later uses.

Principle 3 – Opportunity. Availability must be made as quickly as possible to preserve the value of data.

The transforming possibility of using data for useful purposes diminishes in time. The ideal for the maximization of its utility is the updating of information in real time. In order to comply efficiently with this requisite, it is necessary to use platforms and tools which make information available on the web. Obviously, it is necessary to publish them too, so that they may be found. Nowadays there are many available tools; the most simple and accessible are the shared webhosting services[10] (like github, bitbucket, gitlab, etc), repositories, wikis and pads[11].

The use of such tools in science is diversified in the different areas, but it is still very small, considering the potential benefit in terms of quality, efficiency in the use of resources and impact on innovation.

Principle 4 – Accessibility. Data must be made available for the widest possible number of users and for the most diverse objectives.

Accessibility refers to the ease to obtain information. The need for formal request to access data constitutes an obstacle to automatic access. Accessibility is wider when it offers the possibility of downloading all the stored information in a databank at once (the so called bulk access) or even the possibility of specific remote requests through an API[12].

The ease of use in finding and downloading information is a key point to attend to this requisite. Apparently easy to be met, the effective compliance with this principle goes beyond the simple publication of data on the web. There is a need for a pro-active action by the researcher when publishing, so as to facilitate the locating and use of information. This may include additional information

[10] Shared webhosting services are code repositories – not only for software, but likely to be used for any kind of information which requires some form of coding. They allow for distributed control of reviews and the management of codes, registering alterations, bugs and versions. They may include documentation referring to the code, e-mail listings, wikis, among other tools. They are widely used in open code projects with many collaborators. For a comparison between the main code repositories see Wikipedia (2015).

[11] *Pads* are online multiuser notebooks which allow the registration of alterations and which include chat tools, document import/export, and registration of consolidated versions, among other functionalities.

[12] Application Programming Interface, a set of standards and routines which allow third parties to use their services on the web. The big advantage of the API for the use of open data is to dispense with the need to download, allowing access to the updated database in real time.

to the data, like information on procedures which may facilitate locating and using the desired information from a database.

Due to lack of access to research by other scientists, many work in isolation, wasting time in unnecessary research activities or those which may be optimized by the sharing of experiments and findings. Much useful data are spread, not available to the public, protected or in non-integrated databases, generating inefficiency and waste of public resources.

Principle 5 – Machine processing. Data must be reasonably structured so as to allow automatic processing.

Data must be correctly codified in order to be amply used. A PDF image does not substitute the original document which originated it. There must be correct documentation on the format and codification of data, as well as the meaning of each one of the items so that users may know the meaning and context of the data.

In academia, the argument that a PDF document preserves the integrity of data is still very usual – which is very questionable. A document converted into an image makes it difficult for information to be automatically processed, frequently leading to the loss of graphs, tables and diagrams in the processing of information.

On the other hand, scientific commercial publishers opt for PDFs in order to make copying and the reusing of information more difficult.

A policy of access to scientific data must include a recommendation in relation to file format, so that these will not constitute a barrier to the reuse of information.

Principle 6 - Non-discriminatory. Data must be made available for everyone, without the need for registration.

There should not be a need for registration or any form of subscription. Neither should there be any restrictions to access only to a few specific applications. To that effect, the anonymous access to data should be allowed. That includes the use of anonymous proxies.

The “walled gardens” model of proprietary and paid for platforms of large scientific publishers is definitely out of this principle.

Even subject to discussion, compliance with this item meets the main requisite of the open access movement. The discrimination of access to scientific results constitutes nowadays the most lucrative business. For the sake of an example, one of the biggest scientific publishing companies can be mentioned – Elsevier, whose annual turnover keeps growing, and reached the amount of 11.5 billion dollars in 2013. The company operates with a profit margin of 39% (ELSEVIER, 2013), an exceptionally high figure compared to other economic activities. This lucrative business of scientific information derives from the monopolistic, thus non-competitive environment around it.

Principle 7 – Non-proprietary. Data must be made available in a format upon which no entity has exclusive control.

This principle is particularly important in areas where companies managed to establish a standard software – and frequently, as a consequence, of file format – as the market standard. When a company produces the software needed to read a file with data stored, users’ access to such information becomes dependent of that software. The use of proprietary formats creates the possibility of making the software available only through the payment of a certain amount. In the worst scenario, it may not be available at all. Proprietary formats in general include unnecessary restrictions as to who may use the data, how they may be used and who they may be shared with. Such restrictions exist only for reason of market reserve.

In order to avoid restrictions, it is always advisable to use free/non-proprietary formats. The elimination of occasional costs or other barriers associated to that enables the availability of the data to a bigger number of users.

This problem is not specific to the area of science. It is related to the tendency to establish user patterns, frequently associated to the practice or comfort of the user, which predominate in an environment without governmental policies in relation to the access to public information and to scientific knowledge – considered as public investment in the production of knowledge[13].

Principle 8 – Free licensing. Data must not be subject to any copyright, patent, commercial brands or secret regulations. Some reasonable privacy and restrictions of privilege and safety may be admitted.

The wording of this principle leads to erroneous interpretations. In practice, data needs to be protected by some form of licensing to avoid it being appropriated by another party which may restrict the chain of innovation on the basis of this information. This happens when a new protection layer appears after the transformation of content which used to be under the public domain. An alternative to that is the use of licensing models which guarantee to users the freedom and the principles of open data. To that end there are the so called free licenses.

Within academia, the adoption of licenses continues to be something rather alternative, despite good examples, like PLoS (Public Library of Science) and SciELO which use Creative Commons (CC by 4.0 e CC by NC-SA 3.0, respectively). However, the publishing standard continues to be based on traditional copyright, both in journals and by book publishers.

Until October 2014, the 10 biggest repositories listed on the web – on Webmetrics (2014) -Arxiv.org, Social Science Research

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13 Boultona *et all* (2011) remind us that there are private scientific data which are in the public interest. This case calls for a profound discussion on the need for balance between private and public interests, when information is related to matters on which more widespread access is crucial, like the fight against diseases, famine reduction or the generation of clean energy.

Network, Europe PubMed Central, Research Papers in Economics, HAL Institut National de Recherche en Informatique et en Automatique Archive Ouverte, University of California eScholarship Repository, Smithsonian/NASA Astrophysics Data System, NASA Technical Reports Server, Agecon Search Research in Agricultural and Applied Economics e HAL Sciences de l'Homme et de la Société – either did not have a content licensing policy or that was not appropriate to the digital environment due to its characteristics, i.e. the possibility of sharing and reusing information.

Incentives to open data policies in science

So that the potential of open data is fulfilled in science, there is a need for policies from government agencies to stimulate the enforcement of its principles. To that effect, there are good examples that, if not oriented exactly by such principles, do show advances in that direction. That is the case of the United Kingdom Research Councils (RCUK) which, by proposing a policy of access to research findings, states the commitment to transparency and to incentive to open data, by trying to guarantee that research findings are available through open access to the whole of society, establishing links with social and economic development and with the responsibility towards public funding (RCUK, 2013, p.1).

The Organization for Economic Co-operation and Development (OECD) also follows the same path by publishing the document OECD *Principles and Guidelines for Access to Research Data from Public Funding*. The document defends the promotion of a "culture of openness and sharing of research data", incentive to the sharing of good practices and raising of awareness of costs and benefits of possible restrictions and limitations to access and sharing of research data with public funding (OECD, 2006, p.11).

In 2011, the Research Information Network (RIN) and the National Endowment for Science, Technology and the Arts

(Nesta) from the United Kingdom published the report “Open to All? Case studies of openness in research”. The conclusions clearly show the advantages of a more openness and sharing of scientific data. In summary, the study presents the following conclusions: sharing of data I) avoids duplication in data collection, increasing the efficiency of research and promoting the adoption of open standards; ii) promotes academic rigour and improvements in the quality of research, by making information on work methods, protocols and data more readily available for peer review and scrutiny; III) improves visibility and possibilities of engagement, with opportunities for wider commitments with the whole research community, including new possibilities for “citizen science” and public engagement in research processes and findings; IV) allows the formulation of new research queries and new approaches through the use of data and materials from other researchers, supporting the development of “intensive use of scientific data” with the capacity to aggregate and reanalyse data from a vast range of sources; V) improves collaboration and community building, offering new opportunities for cooperation beyond institutional, national and curricular frontiers towards the sharing of knowledge and experiences; and VI) enables the increase of the social and economic impact of the research, the innovation on businesses and public services, as well as a more substantial return on public investment in research, by allowing the involvement of individuals and organizations from outside the scientific community.

Altogether, these documents point to the need for profound changes, even if gradual, in the way in which scientific data area produced, published, shared and used.

However, such changes require overcoming the contradictions between the digital environment and the traditional copyright system, as well as the existing cultural resistance in many sectors of science.

CONCLUSIONS

In this chapter, we presented the evolution of open information to the present day, with the emergence of so-called open data, now an important expression of the possibility of sharing information in a broader and optimized mode. In parallel, the recognition of the right of access to information and the importance of this for human development in a global perspective was discussed.

The opening of scientific data within the principles of open data undoubtedly brings huge benefits not only to students but also for society in general. The information chain would be enriched with greater diffusion and expansion of possible uses and reuses of information.

However, there are major obstacles to be overcome for the expansion of open data in the scientific realm. One of them is the need for a broader audience - including academic managers – to know its principles and to be able to apply them; of data to be published in an appropriate and comprehensible form, in order to reach wider communities - in addition to the experts - approaching the ideal of “citizen science”. A legal framework is needed to sustain and encourage their availability – such as a law ensuring access to public information and access to data obtained with public funding. In addition, scientific policies are needed to support their availability actively and under free licenses. It is also necessary to overcome cultural resistance, for opening data and information tends to reduce asymmetries between users of such data, reduce privileges between those who have access and detain more information and knowledge. In addition, the opening of data can have the side effect of generating a distribution of resources and decision-making processes, which is less vertical and occasionally more participatory. In short, it tends to include new actors in the process of production and use of knowledge with social and economic impacts which are difficult to measure.

In this process, development agencies, universities, publishers and authors have a strategic role in the development of appropriate institutional policies. There is a need for the establishment of policies to define quality criteria, publication norms and standards, and the creation of indicators to measure the success of such measures in order to ensure their effectiveness, since international documents cited in this text are more geared towards the declaration of principles and the establishment of future goals. The existence of clear policies that address juridical, legal and procedural aspects, to ensure that scientists feel safe to provide their data is also needed.

Increasing the stock of available information freely and openly and stimulating their overall flow can help significantly in promoting human development, innovation and social justice, and may also become a very important step to overcome the knowledge barriers in the world's North-South relationship.

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10

Distance education at tertiary level, open university and citizen science: the challenge of differences[1]

Ludmila dos S. Guimarães

A becoming is not a correspondence between relations. But neither is it a resemblance, an imitation, or, at the limit, an identification. To become is not to progress or regress along a series...
Becoming produces nothing other than itself. [2]

Gilles Deleuze

INTRODUCTION

In the realm of discussions on the relationships between the University, work and technology, distance learning higher education can be seen as a new tool for education and immaterial work in contemporary capitalism.

Distance learning higher education as a possibility for autonomy and continuing education also coincides with contemporary life insofar as cognitive work, living labour, must generate access to some form of income and to that end, the individual (student) who makes use of it must be connected to

[1] Discussion and research findings from the PhD thesis Self-education and Self-worth in Distance Education in Brazilian Public Universities (GUIMARÃES, 2013).

[2] Deleuze (1997, p.18).

brain networks. Participation in these networks demands the subsidy of one's own access to connections in the metropolis and insertion in their production spaces. In other words, the student-worker needs to invest in connectivity in order to guarantee their permanence in the metropolis-connection and qualification in order to create their income; a combined way of paying for their own income, keeping the costs of their education and connectivity within the production spaces.

The present condition and discipline of the production organization is the connectivity, and the surplus of social relations contained in connections the surplus-value, made possible and taken from the living and collaborative labour. In other words, understanding the way in which contemporary capitalism acts upon the creation of subjectivities and accommodates its demands within the knowledge practices, both at the micropolitical and at the macropolitical levels, promoting the coincidence in the same productive game of the social desires and productions.

In that sense, one can challenge the model currently practised in distance higher education in Brazilian public universities, and its relationship with the processes of self-education and self-worth within contemporary capitalism.

The current distance learning policy, in spite of its advances, does not take into account the motivations and expectations in relation to students' education, and as a consequence reproduces an educational model which is hierarchical, disciplinary and parameterized, hampering the exercise of an autonomy geared towards changes in the relationships power-knowledge-labour.

