Open Science Hardware for Citizen Science in Southeast Asia and Africa

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Objectives

The OCSDNET study[1] conducted between 2015-2016 in Indonesia, Thailand and Nepal (the Global South) focused on using open hardware, DIY (Do-It-Yourself) and DIWO (Do-It-With-Others) approaches for Citizen Science engagement (Fienberg, Gay, Lewis, & Gold, 2011; Gura, 2013; Paulos, Honicky, & Hooker, 2008). We organized and followed seven workshops of various sizes with over 120 participants who built open source science instruments. Our objective was to understand how learning to build infrastructure for research (instruments) influences the understanding and appropriation of science in the Global South. We found evidence that the experience of instrument building supported inclusive, interdisciplinary and critical approaches to science and technology. It improved communication between amateurs and experts, supported cooperation between formal and informal institutions of research, integrated scientific practices and tools with traditional crafts and indigenous knowledge, and empowered local communities and projects. In this paper, we will compare our experiences from SE Asia with Afrimakers, a similar project (2014- present) conducted by Stefania Druga in Africa where 150 participants from 8 African countries designed, built and tested prototypes for 11 citizen science workshops and collaborated with teams from neighboring countries. Afrimakers project[2] explored new ways of engagement and learning by connecting technologies and processes from the technology hubs and makerspaces with local know-how and materials from communities, such as metal or wood cooperatives. A team of three fellows from each country would go and train the team from the next country by ensuring that training and know-how is done locally and the future collaborations between neighboring countries facing similar issues, such as pollution and infrastructure limitations, would forge a long term collaboration.

[1] http://ocsdnet.org/projects/hita-ordo-natural-fiber-honf-foundation/
[2] http://www.afrimakers.org/

Perspectives

Research on Do-It-Youself biology (Delgado, 2013; Kuznetsov, Taylor, Regan, Villar, & Paulos, 2012; Seyfried, Pei, & Schmidt, 2014) and related practices in bioart (Bureaud, Malina, & Whiteley, 2014) are converging with calls for eScience, Open Science, Open Access and Open Data (Molloy, 2011; Neylon & Wu, 2009; Uhlir & Schröder, 2007). Attempts are made to reduce the cost of experimental research, increase reproducibility and access to science through building low cost customizable laboratory equipment (Landrain, Meyer, Perez, & Sussan, 2013; Pearce, 2014). Connecting these attempts with hackerspace and makerspace infrastructure and open science goals (open data, open access, online collaboration) creates unique opportunities for citizen scientists, but also scientists from the developing countries to take part in alternative global research networks (Hirosue, Kera, & Huang, 2015; Kera, 2015).
Most discussions on research and innovation in the Global South reproduce the various forms of epistemic violence (Forero-Pineda, 2006; Holmgren & Schnitzer, 2004) when they take the Western model of development as standard, which everyone should achieve, and these discussions often echoes the deficit model in science in relation to the public (Byerlee & Fischer, 2002; Sturgis & Allum, 2004). DIY and open source practices for building open science infrastructure create opportunities to challenge this perception that there is some deficit, which needs to be bridged (Chronicle et al., 2004; Strover, 2003; Warschauer, 2003), and open provoke us to think alternative futures for research and education in the Global South.

In both of our projects we rely on a participative, iterative and co-designed processes for learning and prototyping, which follow three primary principles of game play: freedom to learn from errors, freedom to experiment, and freedom to make an effort (Osterweil, 2007). Learning by doing and learning by playing are two learning models that have proven their efficiency in creating and maintaining participants' motivation. Although most people involved in Citizen Science communities or the Maker Movement are not focused explicitly on education or learning, the ideas and practices of these communities resonate with a long tradition in the field of education and learning, from John Dewey's progressivism (Dewey, 1997) to Seymour Papert's constructionism (Papert, 1993, 1994).

