Legitimacy, Boundary Objects & Participation in Transnational DIY biology

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ABSTRACT
Prior research has stipulated that DIY making appeals to many of the concerns central to participatory design: democratization of technology production, individual empowerment and inclusivity. In this paper, we take this stipulation as the starting point of our inquiry, exploring how it happened that making came to be seen as enabler of participatory values and practices. We draw from ethnographic research that followed a transnational collaboration between DIY biologists, scientists, makers, and artists from Indonesia, Europe and India. The paper focuses on the production of three artifacts, tracing their enactment as boundary objects and experimentation in DIY biology. The artifacts did not only help legitimize DIYbio, but also positioned Indonesia itself as a legitimate participant in international networks of knowledge production. The paper contributes to prior research that has challenged stable frames like West/the rest. It draws out a positionality for PD that opens up making by recognizing its multiplicity crucial to the making of alternative and never stable futures.

CCS Concepts
- **D.2.10 Design**
- **Methodologies**
- **Human Factors**

Keywords
DIY; do it yourself, DIYbio; making; maker; transnational; Indonesia; PD; STS; innovation; knowledge production.

1. INTRODUCTION
In the introductory chapter to the 2014 edited volume on *Making Futures: Marginal Notes on Innovation, Design, and Democracy,* Ehn, Nilsson, and Topgaard [20] propose that "making" offers a unique opportunity to intervene in dominant discourses of innovation. By "making" the authors refer to a series of grassroots initiatives from fablabs and makerspaces over open source hardware prototyping platforms to DIY (do it yourself) science. This contemporary practice of technology production, the editors and contributors to the volume argue, can facilitate alternative futures and practices of "future making" that move beyond market-driven concerns and challenge the pervasive managerial ethos of user-driven innovation. Fablabs and makerspaces, they suggest, can be seen as "platforms for broader participation and new ways of collaborative engagement in design and innovation, pointing at alternative forms of user-driven production" [20]. "Making," here, is positioned as aligning with and further extending the values and practices of PD (participatory design). The vision of "making" to democratize technology production and its commitment to inclusivity, in other words, aligns with a concern central to PD since its inception. Scholars in PD have long critiqued the commodification of user participation in the form of user-centered design, design thinking, and human-centered design [3]. Making appeals to this critique of commoditized participation by offering concrete approaches and hands-on tools for political action. This interest in making reflects a broader shift in scholarly work that has begun investigating both the technological and cultural processes of making. This work includes the study of how the vision of a global maker movement is enacted through specific moments and situated practice [18, 28, 30, 39, 63, 69]. An adjacent body of work has theorized making, open source hardware, electronic art and hardware entrepreneurship as particularly apt sites to envision alternatives to contemporary technology innovation [20, 24, 25, 31, 33, 40, 51, 53, 55, 62].

In this paper, we take the stipulation that contemporary making cultures and tools are avenues to rearticulate participation and political action as the starting point of our investigation. Rather than accepting as a given that making inherently enables political action and democratized participation, we interrogate how it happened that "making" came to be seen that way. What kind of political is achieved through making? Who promotes making and DIY technology production and why? How is the participation of marginal actors and collectives in technology production achieved in practice – and is it achieved at all?

Our goal is to investigate the "making of" making. By this we mean to critically investigate how making came to be seen by critical PD scholars and tech enthusiasts alike as an ideal site to implement long-held ideals. We show that making indeed is a site of participatory design, but in ways different than imagined by the PD community [20]. To begin this project, we draw from long-term ethnographic research with DIY making and hacking collectives in Southeast Asia that has spanned across the last 5 years. We focus specifically on a subset of our findings from a one-year long ethnographic study with Lifepatch, a citizen initiative in Yogyakarta, Indonesia, that brings together people interested in DIYbio (do it yourself biology), open source hardware, and intersections of art, science and technology. We examine in detail the material artifacts that were produced as part of a long-term collaboration between Lifepatch, and a distributed collective of scientists, students, and electronic media artists in India and Switzerland. Their transnational collaborations evolved around a shared interest in the socioeconomic potential of making, open hardware, and DIYscience. They shared the vision that DIYbio was uniquely positioned to democratize scientific processes and production. In this paper, we focus specifically on the three main artifacts that were produced during this transnational collaboration: a water sampling protocol, a digital map visualizing the process of

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water data gathering, and a "how to" for a community-based fermentation workshop. Together, the artifacts would allow a layperson to test and better understand the quality of their drinking water, a pervasive problem in Indonesia, specifically in low-income neighborhoods in Yogyakarta.