The horizon of the formulation of policies for distance learning education as an element of the productive-political dimension of a student's life, reveals that the access to tertiary education occurs through a double and paradoxical process of inclusion and fragmentation of life in the knowledge and labour spheres: self-education and self-worth.

This is a general inflection, a paradox which disqualifies the possibility of differentiation, of new educational configurations and which reaffirms the precedence of academic disciplines in a model for the relationship between knowledge and power, devoid of analysis and decontextualized in relation to the double function which expectations and motivation exert on the production of the subjectivities of distance learning students.

The attempt to elucidate how the micropolitical and macropolitical dynamics interfere in the formation of the subjectivities in distance learning education, and the way in which public universities have responded to or met the challenges in distance higher education and its relationship with labour, may indicate the contours and conflicts faced by autonomy in the dynamics of the Brazilian educational system.

OPEN UNIVERSITY: PUBLIC POLICY AND THE ARCHITECTURE OF POWER

Our analysis and observation of the set of practices in distance learning at the tertiary level are founded on three dimensions: power, knowledge and autonomy. Within the realm of power relationships, it is necessary to describe, analyse and monitor the kind of assimilation of subjectivity which derives from the structures of political and economic structures applied to the virtual space, in other words, in the virtual environments as a space where things happen, and also outside those spaces.

To quote Foucault (1997, p.71): "We need to learn how the subjugation rules may fabricate subjects". This means that the effects of the power structure over the subjectivities may happen in the form of an architecture, the functioning of a learning system, which may reveal the mere morphological identity of the power system. The idea of a power system as power relationships combines, in this sense, with the notion of a modern political system and its developments, as referred to by Deleuze and Guattari (1966, p. 89):

> The modern political system is a global whole, unified and unifying, but is so because it implies a constellation of juxtaposed, imbricated, ordered subsystems; the analysis of decision making brings to light all kinds of compartmentalizations and partial processes that interconnect, but not without gaps and displacements. Technocracy operates by the segmentary division of labour (this applies to the international division of labour as well).

Therefore, the question of distance education may be treated at the same time as a subsystem of a political character, given that it has to do with a social landscape and with possibilities of intervention, and of an ethical character insofar as it implies the work of the individual upon him/herself, from the perspective of the production of forms of life beyond the power mechanisms.

One may also question distance education both in relation to some forms of knowledge transmission and of their production spaces, from the point of view of virtuality, and in relation to the power relationships, to coercive rules, to hierarchies, to task division, which have left out subjectivity, lifestyles, interests and motivations of their real beneficiaries, students and users.

One of the problems of the political aspect of distance education reveals itself in the form of its informational architectures, which is its form of government and its own identity. Furthermore, in the norms, rules, bureaucracies, contention and direction of flows in a global and segmented system, in short, the *territorialization of spaces and relationships*.

One may also think in reciprocal terms, in all the systemic apparatus and in the government architecture internal to the educational (knowledge) institution and the spaces linked to it (in distance education) as focus of resistance and of creation, such as "war machines which invest in the invention of a non-fascist life, which draws lines of flight and allows the emergence of spaces of freedom". (DELEUZE, GUATARRI, 1996, p.113)

In general terms, the issues identified in the current architecture of distance education may be classified in two complementary universes: a) the analysis of the micropolitical universe, with the emergence of disciplinary questions, of employability, flexibility, virtual learning platform and "private" motivations for entry into tertiary education, and b) the analysis of the macropolitical universe, with the emergence of institutional issues of the university, with reference to educational policies for access to higher education. Within these two universes, the form of government applied to distance education, as well as the configuration and orientation to the production of a certain identity, are directed and adherent to the economic and political system of contemporary capitalism, and well corroborated in the formulation of the Brazilian educational policy[3] in the last ten years, when distance education emerged.

Some relevant indicators appear at first in the overview of the power-knowledge relationship, among which can be highlighted the prevalence of the disciplinary phenomenon (as a form of self-organization) and its relationship with the flexibility seen as competence of time management, and the vector for the search and exercise of autonomy.

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[3] See PNE evaluation 2001-2010: challenges and perspectives, carried out by INEP, in three volumes available on: volume 1 http://fne.mec.gov.br/images/pdf/volume1.pdf Access on: April 16, 2012; volume 2: available on: http://fne.mec.gov.br/images/pdf/volume2.pdf Access on: April 16, 2012; volume 3: available on: http://fne.mec.gov.br/images/pdf/volume3.pdf; Access on: April 16, 2012. Published in 2009, presents findings of the evaluation process of the National Education Plan (PNE) 2001-2008 under the coordination and supervision of the Associate Executive Office (SEA), by delegation of the Ministry of Education, with significant support from Inep. The participation of management agencies from the Ministry of Education and the collaboration of researchers from the area of education, gathered by the Federal University of Goiás (UFG) must also be registered. The construction, adjustments and updating of educational indexes for the monitoring of targets, as well as the performance of these indexes, throughout the evaluation period, were carried out by the General Coordination of Information and Educational Indexes of DTDIE/INEP, under the coordination of Carlos Eduardo Moreno Sampaio, with effective support from Vanessa Nespoli.

On the other hand, we may question the artificialization produced by the system which, by allowing the inclusion of the student/user, includes him/her within the models and formats which do not disturb production. In other words, the system offers flexibility and opportunities for study, but in such a format that this inclusion happens through investment of the subject him/herself, and so that it is returned to the system as increased competence, intelligence and knowledge. So the practice of self-worth becomes a motto of generation of worth produced and appropriated by the system, whose justification allows the subject to contribute the knowledge gained in exchange for his/her permanence in the system, in his/her role as a knowledge worker.

On the other hand, the self-education and self-worth ideas corroborate that this very reality accommodates the paradox or the uncomfortable truth that the social capacity to produce something new is disseminated everywhere, and that this capacity is not completely subsumed in capital, and is independent from its valuation. That means that the invention, the creativity, is not exclusive to those who are within the productive system, nor to the geniuses, neither is it the monopoly of science or industry, but rather and effect of subjectivity, a psychic and political power which has value in itself, is capable of self-worth and of constituting new life possibilities – a biopower of the crowd.

In order to better visualize the problem, it is important to understand the variables and intensities which operate in the time and space of distance education; time and space which may be contracted, quick or even instantaneous, brief and perennial, flexible and inflexible, dynamic or static. It is within this time and space that the relationships of strengths, understandings, dispositions and their negative counterparts occur among people and technologies. Two aspects must be highlighted here: a) the fundamental function performed by technology in the relationship with life and with language as a power tool; b) the governmentality carried out through technology and their relationship with autonomy and the production of new forms of life.

To that end, one needs to ask what is the rationality faced by distance education or how the power relationships are rationalized in a system made of teachers, students, administrative staff, government agents, management theories and processes, among others. Or yet, to understand how this rationality operates and guides people's conduct in the virtual and institutional space, how it frames relationships and identifies individuals.

These are totalizing and individual actions, exercised and mediated by technological devices for communication and information, which have the aim of facilitating access to those excluded from public tertiary education and to facilitate the speedier expansion of the system. This is the governmental leitmotiv for the introduction of total actions in the educational system aiming at "equality and social inclusion" of the population. Around it a whole logic is constructed and justified, which orientates individual conduct and political relationships within the educational system and outside it.

The indications and mechanisms of this governmentality, to mention a few, may be observed in the dynamics of curricula, in the forms of monitoring through technology, in student assessment, in the precarious relationship of the University with teaching staff, in the set of articulated and structured practices, albeit uninstitutionalized and even in their exclusion from the agendas of the class organs, in opposition to the demand for distance education contained in the National Educational Plan 2010-2020.

We will next return to the notion of political knowledge addressed by Foucault and its developments in distance education at tertiary level, especially in relation to the concepts of security, territory and population, exactly because it will allow us to place the notion of biopolitics and its intrinsic connections with the power-knowledge strategies.

Biopolitics and power-knowledge in distance education

In the Collége de France Course Summary, Foucault (1997, p.81) calls attention to the fact that initially "the exercise of political power (in Greek and Roman societies) did not imply either the right, nor the possibility of a "government" understood as an activity to direct individuals throughout their lives, placing them under the authority of a guide who is responsible for everything they do and everything that happens to them". What clues can such statement give us to understand what in fact happens in relationships and organizations in the field of distance education?

Initially, we may think of their connection with governmental policies, in the macropolitical sphere, and the determinations and prescriptions in the form of regulations, institutional normatives and a whole set of regulation and supervision instruments which are historically applied and kept for the treatment and control of public education. Next, in the micropolitical sphere, their impacts or effects in the production of a subjectivity geared towards order and discipline, in other words, mechanisms of subjectivity and subjection control.

These power mechanisms operate in more or less subtle formats within educational and scientific discourse, and constitute rules to be obeyed, and to be endured. It reminds us of the emphasis that discipline used to have in the production of subjectivities in the 18th Century, i.e. to form individuals with a docile character, adjusted to the system of vigilance and social control. Is the continuity or maintenance of these principles or values possible in the 21st Century? Under which pretexts and formats are they enunciated?

The question of discipline here is fundamental because it brings to the open and challenges the ideas of government and of governing oneself. Or in other words: it questions both the purpose of the set of rules or principles of conduct, if they relate to the way one leads their own life, or to be driven, with respect to their political function of regulation of the social and economic relations, and therefore, restrictive of one's autonomy. Discipline is then necessary in order to maintain the system structure working, to provide the necessary security and stability for their productivity and political control. Without a fixed apparatus with its engines functioning in a mechanical, disciplinary mode, it is not possible to maintain the necessary resonances to the exercise of power.

The analysis of disciplines or micropowers, according to Foucault (school, the army, factory, hospital, etc.) attest these sources of instability where regroupings and accumulations as well as escapes and flights are confronted, and where inversions are produced:

> Such relationships go deep into the tissue of society, they are not localized in the relationships between the State and its citizens or on the frontier between classes, and that they do not merely reproduce [...] the general form of the law or of the government. [...] They define several risks of conflicts, of struggles and of an at least transitory inversion of the strength relationships. (FOUCAULT, 1977, p.29)

Disciplines and hierarchies have an organizational, governmental character, which is exercised in a singular way, sometimes in a harsh manner, sometimes in a flexible, centralized and decentralized manner.

Thus the political aspect does not cease to question the purposes of governing and the political governmentality[4] which is established around it. The problem of governmentality reveals the exercise of power, its forms, vices and virtues, given that it determines what can or cannot be infringed and why. And it is within this circularity that a political knowledge is constituted and

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[4] Such as understood by Foucault (1995, p.110), as the domain of strategic relationships among individuals or groups – relationships which have at their core the conduct of another or others, and which may resort to diverse techniques and procedures, depending on the case, of the institutional frameworks in which it develops, of the social groups or time in history.

founded for the legitimation and sustainability of the exercise of power over others, the living.

The mechanisms of governmentality transform individuals into micro organizations and operate through them. It is what may be observed in the educational process and its microformation, which produce the adjustments of postures, attitudes and perceptions, anticipating the appropriate behaviour which society expects from individuals.

Governmentality is exercised through the dissemination of discipline methods and procedures adjusted in order to standardize, establishing a multiplicity of power relations which intertwine, and are linked by complex and circular devices to the form of power, and not simply justified by scientific principles and techniques.

The modes of power, types of control and vigilance which are exerted over individuals within the system enable both the knowledge about them and revealing and intervening in their identity.

Taking distance education as an example, it is not difficult, for example, to identify the mechanisms which operate in the process of communication among teachers and students in learning platforms, where can be found the registers of discourse events, on one hand, an on the other the pulverization of hierarchical "entities" which respond as and for the system. Thus the educational institution is in charge of regulating the reciprocity of relationships, regulating the access and the communication through hierarchical levels, keeping their developments under control. That way, the system includes and excludes the circulation of enunciations in conformity with the production of identities which they wish to fabricate. By controlling communication and, therefore, the circulation and flow of ideas, political power is exercised according to a structure and set of rules. This "new" vigilance and control device through the system makes clear that the development of knowledge does not occur independent from power and that the technological apparatus confirms its submission to the logic of power. Thus, one cannot think progress of knowledge without thinking power mechanisms.

No doubt the question of power mechanisms takes us back to the problem of governmentality, in a circular format, given that it has to do with governing things. But what does that mean or imply? That these things that the government must take care of are constituted of men, their relationships, resources, wealth, security, the territory and all that relates to them, their customs, habits, ways of doing or thinking, in other words, the government of people's lives, the government of the living.

The government of the living is also the government of the life of individuals in a convenient form, geared to a purpose, and through the knowledge of things which are appropriate and useful to the life of all, of the population. Thus the need and justification of rationality as political discourse finds its space in history in the government of the living – that's where biopolitics is born.