These practices encourage a project-based, experiential approach to learning with a focus on bricolage or tinkering as a long tradition in many cultures around the world where local crafts and traditions have evolved over centuries, characterized by experimenting and iterating with locally available materials (Resnick & Rosenbaum, 2013). The notion that tinkering and learning ought to be grounded in personally and socially meaningful problems, and position students as producers rather than consumers of knowledge and technology, also draws from the critical educational theories of Paulo Freire (Blikstein, 2013). Digital fabrication and tinkering could be a new and major chapter in this process of bringing powerful ideas, literacies, and expressive tools and research instruments to local communities while relying and contributing to open software and hardware communities such as Github, Instructables, Hackster, Hackaday.

The "Open Science Hardware" approach supports citizen science efforts, but also explicitly science in the Global South, and it was recognized as such in the annual Gathering for Open

Science Hardware (GOSH), which started in 2015. GOSH was initiated by CERN, but also numerous individuals around the world active in the OSH approach as researchers, educators, developers, but also users. When applied to science instruments, open source hardware can lower the costs of the production of various instruments and enable new users to take part in the laboratory practices in places with missing science infrastructure.

This is already happening in the so called makerspaces and hackerspaces, DIYbio and citizen science laboratories around the world, including the Global South. Using open hardware supports customization and design of new instruments, which improve both reproducibility in science and envisioning of new research programmes and agendas in various places. The GOSH community of artists, scientists, designers and philosopher gathered from over 20 countries and summarized these insights from the meeting in the Open Science Hardware manifesto ("Global Open Science Hardware (GOSH) Manifesto," 2016), in which special attention is given to citizen science. The democratized and low-tech approaches to science according to the manifest support of diversity and collaborations, but they also change the culture of and "allow(ing) multiple futures for science," which is an important goal for any development agenda (Ibid.).

Approach and data sources

Participant observation with structured interviews and surveys were analyzed using the para-ethnography framework (Marcus 2007) where subjects are treated as collaborators and partners in the research. In this method, theoretical agendas are reshaped collaboratively and through comparison. Based on this we identified several interesting models and goals in the workshops: citizen science and making as creative form of "hanging out" (Indonesia's "gotong royong"), tinkering and crafting as an old practice with new applications and affordances (culture of improvisation and bricolage in Afrimakers communities of practice), citizen science as reflection on the contradictions of globalization (the transnational networks in Thailand), and citizen science as tool for creating alternative future (the "space programme" in Nepal). We will describe them separately to conclude that culture specific approaches to citizen science in the Global South work better, and that the work on the OSH or any prototypes is not only about infrastructure, but communication and community building through experiencing local and global material cultures and realizing the opportunities and limits in different regions (the rich crafts culture in Indonesia, Nepal or Africa, or the existing open hardware manufacturing in Thailand, which can be utilized for local projects).

Indonesia: Citizen Science as Gotong Royong

The first OCSDNET workshop took place in Indonesia as part of larger festival and symposium of "critical making" between September 14-17 called "Transformaking." The 7 themes of this symposium (Energy, Transportation, Food and agriculture, AeroSpace, Healthcare, Environment, Education, and Disaster mitigation), were also adopted as a focus for the workshop, which started before the main symposium in order to produce working prototypes to display as potential open science infrastructure for the Yogyakarta community. This goal was never achieved and the workshop outcomes clearly showed that the emphasis on such outputs (prototypes, infrastructure, and data) were not important to the participants, which came from Indonesia, Nepal, Thailand, Malaysia, Myanmar, Kyrgystan, Estonia, Taiwan, and USA. The diverse participants were more interested to use the design process of building hardware as a way of creating mutual understanding and discussing what is science and how it works in different communities.

The work on the tools became a process of negotiating different ideas and experiences with science, but also a way of formulating hopes and ideas for the future. The empowerment through science was not about infrastructure, but about the experience of having a say in the future of science and the discussions on how it can serve society. This process of sense making and creation of a mutual understanding were more important than the actual outcomes (built instruments), so people were sharing their experiences of seeing something for the first time under a microscope or using a given equipment for artistic purposes. The openness in knowledge production and sharing as a citizen science approach became more about community building than building an infrastructure to catch up with the science happening in the "West".