For the analysis of our findings, we utilize an established concept in the fields of PD, STS (science and technology studies) and CSCW (computer supported cooperative work) – "boundary objects" – as first developed by Star and Griesemer and subsequently extended by numerous studies of scientific collaboration and technology production [15, 21, 32, 36, 48, 52, 59, 68]. Tracing "boundary objects" allows us to show how different actors came together in order to accomplish their work in DIYbio across multiple sites and interests. Applying the lens of boundary objects, we examine the making of the three specific artifacts oriented towards accomplishing two things. First, the objects enabled diverse stakeholders to enact the social and scientific merit of DIYbio. By producing accessible methods, tools, and standards that would allow people without scientific training to participate in scientific practice, the transnational team demonstrated how scientific expertise could be productively translated into mundane practice. Second, the artifacts became a site to legitimize not only DIYbio, but also Indonesia itself as a site of knowledge production and as a crucial player in transnational networks of science, art, and technology. The artifacts, in other words, became part and parcel of a broader effort to build relations between Indonesia and other parts of the world, in particular to the West. Through the making of these artifacts, this paper shows, the Indonesian DIYbio collective positioned Indonesia as a site of knowledge production, challenging any notions of Indonesia merely constituting a recipient of foreign development aid or the periphery to Western centers of technology innovation [18].

An underlying goal of this paper is to contribute to prior work that has challenged western-centric perspectives of making, design, participation, and innovation. This work has called upon us to reflect on where we as designers and scholars locate design [2, 27, 29, 39, 40, 61] and has provided deep insights into culturally situated practices of science and technology production in the Global South [16, 27, 29, 31]. We contribute to this work by exploring how we (as scholars and professionals in technology design and research) should react when confronted with forms of knowledge and tech production that share our commitment to break with stable categories of who gets to speak/design for others and where to locate design. We show that making can simultaneously be a site of participation and of exclusion, and be both intervention in and extension of the status quo. We suggest that recognizing this multiplicity of making is crucial to opening up making to alternative, never stable futures.

2. Boundary Objects in Transnational DIYbio

In 2012, Lifepatch began working on a project they called "Jogja River Project (JRP)," which brought together DIYbio enthusiasts, scientists from a local university, Gadjah Mada University, and the inhabitants of the local *Kali Code* (English: River Code) community, a settlement of people along a river in the city center of Yogyakarta. The underlying goal was to empower illegal inhabitants of river settlements as well as the wider Indonesian population to become participants in the project of addressing river pollution. Typically, to conduct complex data gathering and analysis like water samples requires expert training as well as financial and institutional support in order to interpret the data. To conduct a water sample analyses involves more than just scoping out water from the river. It is performed through standardized procedures and requires social consensus on what constitutes a quality river sampling. JRP was driven to make this process simple enough to be used by a lay audience, without losing the complexity of the underlying scientific method. In 2013, a group of artists and scientists from Lausanne and Zürich, Switzerland and Bangalore, India joined JRP, turning the DIYbio citizen effort into a transnational project.

Throughout this paper, we employ the lens of boundary objects in order to trace how the making of DIYbio brought together different stakeholders to expand and legitimize DIYbio in transnational science, technology, and art networks. An underlying goal of the collaboration was to demonstrate to others in the sciences and the arts of the merit of DIYscience. For the Swiss collaborators and the Indonesian citizens, working on a concrete problem such as the coliform bacteria contamination of river water in Indonesia, constituted an ideal case to show in practice the relevance of DIYscience. For the Indonesian collective, the project was an important step in demonstrating their unique ability to make technically sophisticated devices and tools in DIYscience.