THE CHALLENGE OF DIFFERENCES: THE CONSTITUTION OF SUBJECTIVITIES VS GOVERNMENTALITY

It is exactly upon the individual, his/her ways of thinking and behaving, in the subjective dimension of action and its articulation with the real, that power exercises its vigilance, discipline and control in a sibylline manner, that is, through values and ideas which it disseminates in order to produce a type of behaviour which is adjusted to the system. It is the system and not the people which produces, commands and enforces the rules; it is a common fact to hear that the control system (automated, of course), *big brother*[5]

[5] Borrowed from the meaning employed by Deleuze and Guattari (1996, p. 80): "Segmentarity becomes rigid, to the extent that all centers resonate in, and all black holes fall on a single point of accumulation that is like a point of intersection somewhere behind the eyes. [...]a central computing eye scanning all of the radii."

style, does not allow this or that, is not programmed for certain functionalities, is under maintenance and off the air, the data have been lost in migration, in updating, etc.

The functioning and efficacy of the system depend on the instance and subjectivity as a fundamental dimension of contemporary politics, as pointed out by Foucault after the 1960's and duly in conformity with their objectives.

By reason of this naturalization of systems over human conduct, where the subject does not exercise his transformative action, but is passive, transformed by his actions, Foucault considers it dangerous to treat identity and subjectivity as profound and natural components, which are not determined by political and personal factors. A set of values of the system culture, with the regulation of actions, space and time, is imposed over routine activities and thinking which are continuously introjected and reinforced with multiple resonances.

Managing the subjectivity is interesting to the system as much as the management of global results, given that it has to do with the efficacy of a total and profound government over others in a deterritorialized terrain with no surface, which is that of distance education. Each individual constitutes a homogeneous segment in relation to themselves and to others, and as a unit of measure presents equivalence in relation to other individuals (units). The dynamics and/or the organization of management in the deterritorialized terrain operates from detachments of a centre of normatives which gives consistency and materiality to a homogeneous political space.

On the other hand, this government is exercised through governmental discipline-management, and is supported by an economic and technological instrumentalization to assure the control of the system and their diverse components. In other words, in order to sustain itself, this government needs little local and individual tactics which may guarantee the execution of the big strategy, given that without the small power relationships it is not effective. It is necessary for an “inflation of power” to happen in daily life for the government of the others to happen: for example, in the educational system, the hierarchies, the evaluations, the defined deadlines, the presentation of theses, the curricula, the disciplines, the virtual learning environment, the campus. *In short, various segments and relationships for the circulation of power.*

The examination of the issue of governmentality as political discourse or as political rationality, stratification and institutionalization is relevant exactly because it directly affects autonomy and the practices of self. It is through control instruments that governmentality legitimises the problematics of the subject, and therefore of their autonomy., with the support of political-scientific discourse and as a power-knowledge strategy brings it to the front

The exercise of governmentality as the government of others, implies the exclusion of the government of the self (or autonomy), since self-care results in opposition, rebelliousness, multiple struggle and resistance to power.

From the point of view of the power-knowledge relationships, governmentality becomes more complex, by posing the question of form and architecture of the way in which societies transmit knowledge, constitute their identity, their values system, their refusals and exclusions.

The mechanics of power as operated within the educational system appear through gestures, repressions, discipline, attitudes, discourse, in the form of learning itself and its ritualized processes, in the inclusion and exclusion of knowledge, which are naturalized and incorporated in normality. Thus continuous control is established over individuals and leads to knowledge which, in turn, produces life habits perpetuated and engendered in a circuit of satisfaction of needs and demands.

From the point of view of higher education, individual thinking and knowledge of self must be encouraged, more than the academics' theoretical production, given that it is students' resistance and refutation of the power-knowledge, the political action and the trajectory towards the student-becoming which may produce the transformation of power.

However, in the political plan, what and how may teachers contribute to this student-becoming? This is exactly the point which relates to autonomy as the search for new possibilities for the construction of knowledge and forms of life, as shown by Foucault towards the ethics and techniques of the self, or the government of the self, as the most important aim of knowledge.

The becoming-student implies making choices amid multiple stimuli and living one's own life with self-criticism. The support to autonomy, to students' freedom, brings teachers to the responsible and continuous questioning of the power relationships about the teaching profession and of the production of knowledge, which is their aim, to the permanent critical examination of the logics of the system in which they operate and the efficacy of the instruments proposed and of the valid and creative contributions to society.

EDUCATION AND UNIVERSITY: DEADLOCK FOR OPEN SCIENCE

The identification of constitutive elements of the subjection phenomenon is relevant and preliminary to the future establishment of a cartography of subjectivities, as well as subsidizing changes in the educational practices in the field of higher education both distance and face to face.

The present political formulation of distance learning, when failing to consider autonomy as an element of the political-productive dimension of students' lives, reveals the fragmentation of life in knowledge and labour and poses difficulties for the emergence of dynamics for open, collaborative and cooperative scientific constructions. *In this sense, some important observations in relation to the current orientation of the educational policy implemented by the State must be highlighted.* They are grounded on impasses and challenges brought about by the interweaving of reality, and for which there is no single model or manner of overcoming.

This discussion does not aim at establishing a new model which would lead to a different architecture of power implemented top down, but rather at suggesting which different values may bring about the establishment of new dynamics, which we propose should always be open.

Going back to our observations on the deadlocks and challenges posed by educational policies and their institutional directives on the "university system", we suggest the following: a) the concept of the open university system for distance education prioritizes and practices a mass, hierarchical, disciplinary and precarious teaching system, which does not stimulate research, invention and creativity, as a result of the excessive standardization applied independent from the context; b) as a strategy to promote inclusion of the population, the effective contribution of distance education for the expansion and interiorization of Public University are limited by the centralization and dependency from the Union, as well as the relationship among federative entities, in other words, limited autonomy in face of juridical and legal issues; c) the metrics applied to the expansion of university, do not know the limits of the capacity for university management, throwing upon them responsibilities and competencies which are not incumbent upon them, as for example, the mechanisms for expenses reports, which ignore the purpose of the university and reduce it to a public organization for the provision of services; d) the intensification of oversized controls applied to the university scale lead to the paralysis of end-activities, like for example the purchasing of equipment, of teaching materials, and research and extension; e) the assessment practices implemented present a mix of quality development character (for example, the self-evaluation mechanism with a focus on the improvement of the quality of the institution), and point towards an evaluation policy oriented to quantification and to the market, which emphasizes the concern with system efficiency (cost/benefit and arguments of fiscal and State budget nature), as may be found in the SEED/MEC (Distance Education Agency/Ministry of Education and Culture) evaluations of the PNE (National Education Plan) 2008; f) the exaggerated regulations practiced by means of various computerized systems, through which the University is kept under control, impair the integrated management of resources, operating under an excess which mobilizes people's time to attend to it, and places obstacles for the search of solutions and alternatives - the University is geared towards the compliance with controls, and not to the best management of resources according to their context; g) the precarious institutionalization of distance education reflects the dichotomy faced by University between expansion and quality of education, revealed both in the precarious infrastructure of the institution an at the satellites (as evidenced by the enunciations and evaluations from Capes - Coordination for the Improvement of Higher Education Personnel) and in conservative arguments from class organs with few or no scientific basis for not joining the task; and finally, the challenge to tackle the demand for more places, in other words, the expansion of places with the reduction of the cost per student, justified by the use of new technologies (under the criteria of the World Bank[6], 1998); h) the dichotomies between verticality and horizontality evident in the Ministry of Education systems - at times centralized and at other s decentralized - and with no communication among themselves, generating evident

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[6] Cf. ARAÚJO, Raimundo Luiz Silva. Basic education financing in the Lula government: elements of rupture and continuity with FHC government policies.2007. 182 f. Thesis (Masters in Education)-University of Brasília, Brasília, 2007.

antagonisms, for example, the hypercorrection in institutional evaluation, of which the University is an object; i) the dichotomy between a becoming of the University which is flexible and mobile, and the rigidity of current curricula and pedagogic projects, essentially disciplinary and geared towards the standardization of reality, in the construction of the identity of subjectivities, which impair the examination of reality from the point of view of differences; j) the question of financial sustainability of distance education, in the face of budget availability, current dependency from Capes financing support and the effective possibility for attracting resources through public-private partnerships; k) the cultural uniformity employed to reinforce the relationship cost/student; l) the internationalization of education and its relationship with the process of transnationalization of higher education; m) the treatment of the system oriented to targets with inputs, outputs and feedback according to universal business criteria; n) the lack of understanding of the system in relation to the student body, their behaviour, reasons for evasion, permanence and persistence in the system, on one hand, and on the other hand the lack of understanding of the student body in relation to the objectives of the programme, the institutional organization, the clerical services.

These observations show the way in which biopower mechanisms, in the form of governmentality, are exercised over the University, in other words, the power-knowledge relationships. The analysis of the macropolitics dimension in distance learning allows us to gauge the extension to which the micropolitical dimension, that of the subjectivities, is not considered or is insufficient from the point of view of the system considered as a set of practices, and public policies which are more committed to quantitative expansion and metrics than with pursuing equity and quality in educational actions. In this respect, objections are made on the grounds that this is a task that belongs in the University, which in turn needs to make it known to the university community, but at the same time impede it with the excessive standards, demands for control and budgetary variations and place obstacles to the implementation of an autonomous programme to reach this objective.

The current difficulties for the renewal of the educational system towards quality, flexibility and mobility required by contemporary life remind us of the tardiness in the areas of health and education experienced in the 1960's and 70's, namely: a gigantic market, not very productive, with a great deficit of professional management, low level of technological knowledge and low capitalization. What do these arguments remind us of? We may quickly identify them with the world economic system of that period (namely OECD, World Bank, WTO among the main ones) in order to justify an attractive area, with great potential for available capital in search of new areas of increasing value for investment.

One may think, contrary to this logic, that distance education may contribute to rethinking self-education and self-worth, i.e. rather than being a mechanism for capturing mass intellectuality, is oriented by other values, by an ethics of subjectivity geared towards autonomy and freedom, so as to constitute a line of flight from the current prisons of existence and an exercise of biopower.

In concrete terms, teachers may: lead students to reflect upon actions they suffer; help them identify their desires and beliefs; potentialize a more political and creative discussion on distance education; investigate the intermediations, the dynamics of interaction, of interactivity with students' quotidianity, or their lifestyles and life plans; organize the collective power through new media (for example, organized activism on the Internet); to put in place a new ethics intermediated by productions with collective value, so that they become collective productions, given that every act is collective; to produce dislocations for a biopotent perspective of distance education in opposition to macropolitics; to practice a minor education, which is more dynamic and contemplates students' expectations.

To this end, the macropolitical dimension of education points to the instituted reality, that of the National Plans, the law, the great programmes and systems, the standards and references, a mega engine for learning and control, for the series manufacturing of individuals. In opposition to the decisions and strategies of macropolitics, the exercise of micropolitics of singularity, of the exercise of differences, of plurality, of multiplicity, of endeavours of revolt and resistance, learning beyond controls, beyond final evaluations and concern with results.

This is evidently not about reconciling the macro and micropolitical imperatives. As a political act, which it is, education needs to deterritorialize the production of these discourses in people's everyday life, deconstruct them, to offer resistance against them. This form of education as an indicator of the ethics of subjectivity at the micropolitical level is established in the politics of everyday life, in direct relationships among individuals, and impact on the macropolitical level.

Such form of education is fragmented, segmented and does not coadunate with any false pretention of totality or unity; it is about the production of multiplicities, where every action and failure are collective, a resistance instrument against control.

> [...] Multiplicities are reality itself, and do not suppose any form of unity, do not enter in any totality, and neither do they refer to a subject. Subjectivities, totalizations, unifications are, on the contrary, processes that are produced and appear in multiplicities. (DELEUZE; GUATTARI, 1995, v.1, p.7)

The questions which emerged in the micropolitical and macropolitical dimensions allowed the visualization of the set of struggles and confrontations which happen in the power-knowledge relationships. The power-knowledge relationships, as pointed out by Foucault , impede the effectiveness of self-potency knowledge.

It is essential to observe that substantial transformations can only happen from fights for autonomy, in the production of differences in opposition to the current regime of identity construction.

The bigger exercise is to think of education as movement, happenings, a set of happenings, dynamics and flows, and therefore, to portray it in various dimensions.