The OSH and citizen science as a process of community-building rather than infrastructure was also a recurring feature of the working of the collaborators and stakeholders in Yogyakarta, Indonesia, regardless of the task at hand. The Indonesian partners at HONF even defined the goals of the workshop as "sharing knowledge between people from different backgrounds, creating and facilitating an environment for innovation, creativity, and problem solving," through which we can gather data about the workshop for outcomes and impact measurement purposes" (interview with Irene Agrivine, May 2015).

In Indonesia, this process has a name - "*gotong royong*" or literally, "hanging out," which means the opposite of losing time with unproductive activities. The hosting organization, HONF, was established on the idea of making "many ideas become together, just as simple as that" (Venzha Christ- Founder of HONF, personal interview, June 2015). The matter in which HONF formed could be described by the phrase "gotong royong," which can mean much more than its literal translation, including one translation as "the joint sharing of burdens together with trusted friends." The experience with similar citizen science events and projects in Indonesia by other researchers (Kaiying & Lindtner, 2016) also confirms this emphasis on building a community rather than infrastructure. It is also present in the documentation of an event in 2014 called "Seni Gotong Royong: HackteriaLab 2014 – Yogyakarta,"[3] which resulted in an exhibition of the artifacts and prototypes created in workshop through such process of such "hanging out" and exchange.

Citizen science defined as such process of "gotong royong" took about 50% of the 10 day workshop. This was even allocated for the purpose of learning through sharing experiences and knowledge in various everyday activities like eating together, sightseeing or seeing an artistic performance. Reactions by our international participants, organizers, and advisers varied between positive and negative feelings during the workshop, which had this inherent conflict in its base between emphasis on learning how to build science infrastructure and just "hanging out"

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[3] http://14.piksel.no/2014/10/24/documentary-hackterialab-2014-yogyakarta

while sharing knowledge and design. The “hanging out” was ultimately understood by the workshop community as an important program feature for understanding the local context, and created an opportunity for the participants to develop a stronger understanding of each other's worldviews around science, development, and design.

Ultimately, though many discussion of open science hardware and science, but also creation of instruments, the group finally mapped the design thinking process to the scientific method. The actual connection of the scientific method to a hardware design process was a clear path toward integrating science and design and led to various ideas of how to build the infrastructure needed to conduct environmental research in Yogyakarta. This was a clear example to our team that positioning our open science hardware workshops as forums for not only for building and making prototypes, but also to foster mutual understanding, was critical in moving forward with the workshops in Thailand and Nepal.

Thailand: Transnational Citizen Science networks and their contradictions

In Thailand we let local university students and members of the makerspace community to organize the workshop in order to map their interests and approaches to citizen science and OSH. The first project was proposed by the Bangkok FabCafe composed of 2 small workshops, in which “students would explore how to invent their own drawing machine using littleBits modules (open hardware tool for beginners with microcontrollers, sensors and motors).”The learning goals were to “understand basic circuits, motor, motion and mathematics” and to bridge “creativity and design process for their inventive solution” and then “present their creations to their peers” in order to “investigate the key factors to drive design solution with technology skill for Thai students.” (Kalaya Kovidvisith, Email Interview, 9 March 2016).

The choice of littleBits as a workshop foundation for an open science proposal was controversial in view of some of our members (Denisa Kera), because it was an expensive solution with similar functionality to less user friendly microcontrollers, such as Arduino clones produced in Thailand. It was supported after many discussions on the relation between local hardware and more international brands, which showed some of the contradictions and dilemmas of using OSH in the Global South. The “fetishization” of the maker culture acoming from the U.S. can have detrimental effects of building local capacity and realizing that some tools can be sourced locally. However, even the commercial mainstream of open source hardware (LittleBits) has a role in promoting open science, because it teaches participants useful skills and then they can switch to local tools. Another important function is that is actually opens the discussion on why should Thai maker culture be dependent on U.S. tools when there is a local production.