In Indonesia, the practice of DIYbio has become a central tenet of an expanding maker/hacker/open innovation community. Since its inception in 2012, Lifepatch has made a name for itself in both local and international networks of technology, art, and design. Lifepatch produces tools, artifacts, exhibitions and machines, many of which are designed to measure and make sense of the local environment in Indonesia. They have been invited to present their work in regional Biennale exhibitions such as the Jakarta and Yogyakarta Biennale (2013; 2015) and they also won honorary mentions and awards at international digital media arts festival such as Prix Ars Electronica. They also received funding from a range of agencies including two Dutch foundations, DOEN and Hivos as well as the Cooperation & Development Centre by internationally renowned university, Ecole polytechnique fédérale de Lausanne (EPFL).

This paper traces how the productions that emerged through such transnational collaborations in DIYbio helped garner broader interest in DIYbio both in Indonesia and abroad. It is, here, where the lens of boundary objects is productive for tracing how DIYbio became a central focus in promoting new avenues of technological and scientific production for diverse audiences. Star and Griesemer (1989) have shown how different actors come together across multiple sites and often divergent interests by drawing upon "boundary objects," allowing them to mobilize a common goal. Boundary objects facilitate exchanges amongst various stakeholders and social worlds in order to achieve agreement [59]. Boundary objects, in other words, are translational artefacts by reducing uncertainty in each world.

We trace how the water sampling protocol, the digital map, and the fermentation workshop – the three artifacts produced by Lifepatch and its transnational collaborators – constituted exactly such a form of boundary objects, i.e. bridges between different domain expertise such as scientists, DIY biologists, and river settlers. We pay attention to how these artifacts operated in situations where technological know-how was negotiated and contested [8, 48]. Prior research has shown that power dynamics affect how different stakeholders interpret the use of boundary objects [21], stressing how the meaning of boundary objects arises through continuous negotiation and not without tensions. In examining how artifacts coordinate different interpretations and uses, Lee suggests, for instance, we pay particular attention to how artifacts continuously change as they move across boundaries [36]. The critical significance behind the production and use of boundary objects is that it is not a seamless process, Lee highlights, but "effortful" and subject to consistent contestation [36]. We follow this approach

by examining how the making of DIYbio artifacts was a site of contestation and negotiation of Global North/Global South and design here/design there binaries, as well as aspirations of global legitimacy and belonging. We show that the making of boundary objects was not only central for the Lifepatch to enable others to participate in DIYbio, but also to demonstrate their own legitimate belonging in global technology networks.

2.1 Making, participation, and DIY culture

This paper contributes to a body of work that has studied the cultural politics of making, arguing for the importance to move beyond familiar divides such as West/the rest, design/manufacturing, center/periphery in scientific and technological production and innovation. Making has become an important site of research for scholars invested in questions of participation and the democratic proliferation of technology use and production. This prior work has provided important insights into 1) interactions between design, crafts and manufacturing [39, 40, 45], 2) aspirations towards countercultural values and other ethical views [25, 30, 31, 45, 62, 63], 3) a mundane source of livelihood [1, 42, 53], 4) basis for entrepreneurial pursuits [7] and 5) engagements with community both within and outside such spaces [30, 31]. A central focus has also been on how self-made tools facilitate the resurgence in crafts, [54], ways of making-do [1, 29] and new paradigms of science [33].

We build on a subsection of this work that has urged to pay particular attention to culturally specific knowledge systems and the heterogeneous practices of making and designing. For instance, Lindtner et al.'s [40] account of the history and culture of technological production in the South of China challenges perceived binaries of "designed" or "created in" the West versus "manufacturing in" or "assembled in" China or other parts of the so-called developing world. Similarly, Jackson et al.'s [29] ethnographic account of the design and repair expertise of mobile repair workers in rural Namibia, Africa, challenges perceived notions of where to locate design. Their work aligns with Björgvinsson et al. [10] who suggest that by studying less visible design practices, we can challenge dominant notions of innovation and product-centric fabrication.