In the context of subjectivity it is notorious that differences can only emerge from the multiplicity of moving singularities, in speed and intensity, in interaction, and that expectations, motivations and wishes must occupy a central place in the production of subjectivities so as to free them towards the common. Singularities within multiplicity and which attend to diversity as a positive element in the production of knowledge, understanding, marked by differences between one another. In that respect, Nietzsche (1998, p. 108-109) says:

> We must, after all, as men of knowledge, be grateful to such resolute inversions of perspectives and customary valuations, as if the spirit, in an apparently sacrilegious and useless manner, became furious with itself for such a long time: to see so differently, to wish to see that differently, requires great discipline and preparation of the intellect for its future "objectivity" - which is not understood as "uninterested observation" (a nonsensical absurd) but as the faculty of having their pros and cons under control and at their disposal: to be able to use the diversity of perspectives and affective interpretations for the benefit of knowledge ... But to eliminate desire completely, to suspend all affections without exception, supposing that would be possible: how would that be done? Would that not be a castration of the intellect?

It is necessary to reaffirm the reciprocal dependence between the common and the difference as processes which coexist fundamentally so that understanding and knowledge are produced. In view of the scale of flows which pose a myriad of challenges for knowledge, it is not convenient to make use of easy, ready-made and quick answers.

In order to obtain alternatives to the current stage of the relationship power-knowledge in the educational field, it is necessary to admit the crisis of the University, the breakdown of the central and identitary models, propagate their breakdown, resist the desire for massification, and above all not let the imperative of autonomy and collective construction of understanding and knowledge.

In this sense, it befitted us to perceive that autonomy as human freedom comes first, is constitutive of the struggle, of being in the world and of human action, and it is not subordinated only to education and law. Education, in this sense, can only "offer" elements and conditions for self-reflection but it cannot direct the results of human action and not even indicate possibilities of judgement. That is because judgement can only happen when thinking is over, given that action is by itself unconditional to thinking and to its own judgement.

CONCLUSION

Autonomy or human freedom is the freedom to act/action in the world, confronted with it and, therefore, contingent and contingenced, inscribed in the plan of the immanence of the radical experience of subjectivity.

We understand, like Deleuze (1992, p. 127) that given that the Self is a habit, a contemplation and that every habit is creative, the self is the result of the contemplation of inhabiting the world, of being in the world, which is grounded on the plan of radical immanence: the conventions, customs, norms. The Self is converted, constitutes a process of actions originated from human freedom, from the arbitrary beginning of human existence, of the conventions in the world. The constitution of the Self, of subjectivity, is linked to the territory inhabiting it and being inhabited by it, moving on a plane which is asserted by it, the plane of immanence, the of the very autonomy.

By the same token, it is the combination of actions under the moving ground of conventions and customs , as well as the capacity to contemplate them, that the Self as a process of subjectivity allows the assertion of the condition of human plurality. In other words, conjunction of autonomy and the world, where human freedom is the constitutive motivation to act.

The experience of the Self, as a consequence of the contingency of inhabiting/being inhabited in the world/territory can only happen in the empirical field.

The processes of subjectivity as phenomenon of an empirical order present people with challenges and responsibilities for their freedom and effective exercise. One of the challenges of the exercise of human autonomy is their limit in relation to other inhabitants of the world/territory, given that freedom demands as a condition for its existence at the same time equity and difference.

Autonomy can only exist among free men, and is itself the immanent plan for human thinking and action. Thinking extends, moves about in the territory and needs it in order to have consistency; in the same way, human action is only founded when inhabiting a territory where it can express itself.

There is no dichotomy between the Self and the world/territory, but only autonomy and difference. The freedom human/autonomy asserts itself as radical possibility of the subjective experiences in the world.

To know and inhabit the territory constitute the same experience, which only happens through the struggle for autonomy. The processes of subjectivity, therefore, are not transcendental, or external, or disconnected from the world, but on the contrary, they are immanent to their existence in the world.

In the same way as thought needs a territory to inhabit and to be inhabited and experienced, self-care can only occur as a consequence of inhabiting a territory with others: a political habit.

Education as a political habit, following from moving subjectivities, is what can give rise to living education and the constitution of the common in the territory.

The direction towards a common territory may emerge from propagated waves of a becoming - difference as new experiences in education, in science and in technology.

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11

Why open notebook science? An approach to Jean-Claude Bradley´s ideas[1]

Anne Clinio

OPEN NOTEBOOK SCIENCE: WHAT IT IS AND WHAT IT IS NOT

Historically, the laboratory notebook has been the main instrument for registering the activities carried out by scientists, serving as a means of documenting protocols and research results, as well as an organisational tool. These are paper notebooks with sequential leaves, dated and used to register the activities carried out by a scientist according to individual preferences and institutional guidance. These notebooks can belong to an individual or to a group; they can have either free or structured entries; they can register only the activities carried out or personal observation and insights.

When the digital format was adopted, the laboratory notebook became an electronic laboratory notebook – ELN. Data was transferred from the material base of paper to software offering facilities such as search engines, the possibility of transferring data, generating backups, direct incorporation of data from scientific instruments, besides supporting some collaboration among scientists.

[1] With the financial support of Faperj and Capes, Brazil.

Going beyond the argument that it facilitates the activities carried out by scientists on a daily basis, Jean-Claude Bradley, a Chemistry professor and researcher at Drexel University in the United States, created the concept of open notebook science – ONS in September 2006. His objective was to promote a vigorous debate on open collaboration in science (BRADLEY; LANG; KOCH; NEYLON, 2011, p.427).

> According to the author, this concept refers to "a way of doing science in which — as best as you can — you make all your research freely available to the public and in real time" (BRADLEY, 2010). This practice does not only include data, information and positive results of a given piece of scientific research; it also disseminates partial status, weaknesses and challenges at a stage when they have not yet been solved by scientists. Sharing the "backstage" of science, its intermediate stages, doubts and difficulties is part of Bradley's strategy aimed at promoting a *"faster science, better science"* and at attracting collaborators and resources in order to solve scientific questions challenging him.

By calling this new practice open notebook science, Bradley wanted to distinguish it from Open Source Science which he had previously used. This term had become ambiguous, given the different meanings and perspectives associated with it – for example, its use in discussions about pre-prints of scientific articles. Even though he agreed that some meanings of the term Open Source Science were consistent enough with our use in UsefulChem[2]", acknowledging the Open Source Software as a source of inspiration, Bradley wanted to clarify his proposal:

2 UsefulChem is the name of a project created in 2005 by Jean-Claude Bradley with the aim of synthesising anti-malaria compounds developed from a perspective of open notebook science. A wiki and a blog with the same name make available his laboratory notebook and his reflections respectively.

> In Open Source Software, the code is made available to anyone to modify and repurpose. What we have been trying to do with UsefulChem is to provide the analogous entity for chemical research, which is raw experimental data along with the researcher's interpretation in a format that anyone can easily re-analyze, re-interpret and re-purpose. A good example ofre-purposing is using some results and observations from a failed experiment in a way that was never intended by the original researcher. This just doesn't happen regularly in science because failed experiments are almost never included in publications. (BRADLEY, 2006a)

He defines "open notebook science" in the following way:

> To clear up confusion, I will use the term Open Notebook Science, which has not yet suffered meme mutation. By this I mean that there is a URL to a laboratory notebook (like this) that is freely available and indexed on common search engines. It does not necessarily have to look like a paper notebook but it is essential that all of the information available to the researchers to make their conclusions is equally available to the rest of the world. Basically, no insider information. (BRADLEY, 2006a)

Posts published by Jean-Claude Bradley show that he lived up to his motto "no inside information" to the highest degree. He shared not only data and information generated by his research, exposing the dynamism, the complexities and the about-turns of scientific activity, but he also made available information that influenced the conditions under which his work was developed. Some examples are the publishing of comparative evaluation of information services on chemistry; making available computational tools created by him; recommendation of articles published by other researchers; public acknowledgement of help from collaborators; and also the open elaboration of grant proposals for his research.

The allegation that the open notebook can speed up and improve the quality of science (*"faster science, better science"*) is a recurring argument among supporters such as Matthew Todd, Anthony Salvagno and Steve Koch, and "evangelists" of open science such as Cameron Neylon, Peter Murray-Rust, among others. Matthew Todd, for example, a professor at the University of Sydney who used to work in close partnership with Bradley on a project of "open drug discovery" states that "[...] selfishly, by the point of view of a scientist" is a great advantage that "people can correct your mistake before you make them" "It helps you to be open because other people can correct your mistakes before you waste time in unproductive lines of inquiring" (TODD, 2014).

But how would keeping an open notebook attract collaborators and resources to solve scientific questions? As a teacher, Bradley observed that his students could contribute towards the opening up of scientific knowledge through the measurements they carried out during lessons. Thus, he created, in partnership with Cameron Neylon and Rajarshi Guha in September 2008, the Open Notebook Science Challenge (ONSC) – a *crowdsourcing* research project, that brought together teaching and research with the aim of collecting measurements of the non-aqueous solubility of organic compounds.

As an open initiative, anyone could join it. The only requirement was that experiments must be recorded as proposed by the open notebook science. This meant that the laboratory notebooks, where the details of laboratory work as well as the raw data upon which calculations were based, could be publicly and immediately accessed. Participants were evaluated every month by Jean-Claude Bradley, Andrew Lang, Bill Hooker, Cameron Neylon, Rajarshi Guha, Steve Koch and Anthony Williams. They accessed and commented on the open notebook, providing feedback to students with relevant opinions. The main evaluation criterion was not the number of experiments, but "who best recorded how they performed their experiments" (ONSC, 2010, p.2)

> Basically we are looking to reward students who show promise of becoming good scientists. This includes maintaining a laboratory notebook (including links to raw data) in a manner that makes it easy for others to understand exactly what you did and what you observed. The log portion of the notebook must be recorded in a timely fashion, usually within 24 hours of performing the experiment. Nobody maintains a notebook perfectly from the start and that is why the organizers will be providing feedback in bold and italics directly on your notebook pages. How quickly and thoroughly you address that feedback is an important criterion. Creativity in the design of the solubility measurement technique in terms of efficiency, speed and reproducibility will also play a strong role in the evaluation. Participation in the scientific community via Web 2.0 networks would certainly be a plus. And, of course, the number of measurements will count. (ONS CHALLENGE, 2008)

This perspective attracted the attention of other professors, giving rise to new cooperation. Brent Friesen, a Chemistry professor at the Dominican University, turned the ONSC into a task for his second-year students. Steve Koch, a researcher in Physics at the University of New Mexico, adopted the practice in his lab, encouraging his students to do the same (BRADLEY; LANG; KOCH; NEYLON, 2011, p .436).

Students also became interested and adopted this perspective. Marshall Moritz was a first-year student at Syracuse University when he found out about ONSC on the Internet. He wrote directly to Bradley, became a participant in the challenge and even received an award for the quality of his contributions in July 2009[3]. Anthony Salvagno was introduced to the practice of the open notebook through his teacher, Steve Koch. He developed a series of introductory texts on the topic. He also started the Open Notebook

[3] Avaliable at: http://onschallenge.wikispaces.com/students Acessed on 05 feb 2015

Science Network[4], an online platform that facilitates the creation and the upkeep of open notebooks with the software Wordpress.

As a scientist, keeping the open notebook allowed Bradley to know and to be known, to connect and to work at various levels with different professionals such as synthetic chemists, computational chemists, biochemists, programmers, mathematicians, journalists, chemical companies etc. If the advantage of working in an open manner is to be able to meet and to collaborate with people you have not met before, for Bradley this collaboration took on different formats.

The scientist acknowledged as valuable contributions some interactions that might seem irrelevant, but that, in fact, were beneficial to his work. For example, David Bradley's suggestion that Jean-Claude Bradley should use the British spelling of the verb "synthesise" in the comments section of one of his early posts helped the latter to expand a bibliometric research that defined malaria as his research topic in subsequent years. Another example was a comment made by Matthew Todd on the UsefulChem Molecules Blog inaugurating a partnership between them. (BRADLEY, LANG; KOCH; NEYLON, 2011, p.428).

Bradley also collaborated with Cheimformatics professionals who dealt with the challenges of representing, manipulating and communicating chemical information from the perspective of open science. He characterised this type of interaction as "metacollaboration" because it did not involve the specific aims of a project, but ways of representing and manipulating chemical information and methods to make them readable by machines (BRADLEY, LANG; KOCH; NEYLON, 2011, p. 432). In this area, Bradley collaborated in different ways with Egon Willighagen, Peter Murray-Rust, Anthony Williams and Andrew Lang: following each other's

[4] Available at: http://onsnetwork.org Acessed on 05 feb 2015

blogs, sharing experiences and knowledge or cooperating in the devising of solutions.

From the point of view of his research objectives, Bradley acknowledged as collaboration, for example, the possibility of working with virtual libraries and 3D *docking information* offered by the project *Find a Drug*. He also stressed the fact that the first "open science loop" for discovering new drugs - "where hypothesis formation, docking, synthesis, and assay results were performed openly in real time" – was carried out in May 2007, with the support of Daniel Zaharevitz, Chief of the Information Technology Branch of the Developmental Therapeutics Program do National Cancer Institute (NCI). Zaharevitz found out about UsefulChem through a network of "open scientists" and offered tests of antitumor activity (BRADLEY; LANG; KOCH; NEYLON, 2011, p. 430).