The actual execution of the workshop revolved around building robots that draw shapes, which was possible with some basic knowledge of math. There were not many discussions about science with the children, but there were however discussions with their parents around the usefulness of design and making of things as a method of learning. At the FabCafe workshop, the parents became very interested in the ideas of design, open science, and creativity in education for their kids, but also for themselves, which confirms some of the experiences from HacKIDemia, which encourages parents and kids to learn and work together and continue the workshop projects at home. These intergenerational setting can be regarded as prerequisite for the deep learning processes supporting hands-on workshops. HacKIDemia project based learning scenarios accounts for these needs and enables personalized and situated learning. Students learn in the relevant context and spaces with their and see how changes actually affect the system of interest while developing new hypotheses and questions to further experiment with.

Nepal: challenging the stereotypes about Global South education with a Space Program

Discussions for the Nepal workshop began in October 2015 with Karkhana , one of the partners in the OCSDNET project. The original idea was to have a hackathon style workshop around open source biology and chemistry hardware, but in December 2015 this morphed into an idea of having a Space Science themed workshop with professional scientists and makers in order to create experiential STEAM education kits for students in Nepal. Space science was a longstanding ambition of the founder of Karkhana to introduce to the organization's work, most importantly to challenge the stereotype than in the developing countries people are interested only in very practical and applied science problems.

The workshop was not limited to just nationals of different Asian countries, but rather to residents, so as to recognize the good work that people do in different countries regardless of citizenship status. Karkhana put together a team of 12 individuals from their staff to organize the summit, which was entirely Nepali driven and run with input from the OSHW project team. Throughout half year process, specific problem frames were identified in order to compose the challenges for the hackathon-style workshop, which would take place over 10 days. The Karkhana team also sourced additional funding from CKUDanmark and invested money from company profits into the workshop as well.

In March 2016, Karkhana launched the "K_space program," which supports STEAM education for space science, and started with a program called "imagining space," which focused on the conceptualization and imagination of space by the schoolkids that Karkhana works with. This included things like drawing and visualizing life in space, as well as arts projects such as paper made space helmets. By August 2016, the problem frames for October were set. The three challenges for the workshop revolved around water rockets, antennas, and "life in space."

The space program focused on satellites and space exploration - running three separate space-themed classes in 2016. The goal of the program was to have Karkhana students build their own launch ready DIY picosatellites in the next 2 years. As part of Karkhana Space Program K_Space, a DIY gathering and workshop for space exploration, was held in Kathmandu, Nepal on October 20-29, 2016. The main objective of the K_Space initiative was to create a DIY Space exploration-focused open curriculum covering a range of subjects across maths, science, engineering, technology, and creative arts that schools across South and Southeast Asia can implement.

The workshop hosted 7 international and 12 national participants, which included educators, programmers, hackers, scientists, tinkerers, artists and anyone else with a keen interest in DIY Satellites and Space Exploration. The final participant makeup included individuals from Malaysia, Nepal, Philippines, USA, UK, and Bangladesh, but also Palestine, Cambodia, India and few USA and UK individuals residing in Thailand and Cambodia, respectively. Throughout the workshop, they were given a number of hackathon-style challenges to create the best solutions for Space education.

The final model of OSH workshops connecting makers and hackers around a curriculum and "kit" gave the best results, which is also consistent with the Afrimakers experiences, where the participating communities could collaborate and exchange know-how more easily by starting with a common starter kit of tools and components and by documenting their projects and remixes of previous projects on a dedicated open platform[4].

OSH as a model of supporting citizen science in the Global South is about fostering collaborations across countries and disciplines in reforming how science is perceived and taught everywhere in the world. The emphasis on hands on and direct experiences is essential for "opening" the black boxes of science and technology, and instead of only relying on something coming from the west, the Nepal proved that they can develop a local expertise and invent a new model for global education.

Afrimakers: enable youth to solve local challenges with rapid-prototyping and open science while exchanging know-how regionally

The idea of this project was born in 2013 at Re:publica conference in Berlin where one of the author of this paper (S. Druga) organized a series of rapid-prototyping workshops for the Afrilabs community members which were gathered from tech hubs, fablabs and makerspaces from all around Africa. After they learned how to solder their own battery charger for their phones or design and build an affordable water filter the participants expressed the desire of bringing these workshops and the HacKIDemia hands-on learning approach for youth back to their countries. After several in-person and online conversations the idea of Afrimakers community project was born.