The sites we studied were already well versed in such critiques of a Western-centric view on design and innovation. In our research, then, we paid particular attention to how individuals and collectives remake themselves through the visions and material practices of technological production. This is closely aligned with work by [2, 28, 29, 39] that has shown how making and designing has become centrally enrolled in envisioning alternatives to dominant modes of innovation and where it is to be located. A related area of research that informs our work is prior research on DIYbio in Indonesia. Especially, Denisa Kera's research on Indonesian DIYbio hacking as a site of knowledge production in science and technology and Barker's research with Indonesian hobbyists who leveraged Western countercultural ideas to create a national Internet has shaped our early explorations and how we approached our sites [6, 30, 31]. Building on their work, the starting point of our investigation into Indonesia's transnational DIYbio scene was to take seriously their global aspirations and hopes to dismantle what counts as legitimate knowledge production, and who gets to participate.

3. METHODS

This paper draws from long-term ethnographic engagements with DIY maker, hacker and DIY biology collectives in Asia by both authors, zooming in on a subset of our findings from a one-year long research project in Yogyakarta, Indonesia between 2014 and 2015, conducted by the first author. The research is based on standard ethnographic methods such as formal and informal interviews and in-depth participant observations at the DIYbio laboratory of Lifepatch, their public events, DIYscience deployments in the wild, collection and analysis of artifacts as well as during the fabrication of objects and platforms. We were curious to understand in ethnographic fashion - why and how our interlocutors in Indonesia were practicing DIY making and hacking to enable participation in citizen science. A central part of this research was active participation in workshops, meetings between River Code residents and Lifepatch members as well as festivals and events held by Lifepatch and Hackteria, a community platform for artists, scientists, hackers, and researchers first initiated in Europe. Specifically, this included a series of fieldtrips, workshops and exhibitions focused on DIY biology, co-hosted by Hackteria and Lifepatch throughout 2014. These events brought together hackers, artists, and scientists from across Asia, Australia, Europe and North America. Throughout these various engagements, we paid particular attention to both material productions and articulations thereof.

The research site itself was multiple, ranging from Lifepatch's DIYbio lab space to River Code in Yogyakarta and international collaborations in dispersed sites. A central goal of this research was to understand the role transnational collaborations play in the production and promotion of DIYbio tools and artifacts. For this purpose, we drew from multi-sited ethnography [12,16,43,70] and multi-sited design [69] in order to uncover how transnational connections are enacted and formed within a particular locale. A central goal of multi-sited ethnography is not to travel to multiple places, but to recognize that contemporary phenomena often escape the boundaries of the local, and so must be examined as inherently multi-sited phenomena [43]. This approach allowed us zoom in on how the global aspirations were enacted within a single site, in this case through DIYbio practice in Yogyakarta. We paid particular attention to the ways in which a transnational DIYbio scene was enacted through on-site collaboration, the sharing of knowledge online, the attendance of international art and science events, and the production of artifacts. Although not the focus of this paper, throughout our long-term research, we have traced knowledge networks across Asia, examining in particular the emergence of a collective sense of identity, of what some called the "pan-Asia" design and innovation network.

Our fieldwork included hands-on participation in maker projects, drawing from methods such as research through design and critical making [5, 51, 71]. Throughout, we collated hundreds of hours of video and audio material of interviews, field visits, panel discussions, hands-on workshops and discussion sessions. In total, we conducted over 150 formal and informal interviews with relevant stakeholders including makers, artists, scientists, policy makers, government officials. As common in ethnographic research, we prepared sets of interview questions, which we expanded and modified as we went along and identified emergent themes and new questions. We combined discourse analysis, situational analysis [19]. Although we have interviewed people from a wide range of backgrounds, for the purposes of this paper, we draw on a subset of our interviews with DIY biologists, scientists, makers and artists involved in the Jogyakarta River project. Interviews were conducted in Indonesian by the first author, who has professional training in and speaks advanced Indonesian.

4. BOUNDARY OBJECTS, ENACTING DIYBIO & LEGITIMIZING INDONESIA

The early stages of the Jogja River Project (JRP) started out with the Indonesian citizen initiative Lifepatch inviting local and international collaborators on long walks along the main rivers of Yogyakarta. The walks were oriented at demonstrating the importance of intervening in how water quality was

currently communicated to those affected. Articulating the relevance of a DIYbio intervention also helped make visible a unique opportunity that extended beyond the immediate concern of poor water quality. Indonesia, its rivers, and the walks constituted an ideal site to demonstrate to a broader audience both the workings and the importance of DIYbio – a kind of science that engaged citizens as participants in the process of designing and using scientific tools. What followed from the river walks was an intense collaboration around the making of three artifacts. In the sections that follow, we elaborate in detail what went into the making and in the subsequent usage of the three artifacts as boundary objects.