Matthew Todd also considered an advantage to find unpredictable collaboration through the "opening" of scientific knowledge and online serendipity. Currently, Todd coordinates the Open Source Malaria[5], an open research project that also adopts the self-definition of open notebook science. However, he establishes a difference between the upkeep of an open notebook and that of a blog: "You can describe what you have done daily in your laboratory without making open science" [...] "Having an open notebook is crucial, where you are honest about success and failures and what you have done, including all the raw data. That´s what I mean by open science, but it is becoming a very dilated term." (TODD, 2014).

In August 2005, Bradley (2005b) already distinguished between three types of online publications in the area of science. The first type is blogs of "general science updates" that "basically report on news in science as it comes out in press releases and publication in major journals". The second type is constituted by "personal science

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5 Avaliable at http://opensourcemalaria.org/ Acessed on 07 feb 2015

blogs" that "report on the daily grind of working in a lab" and are "usually anonymous" Last but not least, blogs presenting results of experiments and reviews of scientific literature – something he had been experimenting with his students and that, a year later, would be called open notebook science.

> This is what I would like to see a lot more of. Experimental details. Links to literature. Basically scholarship. By definition these blogs should not be widely popular because the detail required to explain the concepts makes them accessible to those familiar with the field (a nice example of the long tail). These can be new experimental results or detailed reviews of the literature. This is what I am trying to achieve with the students working in my lab or taking my organic chemistry class. It is much more difficult to maintain the standard of scientific rigor with undergraduates but I think we are getting there. (BRADLEY, 2005b)

The Pseudo Open Notebook Science

In practice, the majority of scientists who keep open notebooks adopt Bradley's policy of "no inside information" only to a limited extent. The result is notebooks that are only partially open or pseudo-open notebooks (PONS) (BRADLEY, 2009; BACON, 2008). The omission or postponement in the publication of data and information are examples of this discrepancy.

An exploratory study carried out by Grubb and Easterbrook (2011) indicated "absence of consensus on the meaning of 'open' in a group of 20 scientists identified as promoters of open science and open knowledge. Disagreements encompass different aspects of open scientific practice, including the sharing of data and results, aspects that characterise the proposal of an open notebook science. Respondents agreed that data and research results should be freely accessible to anyone, but disagreed in relation to the moment of disclosure. Some stated that it should be "as quickly as possible", whereas the great majority argued that they preferred disclosing data and results "only after publication" (GRUBB, EASTERBROOK, 2011, p.7). It is noteworthy that two participants stated that data should only be shared on demand.

The authors concluded that there are three stances in relation to the sharing of data and results: a) those who share them right away; b) those who eventually share them; c) those who believe in the sharing of data and results, but who do not carry it through due to concerns with issues of patenting and plagiarism.

Aware of these barriers, in 2009 Bradley developed a number of logos inspired by the modularity of Creative Commons licences, aimed at identifying different degrees of openness of research notebooks.

Table 1: Logos and degrees of openness in Open Notebook Science

Openness degree	Description
All Content - Immediate (ACI)	**ACI All Content - Immediate -** The entirety of the lab notebook and associated supporting raw data are available to the public in as close to real time as possible. If it isn't in the notebook others can assume that you haven't done it.
All Content - Delayed (ACD)	**ACD All Content - Delayed** - The entirety of the lab notebook and associated supporting raw data are available but after a significant delay - perhaps for patenting or publication reasons.

Openness degree	Description
Selected Content – Immediate (SCI)	**SCI Seclected Content - Immediate** - A portion of the lab notebook and associated supporting raw data are available in as close to real time as possible. Others cannot assume that if it isn't in the notebook you haven't done it.
Selected Content - Delayed (SCD)	**SCD Seclected Content - Delayed** - A portion of the lab notebook and associated supporting raw data are available after some delay. Others cannot assume that if it isn't in the notebook you haven't done it.

To clarify what open notebook science means in practice, Open Source Malaria formulated six "laws" regulating its activities. "This is a kind of conduct law, it is not the Panton Principles that are important for data, for example. This is about how you should operate if you want to be a part of the project. You don´t have to do this, but if you don´t, you can't be associated with the project" (TODD, 2014). They are: 1) All data are open and all ideas are shared. 2) Anyone can take part at any level of the project. 3) There will be no patents. 4) Suggestions are the best form of criticism. 5) Public discussion is much more valuable than private email. 6) The project is bigger than, and is not owned by, any given lab. The aim is to find a good drug for malaria, by whatever means, as quickly as possible (TODD, 2011).

THE ORIGINS OF *OPEN NOTEBOOK SCIENCE*

Open notebook science is one of many innovations in the scientific area whose origins can be located at the junction of new forms of collaboration in digital environments and influence from free culture. The practice is considered one of the initiatives of open science, a movement that congregates activists and scientists from various fields of knowledge, encompassing different meanings and initiatives[6], and adopting different perspectives and assumptions. It shares the premise that current modes of production and communication of scientific activity are inadequate and that they create, particularly in the sphere of institutionalised science, legal and economic obstacles to accessing information and knowledge. In this context, the Internet is perceived as a "technological opportunity" to resume or promote "true science". This vision had already been put forward by the pioneering movement in support of open access to scientific journals in the Budapest Declaration (2002).

> An old tradition and a new technology have converged to make possible an unprecedented public good. The old tradition is the willingness of scientists and scholars to publish the fruits of their research in scholarly journals without payment, for the sake of inquiry and knowledge. The

[6] Besides open notebook science, open science brings together initiatives such: 1) Open Access – this refers to access to scientific literature so that anyone can research, to consult, download, print, copy and distribute the complete text of articles published in scientific journals (gold open access) or kept in other sources of scientific information such as institutional libraries (green open access); 2) *Open Data* – an expression popularly connected to the question of transparency and interoperability of governmental data, but with broader content. In the area of science, Open Data requires the publishing of the primary data sets of a given piece of research because it is thought that keeping them undisclosed prevents their reproducibility and thorough scrutiny. This omission also prevents the re-utilisation of data in derived research, hiding inconsistencies, plagiarism or fraud; 3) *Open Hardware* – It refers to the unrestricted dissemination of information required for building scientific tools through the adoption of standards that ensure their reproduction in large scale; 4) *Citizen Science* – it alludes to the various degrees of participation of non-specialists in scientific research; it aims at broadening public engagement. It is not restricted to data collection or to sharing spare time of personal computers, but it can also involves data analysis and developing technology ; 4) Open Education – A trend that seeks to reconsider learning processes and that has as one of its exponents the debate about the open licensing of teaching and research materials (open educational resources).

> new technology is the internet. The public good they make possible is the world-wide electronic distribution of the peer-reviewed journal literature and completely free and unrestricted access to it by all scientists, scholars, teachers, students, and other curious minds. Removing access barriers to this literature will accelerate research, enrich education, share the learning of the rich with the poor and the poor with the rich, make this literature as useful as it can be, and lay the foundation for uniting humanity in a common intellectual conversation and quest for knowledge. (BOAI, 2002)

Jean-Claude Bradley (2013a) shares the vision that the Internet is a “technological opportunity”, but he stresses the fact that the possibility of transforming one’s relationship with information and knowledge brought about by technology may be easily discarded. The author reminds us that, since 2003, the popularisation and dissemination of podcasts enabled teachers to make teaching materials available online. However, the majority of educators chose an intermediate position, sharing only some of their materials, in the hope that they might be able to commercialise others considered more relevant or differentiated.

Going against the tide, Bradley exploits technological opportunity and an open knowledge perspective by sharing educative materials (podcasts of lessons, slides, texts etc), tips on the use of tools and reflections on his experience in the academic milieu through the blog Drexel CoAS E-Learning, started in February 2005. He signs the blog as coordinator of *E-Learning* at the College of Arts and Sciences of Drexel University.

In this blog, Bradley published a series of posts that allow us to observe that the origin of the concept is directly connected to his role as university teacher: his experience and experiments with e-learning, the debates about the shortcomings of the peer evaluation process as well as the potential of the Internet for scientific communication. Another source of information is the blog UsefulChem[7].

The idea of being useful

In the initial *posts* on the blog UsefulChem, Bradley reveals one of the factors that motivated him to elaborate the concept of open notebook science– the desire to make a "useful" contribution to society as a scientist. This desire is reflected in Bradley's choice of title for his blog "*Useful Chemistry*" and in his positive comments about the initiative by Elias Corey, from Harvard University and winner of the 1990 Nobel prize, of dedicating himself to the production of Tamiflu (oseltamivir), an antiviral drug used in the treatment of avian influenza, in a process that did not contemplate patenting. Bradley's comment on this fact was: "This is a good example of chemists focusing their attention on chemical solutions to real immediate problems, which is the spirit of what the UsefulChem project should strive to achieve and maintain" (BRADLEY, 2006b).

Starting from this desire of being useful, Bradley carried out a bibliometric study on *Google Scholar* and *Scirus* to "identify specific problems and objectives in chemistry, as stated by researchers in their articles" (BRADLEY, 2005c). Subsequently, he decided to research the development of anti-malarial drugs. In an interview to Richard Pointer, Bradley stated:

> In thinking about what has meaning for me as a scientist, I realized that the work I was doing wasn't having the kind of impact that I would like it to have, and it was not benefitting mankind in the way I would have hoped. I concluded that this was partly a consequence of secrecy.

[7] Available at: http://usefulchem.blogspot.com Accessed on 01 feb 2015

> However, I couldn't be open with the project I was then working on, because I was collaborating with someone who didn't feel the same way as me. My decision to do open science meant cutting ties with my previous collaborators. Having done that in 2005, I started the project UsefulChem (BRADLEY, 2010).

On quality: what is satisfactory information?

Bradley antecipated that the open notebook could enrich communication in science because it would offer enough information so that a reasonably competent peer could replicate the reported experiments. He acknowledged positive instances in which authors specified their methodology for collecting and analysing data in order to ensure reproducibility, but he noticed that most scientific journals offered little detail about how experiments were carried out. Information was highly condensed, even in online versions where there is no restriction of space (BRADLEY, 2007).

Faced with the constant evidence that there are gaps of relevant information in articles published in scientific journals, Bradley questioned: "What is the current standard for considering a "'satisfactory information" in Organic Chemistry communication?" (BRADLEY, 2012a). "If you are organic chemical and want to repeat an experience, you cannot figure out how they did what they say they did so, because they lack information. But if you have access to the lab notebook, you can see if it's you or him that is making a mistake" (BRADLEY, 2008c).

An example frequently referred to by the author (BRADLEY, 2012b, 2013b) to make evident the disservice caused by "dissatisfactory information" as well as the advantages of keeping an open research notebook is a situation that took place during one of his lessons. This had to do with the synthesis of dibenzalacetone, a substance commonly found in organic chemistry labs. Bradley proposed this experiment and several students used ethyl acetate to achieve re-crystallisation. This did not make any sense to him because this substance cannot be mixed with water. To understand the students' choice of this substance, Bradley traced the mains sources of information in organic chemistry and found out that it has been inadequately used in this process since the publication of a specific article in 1903.

For this reason, as he taught the course "Recovering Information in Chemistry", Bradley encouraged his students to distrust all sources of information, including the most prestigious ones. He emphasised that peer review must not be considered incontestable proof of information and legitimacy; he wanted to change his students' attitude from that of mere users to curators of information. In other words, he wanted them to be capable of collecting, selecting and evaluating relevant information in organic chemistry.

Thus, Bradley proposed another exercise: students should collect information about a specific experiment from five different sources. They should check the reliability of the content evaluating protocols and requirements of each procedure to understand discrepancies between the different sources. "This training should make them learn that no sources should be trusted implicitly". There aren't "trusted sources" (BRADLEY, 2010b).

About quantity: the wastage of relevant scientific information

Besides qualitative criteria, Bradley also analysed quantitative aspects of the dominant mode of production and communication in science. He estimated that 87% of his work would be restricted to the small group of researchers in his lab if he did not adopt the open notebook perspective (BRADLEY, 2013b). The issue was that the majority of experiments carried out in his lab did not achieve an "expected" result and, for this reason, were labelled as "failures". Even though it is inappropriate to consider as failing an experiment whose hypothesis has not been confirmed, Bradley knew that this type of result significantly decreased the chances of having it published in a scientific journal. Bradley considered as a waste of resources the difference between the volume of scientific knowledge produced by scientists and what they make available to society through formal communication.