The original idea transformed into a co-design a project that will be mainly run and continued by locals in different regions. The initiative was supported by teams from 8 African countries: Egypt, Kenya, Tanzania, Rwanda, Zambia, Botswana, Ghana and Nigeria. The Afrilabs members recruited local teams of students, social entrepreneurs, makers and community organizers based on their project proposal that were aiming to tackle a local challenge, such as access to clean water or electricity, and get the support to prototype and test potential solutions. All the projects were documented both in the form of tutorials and list of materials but also as stories and blog posts that captured the learning and building process and the best practices in terms of local and regional collaboration.

The project was funded as a community initiative on Indiegogo crowdfunding campaign and started in January 2014 as a collaboration between HacKIDemia and Afrilabs member organisations. The main idea of the project was to plant the seed of local change through social entrepreneurship, digital fabrication and regional collaboration. Each of the eight initial hubs

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[4] http://www.Makehub.eu

received a maker box of tools and components which the local teams were trained to use for their projects.

The local teams started by identifying needs and problems they wanted to tackle in the first days. After they will build and test a series of prototypes and go on tours to local electronics and crafts markets, cooperatives and craft communities. Once each team had an initial prototype and project idea they organized and ran hands-on workshops in local private and public schools and universities. The purpose of these workshops was to outreach and train a wider local community while practicing newly acquired skills by teaching. Many of the participating students were surprised to see how fast younger children could learn skills and concepts which they thought would be inaccessible to younger audiences. Not only the children learned just as fast or faster than the mentors how to build an air monitoring station for example but they also came up with research questions and experiment designs which provided new insights and ideas to the local teams.

The most important part of this project were the fellowships that we offered for members of each team to go and train other hubs and communities in the region and near countries. This enabled community organizers and pro-active participants from neighboring countries such as Kenya and Tanzania to collaborate on common challenges such as access to electricity and exchange best practices and resources. Usually, the social programs in these countries have a strong external participation and influence, which leads to complicated power dynamics and social dependencies while promoting a neo-colonialist model of learning (Slemon, 1994). With Afrimakers we saw the opportunity to give the locals the opportunity and platform for leveraging new technologies and open science methodologies in their own way, develop a culturally situated epistemology and identity while recognizing and discovering the richness of local traditions, crafts and know-how and learn how to connect it and combine it with new prototyping techniques and materials.

Results

Participants of these two studies gained direct experiences with production of scientific data and knowledge through various workshop formats, which tested how to use Open Science Hardware (OSH) and citizen science in the Global South contexts. The top down approach, which emphasis only infrastructure and views citizen science as a process of catching up with professional science and science from the “West” gave no results in terms of enabling the participants to do science or connect it in any ways with their communities.

One surprising moment in some of the workshops (especially in Thailand) was that even OSH and related maker activities are perceived as something coming from the “West,” which has to be replicated or in some way negotiated. The bottom-up approach to the workshops, which let the local organizers to define the format, tools and goals of the workshop gave better results in terms of empowering the participants to imagine “alternative futures” of science in their own region and also sharing experiences, knowledge and views on how science can serve their local communities.

The emphasis on OSH plays a major role in connecting science (and citizen science) with other everyday (and material) activities happening in various locations. The best results relate to creating a sense that the participants and stakeholders are not just replicating something happening elsewhere but defining their own program as we see on the example in Nepal and Africa. The OSH part is important, because it not only teaches participants how to build one or more science instruments, but actually creates and designs an educational tool (kit), which can spread the knowledge further and build capacity to do science and research.

