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

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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]

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[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

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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

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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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