> There is also a tremendous amount of useful information in reactions or reaction attempts that is never shared. Regardless of whether or not a reaction is 'successful', if its execution is carefully recorded it can provide valuable information. Some excellent tools and standards exist that allow for easy semantic tagging of chemical reactions and properties so that an experiment can be available for discovery as soon as it is started. (BRADLEY, 2013)

Bradley believed that the fact that a certain scientific content was chosen or not for publication by scientific journals did not make this particular content irrelevant or diminish its validity for teaching and research activity. On the contrary, his experience as a teacher and researcher was that these two instances could converge and strengthen each other when the open knowledge perspective is adopted. From his point of view, science is not made up only by "successful" experiments that achieve "expected results", but also by what goes "wrong".

The limits of peer reviews

In *posts* published between February and March 2006, consequently previous to the publication of the concept of open notebook science, Bradley concluded that the Internet and its online search engines represented a such a structural change in the access to information that the peer review process should be seen in a new way by scientists.

Bradley reported that, up to the early 1990's, gathering information was an arduous job, demanding the physical displacement of students and researchers to libraries in order to locate, analyse, select and, finally, photocopy articles of interest for their research. Peer review worked then as a curator service to help avoid wastage of time with sources of information whose return was not clear and guaranteed (BRADLEY, 2006c).

With the Internet and its search engines, locating relevant scientific literature and obtaining a copy of articles of interest through download is no longer an exhausting task. This change would alter the function of peer review, as the time spent accessing sources would be optimised by new technological possibilities. Therefore, scientists would start determining the value of a piece of scientific work on the basis of new criteria. These would be, according to Bradley, its quick availability online and the quality of descriptions of the experiments carried out (BRADLEY, 2006d).

> So, peer review, actually, the way I used it as a scientist was to make a decision as to how much time I should spend trying to hunt down a particular reference. [...] What's interesting here is I'm not really that interested in whether the article is peer reviewed or not. I'm more interested in, do they have the experimental conditions for the compound that I'm trying to make, and I can judge whether their description of the experimental is actually valid, or how likely is it to be good, just based on the way in which they describe it. [...] So it's kind of an interesting situation, because, I'm not using peer review in the way that I used to use it, to protect my time. So now it's something completely different that determines the value of an article. It's whether or not I can get it online immediately, and if I can't I usually don't bother. Again, unless I'm very desperate, and then I'll try to hunt it down. But honestly there's so much repetition now in the scientific literature that you can usually find what you're looking for online directly, or at least know that it hasn't been done, that's the other way to look at it. (BRADLEY, 2006d)

Bradley pointed out that peer review, from the perspective of the editor of a scientific journal, "is as a cost-effective way to maintain the quality and focus of journal" (BRADLEY, 2006c), but he stressed that this system of evaluation is restricted to and caters for the private interests of only three actors: 1) the author, who is interested in publishing his "findings, 2) the editor, who approves the piece of work and evaluates its conformity to the editorial policies of the journal with the aim of ensuring it is seen as a reference in a specific area of knowledge, 3) the evaluators, who analyse the information, but are not obliged to replicate the experiments that subsidise observations and conclusions (BRADLEY, 2012a).

In this context, "Peer review is not intended to validate individual measurements - its function is to ensure that the authors made appropriate conclusions based on their processed datasets and the state of knowledge in the field" (BRADLEY et al., 2009, p. 2). Thus, if evaluators do not replicate experiments, they cannot check the possibility of fraud. "This only can be determined over time, after other researchers have had a chance to try to use reported techniques" (BRADLEY, 2006c). Bradley considers that "When supporting information is not immediately available, peer review may not work the way many assume it does" (BRADLEY, 2005a).

> With these criteria, I think that (if done with care) blog posts of scientific research are potentially easier to authenticate than a paper in a printed journal because every statement can be supported by a hyperlink that can be immediately verified. Every conclusion can be supported by online data. It will be interesting to see how close we can get to this with the two students working in my lab and blogging about it this summer (BRADLEY, 2005a).

Besides, Bradley acknowledged the fact that a series of scandals, such as the publication of frauds and of computer generated documents of random jargon, added to the facility of creating an online "scientific journal" with anonymous evaluation, turned the expression peer review into an indicator of poor quality (BRADLEY, 2006c). He questioned:

> The idea that peer review is useful to "authenticate" research has always seemed a bit strange to me. After all, the targeted audience for most scientific articles consists of (by definition) peers of the author. What makes the reviewers selected by an editor any more capable of validating an article than the targeted audience? (BRADLEY, 2006c)

Starting from this scenario of uncertainty and anonymity, Bradley intended to teach his students to distinguish what he considered an "apparently authoritative reference" and an "authenticable one" (BRADLEY, 2005a), developing "the ability to assign a probability of authenticity to a document found out of context" (BRADLEY, 2005a). "I am not saying that peer review is of no value. [...] But how do those reviewers authenticate the manuscripts they receive for publication in those journals? Those are skills I want my student to learn". (BRADLEY, 2005a). He commented: "In chemistry, that means that every statement expressed as a fact has a reference. Every conclusion is linked to experimental data. Opinions and speculations don't need a reference - the author is the reference" (BRADLEY, 2005a).

The importance of the miscellaneous

Despite the fact that his main argument was that articles published in peer reviewed journals were a reduced version of scientific activity, whose wealth of details was kept under lock and key in the notebooks behind the closed doors of a laboratory, Bradley (2008b) perceived the open notebook as a complementary tool not intended to replace the current format, but to enrich it: "There is a plenty of room for both types of communication" (BRADLEY, 2006c). And he adds:

> If you work in a lab for a couple of years, one day you realize that almost everything that you do does not get published, because the experiments have either failed or there suboptimal someway and they have to be repeated […] If it does not fit into a bigger history that you can wrap up, you really can't publish it. So we are not avoiding publishing normal articles, we are just basically putting our lab on a wiki directly so people can benefit of what we do in day-day basis." (BRADLEY, 2006f)

In the quote above, Bradley identified another important characteristic of the dominant mode of scientific communication that he intended to transform: the need to build a narrative, "a bigger history that you can wrap up", to publicise scientific knowledge through peer reviewed articles.

The research paradigm in chemistry requires the elaboration of experiments based on established theory or potentially new theory in the field; these experiments must be executed and procedures and results must be recorded in laboratory notebooks. However, the process of communicating scientific knowledge to a wider audience only starts when certain results are reached. At this stage, a summarised and edited version of what was carried out in the lab is elaborated, putting together a coherent narrative and a limited amount of information and of supporting data. This version corresponds to the format of the scientific article, presenting a cohesive report on the scientific activity in which all the parts seem to be in the right place all the time.

Given his experience, Bradley knew that science, on the contrary, is a disorderly process, with backward and forward moves, unconfirmed hypothesis and a lot of re-working. For these reasons, he hoped for greater transparency in science, not only to prevent fraud, but also to promote opportunities for teaching and learning.

> There is not a document produced by a human being that is not shaped by a motive other than impartial disclosure. Often what is not mentioned is just as important as what is. Experiments that don't yield desired results are usually not reported. And that is even more true for experiments that are somehow botched or suboptimal in some way. Any chemistry grad student can tell you that there is tremendous value in discussing failed experiments with others who are equally or more knowledgeable. However, this discussion is usually limited to lab co-workers. By recording ongoing experiments in blogs, I can help you just by knowing what you are trying to do, even if you have not yet succeeded. (BRADLEY, 2006e)

Besides transparency and access, through platforms indexed by search engines, Bradley intended to promote "replication". In his own words, "There is no gatekeeper to convince in this system. No software to download. No server to set up. Almost no learning curve. Anyone doing science is free to replicate in their field of interest. Fully democratic science." (BRADLEY, 2006e)

The author concluded that "we have to separate the problem of efficiently communicating scientific information from the problem of convincing a committee of the impact of a faculty member's scholarship" (BRADLEY, 2006c). Considering that peer review is a "kind of gold standard in academic promotion and tenure when counting publications" (BRADLEY, 2006c), the process of communication in science requires the elaboration of narratives, the presence of authors and a publication format that operates like assets that build and confer value to careers. Therefore, the credit system in science formats the manner whereby scientists disseminate their work.

"And when doing open science, the first concern is the communication of the information." To this end, Bradley proposes a major change: "First disclose, then discuss and finally convince, when necessary." (BRADLEY; 2006d)

A FEW COMMENTS

This paper presents the partial results of a non-exhaustive documental analysis aimed at systematising the ideas of Jean-Claude Bradley, author of the notion of open notebook science. In accordance with what we reported above, we believe that the proposal for open notebook science should not be reduced to an incremental innovation of the traditional tool for recording scientific activity. It should not be confused either with scientific blogs that disseminate science to a wider public, often operating a kind of translation of the hermetic language of researchers to another language, accessible to non-specialists. Open notebook science is part of a wider and consistent debate about science, motivated by Jean-Claude Bradley's personal ambition of transforming scientific activity and fostering learning processes.

The open notebook is an innovation that intends to change the production and communication of science, developed on the basis of Jean-Claude Bradley's perception that scientific activity is, even nowadays, based excessively on trust. Therefore, one of its objectives is to promote transparency in the processes of validation of scientific knowledge, replacing trust with proof.

> A major flaw in the current scientific publication system is that there is still too much trust. Readers are expected to trust editors to choose appropriate anonymous peers to review submissions. Reviewers trust primary authors when reporting the summarizing of their research results. Primary authors trust their collaborators, students and postdocs to give them accurate information when writing papers. If we make the laboratory notebook and all associated raw data public we can significantly reduce the amount of trust required to keep this house of cards standing. (BRADLEY, 2007)

When he stated that "Science is about mistrust", Bradley reminded us that "a key aspect of the scientific revolution a few centuries ago was moving from trust in an authority to mistrust of everything and everybody" (BRADLEY, 2007). His scepticism is not focused so much on the fabrication of data, even though he believed that it did occur, but on the "trusted source cascade" that arises from the mistakes and shortcuts that scientists take in order to publish scientific articles under pressure. He points out that "[...] once these errors are in print it is very difficult to get people to correct them, if they are ever discovered (BRADLEY, 2007)".

To this end, Bradley wanted to change the habit of scientists and students of using certain information based only on the fact that it had been published in peer reviewed scientific journals, with no regard for details and for the provenance of data underpinning their conclusions. He also wanted to encourage scientific rigor and pointed out that "as long as scientists don't provide full experimental details recorded in their lab notebooks, this type of uncertainty will continue to plague science" (BRADLEY, 2010b). This is why phrases such as "*no trusted source*" or "no inside information" are recurrent in his posts.

Bradley wished to open up the "black box" of science because, once data and information created or associated with research is openly available, it allows for the study, scrutiny, validation or rejection by a broader audience than the traditional process of peer review. Even though other factors, such as asymmetries in information, lack of materials, tools or infrastructure might hinder access, the use and re-use of scientific knowledge is recorded in open notebooks.

It is important to keep in mind that Bradley's emphasis on the need to keep detailed records of experiments carried out in science labs should not be confused with placing excessive value on written knowledge. On the contrary, in several posts, the author points out that his desire to communicate information on chemistry "in the best possible way" was not restricted to a specific medium. He tried out different tools and online services. Besides podcasts, he used Flickr to share images of experiments; *Second Life* to create 3D visualisations of molecules; *Youtube* to publish his experiments and presentations. Bradley also published a paper[8] on the *Journal of Visualized Experiments* (JOVE), a peer reviewed scientific journal that publishes articles on experimental techniques in audiovisual format.

> It really is true that we can save an awful lot of words with a quick video or image when reporting experiments. Even for ostensibly simple procedures like distillation it is amazing how everyone in our group had different assumptions about a "standard setup". In these cases the pics were invaluable to fill in for everything not said in the log. Videos are usually even more useful because the dynamics of a reaction can be ascertained. (BRADLEY, 2006g)

Finally, it is worth remembering that open notebook science is an extremely new concept, originally elaborated within the field of organic chemistry by a professional scientist working at a university in the USA, with a particular experience in the areas of teaching and research and particular ties with debates on open science. This context influenced Bradley's initial conception, but practice may cause it to take on new formats as it is still under construction by its followers. This documental research has not uncovered any records indicating that Bradley intended to make open notebook science into a standard procedure in the field of chemistry, much less for other disciplines. However, scientists from other areas of knowledge, particularly biology and physics have been experimenting with this concept and may develop new formats for it on the basis of their understanding.