The trans-regional training and prototyping collaboration experience was transformational in the case of many of the fellows as revealed in the follow-up interviews in Africa. Many of the mentors expressed the impact that DIY projects had on their approach to education and community projects: *"I would say the maker movement has really rescued me. Before that, I didn't feel as if I was actually learning things. I studied Electrical Engineering, and a lot of the things we learn are quite abstract, and also quite old. It was really fundamental, we learned on transistors, but there wasn't a real connection to what people are actually doing now. You see a lot of people working on microcontrollers as Electrical Engineers, but there seemed to be a disconnect between the real world and what we do in university. When you work with those controllers, there is also a lot of programming involved but that I didn't really learn. I wasn't sure how I could use it for my practical education, so that was something I discovered through making."* (Opemipo, 22 years old, organizer Afrimakers in Nigeria, interviewed one year after the start of the project)

The fellows recognized both the benefit of learning by doing and documenting and reflecting on projects: *"I found a lot of value in documenting my projects, because I realized it is easier to learn by doing. Before I got into Bongohive, when I had science in highschool, it would never cover electronics for that I had to learn by myself. So, when I went to Bongohive, I got the feeling of learning by doing and by documenting it, I realize that this is the best and quickest way to learn and try stuff."* (Sitheh, 20 years old, mentor Afrimakers Zambia)

When asked how the DIY and maker movements could have an impact in their communities many of the mentors expressed the hope of improving education and creating more applications that are relevant to the community problems: *"We started this student Maker faires, and the idea is basically to introduce more engineering students to the Maker Movement and get them fuse with the local artisans. Trying to combine this with the university is our dream for the future."* (Jorge, 26, mentor Afrimakers Ghana)

While the participants discussed the impact DIY has and could have in their community they also recognized the importance for culturally and locally customized solutions: "*One of the important things about the Maker Movement is that it is not just electronics; it is also arts and crafts, and food. I would say, from the economic perspective, we need more of an idea of creating unique African, or Nigerian products. For instance in Nigeria, we have a power problem, and a lot of people don't buy rechargeable lamps, and these lamps are also not very potent. The question is* *why don't we have someone actually create something that could maybe also be fashionable, or, of exotic looking, African flavor, and try to give it an African feel. So, I feel if more people would add their own perspective, and use their traditional culture, getting influences from their own environment, that is something the maker movement can add, and would definitely bring advantages economically."* (Opemipo, 22 years old, organizer Afrimakers in Nigeria)

Currently, there are activities in all the countries involved in the OCSDNET study. Also, the Afrimakers workshops and projects are still entirely ran by locals who continue to host meetups, workshops and trainings. Many of the mentors and fellows that participated in the initial workshops in 2014 are currently very active in the local maker movement and have continued to visit each other and even came back to the same conference, Re:publica, in Berlin one year later in 2015 to demo and showcase some of their projects and products such as Risha, extremely affordable laser cutter for designed for craft communities in Egypt or a phone repair kit and set of stencils developed by the team in Tanzania

These initial seeds of local, regional and trans-regional collaborations in the Global South are proposing a new approach to scientific exploration and technological education which leverages the opportunities that come when confronted with scarcity and complex challenges. While frugal innovations were researched in the context of emerging markets and economic growth (Zeschky, Widenmayer, & Gassmann, 2011), these experiences demonstrate how these extremely affordable solutions to local challenges could help create new models of learning by doing and by researching. Based on our two studies, we can define three stages of OSH use in citizen science as a model for education: replicating and learning by building existing tools, using tools to connect them with everyday activities and new domains of culture, knowledge etc, and the last stage is actually designing a tool or a kit, which enables stakeholders to connect their interests and goals and also build local capacity for science.

Significance

The democratized and low tech approach to science infrastructure goes hand in hand with support of diversity, horizontal relations and collaboration, new definition of impact and changing the culture of science, which all start with a new approach to education. The OSH and citizen science approach to education give new meaning to the statement in the Article 27 of the Universal Declaration of Human Rights that "Everyone has the right freely to participate in the cultural life of the community, to enjoy the arts and to share in scientific advancement and its benefits". The right to science is transforming into direct participation in the creation and definition of scientific research, its goals, even reflecting directly upon its benefits and policy.

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