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8 BRADLEY, J.; MIRZA, Baig Mirza, K.; OSBOME, T.;WILLIAMS, A.; OWENS, K. Optimization of the ugi reaction using parallel synthesis and automated liquid handling. *J. Vis. Exp*. n.21, e942, 2008. doi:10.3791/942. Disponível em: http://www.jove.com/video/942/optimization-ugi-reaction-using-parallel-synthesis-automated-liquid. Accessed on: 28 jan.2015

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12

Guidelines for a contemporary, open academia

Alexandre Hannud Abdo

INTRODUCTION

As a researcher interested in taking advantage of current possibilities to work in harmony with practical academic principles – criticism, verifiability , incrementality, recombination, replicability– and those of society – dialogue, participation and rational use of resources – I often face the lack of support or obstacles to the good fruition of my work. Several times these difficulties arise from the very lack of technique and habit of doing research with such possibilities in mind, but there is also a lot which academic institutions can do for those who have been fighting against the cultural inertia of a profession.

Universities, institutes and research agencies, especially in Brazil, have lived at least for a decade in a state of contradiction. On one hand, the movement for more sharing and collaboration with respect to knowledge kept and produced, and with respect to available resources, cannot be postponed any longer, as we see a growing number of applications in academia of innovations made possible by technology and by collaboration and sharing culture, which have already transformed and made more dynamic both society and the economy (BENKLER, 2006). Even in administrative aspects there is an urgent need to cast light over the accounts and contracts of those institutions. On the other hand, a corporative attitude, of high walls and of "owners of knowledge", acts against these innovations. Disconnected from contemporaneity and fed by habit and for the justified perpetuation of the way of life of part of academia, this kind of attitude manifests itself in different aspects of academic life, and can be found sometimes entrenched in vicious cycles of privileges and anachronistic interests. These need to be overcome so that, gradually, academia may give room to new experimentations with its modes of production.

Infrastructure, training and scientific policy – the latter in terms of funding, acknowledgement, guidelines and incentives – are aspects of academic life over which institutional support can make a difference to the adoption of operational innovation. By crossing them with the axes of practice of open science, from open access to citizen science, it is possible to draw a framework for what needs to be done in order to position an institution as mobilizer of a more effective and development prone kind of research.

This text does not seek to justify a position for open science, which we believe has been extensively justified in so many others (NIELSEN, 2011; CARDOSO; JACOBETTY; DUARTE, 2012). Thus, we start from the principle that universal and immediate access to the products of scientific processes, which allows for collaborative participation in this process and stimulates competition that rewards the capacity for innovation and not access to the means, is of the essence in detailing de actions described.

INFRASTRUCTURE

REPOSITORIES

Research work has several products which, from a perspective of open science, we wish to share. Theses, articles, books, educational resources, multimedia objects, data, protocols, designs (instrument documentation), software and materials are part of this universe. Institutional repositories are extremely important to reduce researcher's efforts to preserve and share such products of his/her work so that others may study them and work on them. In order to maximize their openness impact, these repositories must be interoperative with other institutions, replicable and likely to be aggregated into reference centres. They must also be developed openly, and identify in their content the licenses and other associated clearances.

These repositories do not need to be the property of each institution, but may result from consortiums or direct funding into repositories shared by different institutions.

In Brazil, a significant number of institutions have repositories for theses and articles, however very few present or participate in repositories for other categories. Notably, during some time as from 2003, there was development and availability of a software repository within the State of São Paulo Research Foundation (Fapesp), as part of the Virtual Incubator project (SIMON, 2004), which was closed due to economic difficulties after the end of their umbrella project, TIDIA (Information Technology in the Development of Advanced Internet Project). It must also be mentioned that there are some repositories in the country dedicated to the systematization of data of thematic collaboration, like SinBiota[1], even though they are restricted.

In practical terms, Brazilian researchers who, out of their own interest or requirements of their areas of study use any repository, resort to public repositories, whether or not they have an academic basis and maintained without the participation of national institutions. That is the case of data repositories

1 Available on: http://sinbiota.biota.org.br/about/. Access on: December 4, 2014.

(Dataverse[2], GenBank[3], Figshare[4], PaleoBioDB[5]), *software* (Sourceforge[6], Gitorious[7], Github[8]), of multimedia objects (Wikimedia Commons[9], Flickr[10], YouTube[11]), of articles (arXiv[12]), *designs* (CERN Open Hardware Repository[13], Instructables[14]), materials (iGem Registry of Standard Biological Parts[15], DNASU Plasmid Repository[16], Addgene[17], repositories aggregated to Specimen Central[18], EuroBioBank[19], Cooperative Human Tissue Network[20]) etc.

However, caution is needed because these repositories in principle are not linked or do not have responsibilities towards the researcher or their institutions. Thus, except in cases in which they are managed by initiatives with solid academic basis, such repositories do not fulfil the need for institutional repositories and should not be trusted for the preservation of their contents, because their business models, access policies and their mere existence are subject to change with no public commitment.

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2 Available on: http://thedata.org/. Access on: December 4, 2014.

3 Available on: http://www.ncbi.nlm.nih.gov/genbank. Access on: December 4, 2014.

4 Available on: http://figshare.com/. Access on: December 4, 2014.

5 Available on: http://paleobiodb.org/. Access on: December 4, 2014.

6 Available on: http://sourceforge.net/. Access on: December 4, 2014.

7 Available on: https://gitorious.org/. Access on: December 4, 2014.

8 Available on: http://github.com/. Access on: December 4, 2014.

9 Available on: http://commons.wikimedia.org/. Access on: December 4, 2014.

10 Available on: https://www.flickr.com/. Access on: December 4, 2014.

11 Available on: http://youtube.com/. Access on: December 4, 2014.

12 Available on: http://arxiv.org/. Access on: December 4, 2014.

13 Available on: http://www.ohwr.org/. Access on: December 4, 2014.

14 Available on: http://www.instructables.com/. Access on: December 4, 2014.

15 Available on: http://igem.org/Main_Page. Access on: December 4, 2014.

16 Available on: https://dnasu.org/DNASU/. Access on: December 4, 2014.

17 Available on: https://www.addgene.org/. Access on: December 4, 2014.

18 Available on: http://www.specimencentral.com/. Access on: December 4, 2014.

19 Available on: http://www.eurobiobank.org/. Access on: December 4, 2014.

20 Available on: http://www.chtn.nci.nih.gov/. Access on: December 4, 2014.

Scientific communication platforms

Besides repositories, the academic community needs platforms for the management of their communication processes. That includes peer review and journal publications, the organization of conferences and the publication of annals, as well as channels for collaboration and exhibition, or prospecting collaborators from inside and outside academia. Moreover, we may contemplate the registration of research journals, particularly within the open research journal practice.

In this category in Brazil, there are among others SciELO[21], The Lattes Platform[22], Stoa[23] network and the closed down Fapesp's Virtual Incubator.

SciELO, whose aim is the publication of periodicals with open access, has shown interest in making available more dynamic tools to support the execution of the editorial process, like the software Open Journal Systems[24] and recently there are signs of opening its software basis through programming interfaces which would allow access to data through third party applications (APIs), opening the way for innovative uses.

As for the Lattes platform, from the National Council for Scientific and Technological Development (CNPq), a national bank of academic résumés which has the aim of facilitating the evaluation and contact between collaborators, operates exclusively in static form, with no interoperation with other instruments or the possibility of downloading its data, despite the requirements of the Information Access Act, making it difficult for any innovative use for scientific evaluation or collaboration.

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21 Available on: http://scielo.org/. Access on: December 4, 2014.

22 Available on: http://lattes.cnpq.br/. Access on: December 4, 2014.

23 Available on: http://stoa.usp.br/. Access on: December 4, 2014.

24 Available on: https://pkp.sfu.ca/ojs/. Access on: December 4, 2014.

An interesting case is the creation of the Stoana USP network, in 2007, which provides for virtual learning environments based on the software Moodle, plus a wiki space, for the collaborative production of web pages, based on the software Media Wiki, and the creation of blogs and the organization of communities and events based on the software Noosfero.

Prior to this initiative, during a period of time starting in 2004, there was development and availability of a platform for collaboration portals, based on the software Plone, within Fapesp's Virtual Incubator project (SIMON, 2004), mentioned before.

Other communication and collaboration environments are hosted by foreign organizations, but used in Brazil. The most important example is Wikipedia[25], used daily not only by some academics developing their work and study, but by the lusophone population for general learning and culture, and being developed by voluntary contributions from part of both groups.

A brother project to Wikipedia is also adopted by Brazilian researchers: Wikiversity[26]. It hosts wiki pages for groups and professional research projects , or learners and amateurs, who can create spaces there to present their work, organize collaborations and keep registers of study or research, like open research journals, with the possibility of receiving contributions or simply guaranteeing the transparency of the work.

It is noteworthy that the use and participation in these wikis by Brazilian academia lacks recognition or institutional support. In spite of that, there are interesting cases of academics using them on an individual basis, both in class and in research projects, in order to promote collaborative forms of learning and investigation.

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25 Available on: http://pt.wikipedia.org/. Access on: December 4, 2014.

26 Available on: http://pt.wikiversity.org/. Access on: December 4, 2014.

The Wikipedia at University programme[27] must be highlighted in this respect.

Still on the international front, there are other wikis like OpenWetWare[28], environments for the creation and recombination of teaching material like Connexions[29] , social media focused on academics like academia.edu[30] and also the use, oriented to research aims of other social media and non-specific platforms like Wordpress, Twitter and RedMatrix.

Fabrication laboratories

If we consider the possibility of collaboration on shared design of scientific instruments, a requisite for the total use of these opportunities is the availability, at teaching and research institutions, of equipment for their development. If possible, they themselves open and using free software. Examples are 3D printers, laser cutters, lathes, milling machines and similar tools, controlled via Computerized Numerical Control (CNCs).

In this line, institutions like the Academic Techonological Centre of the Federal University of Rio Grande do Sul - UFRGS[31], are already trying to build and standardize a basic set of open manufacturers which allow the production of most parts of scientific instruments based on their design, besides innovating by improving existing design and developing new instruments.

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27 Available on: https://pt.wikipedia.org/wiki/Wikip%C3%A9dia:Wikip%C3%A9dia_na_Universidade/Cursos. Access on: December 4, 2014.

28 Available on: http://openwetware.org/wiki/Main_Page. Access on: December 4, 2014.

29 Available on: http://cnx.org/. Access on: December 4, 2014.

30 Available on: http://academia.edu/. Access on: December 4, 2014.

31 Available on: http://cta.if.ufrgs.br/. Access on: December 4, 2014.

Free Computing

When using or collaborating with the use and development of scientific application software, the members of an academic institution would benefit from developing their work and study in free computational environments, with open codes. It is incumbent upon the institutions, therefore, to make available and to promote computers with free operational systems and free programming languages for the use and development of those software.

To that end, some institutions have introduced the Competence Centres in Free Software, like USP in the Butantã[32] and São Carlos[33] campi, and the IFRN[34] , in the Caicó campus.

Multi-user equipment

The practice of constructing multi-user equipment makes viable not only the rational use of resources, allowing more widespread and fair access, but also stimulating collaboration among researchers using this kind of equipment. This process includes the availability of computational resources, like the Nuvem USP[35], laboratory facilities like the Nanotechnology National Laboratory[36], and large scale scientific equipment, like the Brazilian Synchrotron Light Laboratory[37].

32 Available on: http://ccsl.ime.usp.br/. Access on: December 4, 2014.

33 Available on: http://ccsl.icmc.usp.br/. Access on: December 4, 2014.

34 Available on: http://ccsl.ifrn.edu.br/. Access on: December 4, 2014.

35 Available on: http://www.cce.usp.br/?q=node/52. Access on: December 4, 2014.

36 Available on: http://lnnano.cnpem.br/. Access on: December 4, 2014.

37 Available on: http://lnls.cnpem.br/. Access on: December 4, 2014.

TRAINING

Support teams

In order to orientate and help researchers and research groups to adopt several open science practices, let us consider the organization of technical support teams, made up or supported by librarians and researchers with relevant experience. A series of actions are allocated to these teams.

With respect to publications, they should produce and forward personalized suggestions on open access periodicals of more relevance to each researcher of a given institution. With respect to the data, they should help researchers to preserve and share their data, adding metadata and appropriate annotations, and to choose the means and the repository where to share them. With respect to design, materials and other research objects, they should guide researchers to find the appropriate formats, licenses and procedures to preserve and share them, identifying the best repositories or, if those are not available, institutions or solutions for that.

In all cases, it is necessary that these professionals have the basic understanding on licenses for the general public and storing formats applicable to each object type, that they understand the importance of free licenses and open formats for preservation and sharing, and that they know how to seek orientation for themselves when more complex matters arise.

Besides the support to preservation and sharing, these teams could also help research groups to communicate effectively online, be it in contacts that lead to collaboration, or in the organization of information and group procedures, and in the production of open research journals.

Together with the existing open science communities, these teams may form permanent reference spaces for learning and improvement of practices.

Courses and workshops

Adopting open practices in research requires the learning of concepts and procedures which are still being incorporated by general academic culture. With that in mind, institutions may, together with their more informed members and with existing open science communities, organize workshops and produce materials about new sharing practices and collaboration in academic work. In addition, they may, in other training activities whose topics relate to innovation in open science, include considerations which are pertinent to such innovation. For example, workshops to enable researchers in the writing and publication of articles must highlight the importance of open access, and give guidelines and resources aimed at publication in periodicals which practice such access.

Another point is that open academic practices frequently involve the use of information technology. Considering that the general quality of comprehension and practice of computing is still very incipient by most part of academia, even where it is routine and essential for the production of knowledge, it is doubly beneficial to promote courses to elucidate researchers on the functioning and practical use of computers. The Software Carpentry[38] initiative, which is also in operation in Brazil, has exemplary work in this sense.

Learning material

It is important that manuals and learning guides are produced for support or self-instruction, and institutions can confer these materials more quality, professional production and recognition. Videos, texts and high standard multimedia resources, made available with free licenses and open formats, enhance the quality

38 Available on: http://software-carpentry.org/. Access on: December 4, 2014.

of local learning and can also be adopted and adapted to other contexts, promoting the recognition of the creator institution.

SCIENTIFIC POLICY

In relation to institutional policies, it is possible to suggest actions at different levels which would benefit and qualify the scientific production through incentives and facilitation of more openness.

Publication

Funding publication costs of free access periodicals, as already done by some institutions. Parallel to that, invest in the quality and recognition of open access periodicals organized by the institutions themselves, scientific associations and other non-profit making groups. These actors are particularly important to guarantee the publication will not be charged when the researcher does not possess the means, as done by Public Library of Science[39]. With that, pressure can be put on actors with profit making aims to adopt similar policies, like those of PeerJ[40].

It must be predicted that the results of the research carried out at the institution or with its support will be published with open access.

Recognize and reward researchers who opt for publishing with open access. To strengthen the consensus of the Budapest Open Access Initiative[41], particularly the need to use free licenses and open formats. This implies avoiding licenses with incompatible restrictions, like those which restrict commercial aims.

39 Available on: http://plos.org/. Access on: December 4, 2014.

40 Available on: https://peerj.com/. Access on: December 4, 2014.

41 Available on: http://www.budapestopenaccessinitiative.org/translations/portuguese-translation. Access on: December 4, 2014.

Data

Institutions must anticipate that data produced by research projects conducted by their staff or with their support will be deposited in open access public repositories or at least made available for institutional preservation.

Periodicals must anticipate that unpublished data used in articles are published with the latter, made available in trusted open access repositories. In relation to data from previous research, it is important that the way in which other researchers may obtain them is duly informed.

Specialized periodicals must be encouraged to publish and recognize the production of data, documenting this production, indexing it and allowing it to be cited.

Recognize and reward researchers who opt for publishing their data openly.

Reinforce the adherence to orientation of formats and licenses contained in the Panton Principles for Open Data in Science[42], as well as those referring to the citation of data in the Joint Declaration of Data Citation Principles[43].

Instruments

It must be predicted as a functional and funding requisite, with the availability of funds for that purpose, that researchers document their designs for scientific instruments and improvements, making them available in open repositories, as well as the publication of software developed for research purposes with their code available under a free license, such as GNU-GPL[44] or MIT[45]. In the same

42 Available on: http://pantonprinciples.org/. Access on: December 4, 2014.

43 Available on: https://www.force11.org/datacitation. Access on: December 4, 2014.

44 Available on: http://www.gnu.org/copyleft/gpl.html. Access on: December 4, 2014.

45 Available on: https://pt.wikipedia.org/wiki/Licença_MIT. Access on: December 4, 2014.

way, that the use of instruments available in these repositories is preferred in relation to non-shared alternatives.

Research groups which use the same or similar instruments must be encouraged to collaborate with their production and improvement.

There must be investment for the production of open instruments design as a replacement for non-shared alternatives. A survey can be done to find out which instruments would have more impact if open, and then task forces could be put together to produce them.

Recognize and reward researchers who opt for publishing their designs openly.

Reinforce the adherence to free licenses, such as CERN Open Hardware License[46], adopted by the CERN repository of equipment design.

Materials

It must be predicted as a functional and funding requisite that the protocols and documentation of materials obtained in research work, and the materials themselves, when applicable, are shared in open repositories, with resources made available for that.

Recognize and reward researchers who opt for sharing their materials openly.

Reinforce the adherence to well structured banks and procedures in each institution or area.

Research process

Recognize and reward researchers who opt for conducting their research openly, sharing their research journals for collaboration, usually through wikis or academic blogs.

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46 Available on: http://www.ohwr.org/projects/cernohl/wiki. Access on: December 4, 2014.

Publicize research findings in order to motivate the collaboration of researchers in other areas or groups and institutions.

Pull together concentrated efforts for open and massively collaborative research in areas where this transparency and collaboration may be critical for the advancement of knowledge.

Promote the investigation and improvement of virtual environments which favour scientific collaboration

Innovation

Policies for innovation must contemplate the possibility of researchers' option for a paradigm of open innovation, free from patents or, if necessary, to register patents for recognition or defence, publishing the innovation with licenses that allow royalty-free access, but requesting from users the commitment to reciprocate this freedom in case they distribute modifications of that innovation. An instrument that performs these objectives is CERN Open Hardware License, already mentioned in this text.

It is important to note that in the current innovation discourse, the efforts to map out and make innovative contributions more visible get mixed up with a view of the monopolistic exploration of patents as the main destiny of these innovations. This is an ideological perspective, disconnected from what economic science has to say about the issue, especially from the perspective of developing countries. It is urgent to experiment with new approaches to innovation which are not tied up with the reinforcement of monopolies.

Education

Institutions must recognize and encourage contributions to knowledge spaces in which the logic of openness and public spirit predominate, such as Wikipedia, Wikibooks and Wikiversity, apart from science blogs.

It must be presumed that all learning material produced or financed by public institutions is deposited in open repositories under the conditions of Open Educational Resources.

Recognize and reward researchers who opted for sharing their educational resources openly. For example, in Brazil, the Federal University of Paraná (UFPR) confers an increase of 25% in the teaching staff point system for Open Educational Resources[47].

In face to face classes, teaching dynamics based on active learning such as peer-learning and SCALE-UP[48] must be stimulated, re-directing the role of lectures in favour of videos and other asynchronous resources (HENRIQUES; PRADO; VIEIRA, 2014).

University publishers must be provoked to renew their economic and intellectual models, working to reproduce Open Educational Resources, focusing on digital publications, investing in environments which allow the adaptation of these resources, and establishing printing according to client demand or product requisite.

Reinforce the Cape Town Open Education Declaration[49], in particular with respect to free licenses and open formats for educational resources.

Citizen science

Academia must recognize spaces for the production of knowledge which are non-professional or not linked to traditional institutions, be they virtual like communities linked by wikis,

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47 UFPR is a pioneer in valuing Open Education Resources (OER). UFPR Social Communication Department, 2014. News. Available on: http://www.ufpr.br/portalufpr/blog/noticias/ufpr-e-pioneira-na-valorizacao-de-recursos-educacionais-abertos-rea/. Access on: December 3, 2014

48 Available on: http://scaleup.ncsu.edu/. Access on: December 3, 2014.

49 Available on: http://www.capetowndeclaration.org/translations/portuguese-translation. Access on: December 4, 2014.

discussion groups, collaborative repositories, social media and other environment, or physical, like hackerspaces, makerspaces, culture points and similar organizations. In addition, there must be a register and evaluation of the interchange between universities and these community spaces for the production of knowledge, to understand the importance of this interchange in social development and innovation, and thus suggest improvements for orienting universities. Better structured citizen spaces must be understood as centres for the production of knowledge and able to receive funds for research in their role as research institutes.

Extension actions, more than sharing of knowledge, must expand the space of the university, reaching all people and the whole territory, within a maximum perspective to engage the totality of the population in the academic production and its application.

It is also necessary to promote the investigation and refinement of instruments which allow the population to contribute with computers and other resources, or performing data collection and cognitive activities for academic projects in a distributed mode. For example, BOINC[50] and PyBossa51 instruments. Besides their adoption by research groups.

In addition to contributing with tasks or resources, academic production must recognized and foster the participation of citizens as full collaborators in equal conditions to professional collaborators, be this citizen participation originated from group initiatives in academic institutions or from the very citizens acting in non- professional spaces.

50 Available on: http://boinc.berkeley.edu/. Access on: December 4, 2014.

51 Available on: http://pybossa.com/. Access on: December 4, 2014.

Evaluation and recognition

As highlighted in specific cases, institutions my give recognition and incentives to their members or beneficiaries who opt for open practices. But more than that, many open practices may, immediately over an agreed transition period, be incorporated into the requirements of academic work. That can be done in levels of granularity: of the advisor, the research group, the department, the institute or area, the university or agency.

The proposal for an open academia still requires and allows the improvement of the evaluation systems. By making possible the indexing and referencing of what before were the insides of the production process, it opens the way for expressions of recognition more which are more significant than mere citations. These new forms do not even need to fit the article authoring scheme, nor need they to be restricted to a process of linear review. There is a need and the opportunity for institutional investment in more informative forms of evaluation of research work, understanding that research with open practices facilitates this improved evaluation and should be favoured for that reason.

The evaluation of researchers, given this wealth of information, will also benefit from more transparency and explicitness of its reasons, instead of having opaque committees deciding on the distribution of merits and academic resources, or an appeal to numerology so as to avoid developing appropriate processes and taking responsibilities.

Specifically on open practices, it is possible to promote the theoretical and experimental study of its advantages and difficulties in the face of current production models, leading to more efficient policies to stimulate openness and to receive its benefits. Within this experimentation spirit, as well as with a sense of vanguard, it is reasonable and expected that institutions create special funding lines with expectations of total opening of academic work.

ON THE WAY TO DEMYSTIFYING KNOWLEDGE

Hand in hand with the opening of their practice, it is also incumbent on academic institutions to contribute to the demystification of scientific process. It must be understood that the general demystification of institutions – public and private – is on course. Requirements for transparency and participation have never been so intense or gathered such numerous adherences. And together with that, there is a process of replacement of social functions, where Wikipedia, YouTube and also the massive online courses represent the reinvention of the organization and transmission of knowledge and culture, starting from more transparent and participatory relationships.

In Brazil the context for these occurrences must be pointed out: an academic community just out of a period of dictatorship and still fighting against the cultural and institutional heritage of that period, led to an ill-prepared expansion and exposed to the power that dialogue acquired in the transition for a more democratic society, power that was multiplied in the interconnected society. Thus, the first reaction of this community may have been to protect itself from this dialogue, through the tools at hand, the maintenance of the mystification inherited from dictatorship, with isolation and little dialogue about their processes and institutions. They became little capable of intelligence as a collective, suffering from creative paralysis before the new possibilities for the diffusion and production of knowledge, except for rare enlightened impositions. This irrationality, this mystic posture of institutions and the academic community have delayed advances and when these delays are surpassed without their participation, the credibility and social role of academia is transferred to other actors. There are also economic, political and administrative consequences of this phenomenon, but they will not be discussed here.

Our aim is to propose that measures be taken to change the posture of institutions and of the academic community, exposing themselves and making known to themselves and to society the dynamics and objects of their research, of their organization, and of the distribution of resources, their social nature and the collaboration networks among peers which lay the foundation of their reliability, and also their fragilities and the mistakes made. This entails actions ranging from the reformulation of school teaching materials to the dismantling of the myth of the individual scientist and to stimulate the proximity with research practice; to the stimulus, in undergraduate courses, to joint reflection on science; to the critical adoption of open practices in research, like those discussed in this text; until, finally, the intensive use of information and research registers, from the individual to institutional level, in order to re-establish the science of science, making the rethinking of processes a routine and integral fact – which will only be possible under an open practices paradigm.

Nowadays, there is no need to set limits to the participation of society in the production of knowledge. In the near future it is possible that such limits will not even be accepted , given the damages they may cause. Following on the advances of the access to technologies and of the availability of information, every day it is more incumbent upon the individual researcher, professional or citizen, to opt for the desired degree of participation, and not up to academic institutions and professional researchers of the area to regulate it. For the latter, the responsibility is to structure the production of knowledge so that the maximum number of contributions may be accommodated.

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This book brings contributions by researchers from different areas and a wide range of countries, including Brazil, who have a significant role and reflection in the field of open and collaborative science. Open Science is part of the new dynamics of production and circulation of knowledge as well as the new role played by these dynamics in contemporary processes of social participation and change. Thus, this publication is geared not only towards the academic world, but also to everyone who cares about the democratisation of knowledge and information.

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