The initial focus of the project was to generate a *water sampling protocol* that was based on the actual data samples taken from the local rivers in Yogyakarta. The goal of the water sampling protocol was to provide an instruction of sorts – a "how-to" guide for sampling a river for "biomarkers," or biological entities, which in turn measured the water quality of the river. In this case, the "biomarker" was the bacterium E. coli and the fecal contamination levels in drinkable water bodies such as wells located close to the river. Through JRP, numerous versions of the protocol were made and tested out in order to refine the protocol for the local context. While the protocol can help interpret water quality, the process of interpreting itself is complicated. The team decided to produce a *digital map* that visualized the complexity of the data in simpler and more accessible ways. Simply put, the map translated complex data into information legible to a broader audience. DIYbio, however, shouldn't stop there, the team agreed. A central commitment of DIYbio, as with other similar open hardware hacker and maker projects, is to engage people directly and in a hands-on fashion with science and technology. The team began to *host fermentation workshops* in order to demonstrate how the protocol and the digital map could be deployed in practice – in this case, to produce safe fermented wine. In what follows, we unpack how the water sampling protocol, the digital river map and the fermentation workshop performed two different yet interrelated boundary functions. We focus specifically on – as laid out by Star and Griesemer – standardized forms, ideal types and how these objects were enacted and "lived on" in and beyond Indonesia.

4.1 Standardized Forms and Knowledge Production: The Water Sampling Protocol

An important skill that biologists, field ecologists and other scientists draw upon when monitoring pollution in water bodies is to follow a water sampling protocol [22]. The protocol acts as a standardized form. Water sampling protocols differ based on where they are put to use and by whom. For Lifepatch, establishing an Indonesian water sampling protocol, then, was an important step in situating their work in relation to established scientific practice and institutions. Throughout JRP, Lifepatch members designed and tested numerous water sampling protocols to develop a localized standard. The standard was consistently revised and negotiated between different stakeholders of various expertise and nationalities. Making the standardized protocol was not only about adapting scientific methods for a local context; it also involved negotiating Lifepatch's position in their transnational collaborations. While developing the protocol, stories often returned to the origins of the project. Lifepatch members stressed that it was the "river walking" experiences they had organized on their own, prior to the transnational collaboration, that laid the important foundations for contemporary Indonesian DIYbio. For instance, Agus Tri Budiarto, the director and co-founder of Lifepatch, emphasized that the river walks themselves enabled the very making of the protocol: "We first started JRP by walking in the river. I invited some people (students from universities and biodiversity collectives) by Facebook and they invited more to accompany me to walk in the river. I walked in the river like a crazy man. Some came to document plants and living species there. Others came to archive the waste in the river. They found many slippers."

Situating Lifepatch at the core of the project's origins was crucial for the Indonesian community to demonstrate that this project constituted all but a foreign aid or developmental effort. Lifepatch, through their extended local and transnational network, in part mobilized through social media, was already globally connected, Budiarto stressed. Lifepatch didn't require foreign interventions or formal institutions to help them be connected, its members repeatedly emphasized. Walking a river itself was science enacted, and producing the protocol was aimed at demonstrating that boundaries between scientific expertise, DIY biologists and a broader public can be redrawn.

An important and long-term collaborator of Lifepatch throughout JRP was Sachiko Hirosue, a Japanese lecturer and scientist from École Polytechnique Fédérale de Lausanne (EPFL) Switzerland. Sachiko Hirosue and one of the Lifepatch members, Nur Akbar Arofatullah, first met in 2011 during an event hosted by Hackteria.org called HackteriaLab 2011 in Romainmotier, Switzerland. Discovering their shared interest in microbiology, they began working together, first remotely, and then back and forth between Switzerland and Indonesia since 2012. Their collaboration extended into a series of exchanges between students at EPFL and DIYbio enthusiasts in Yogyakarta, Indonesia and Bangalore, India. Hirosue was not only an ally in promoting and legitimizing DIYbio in Indonesia and abroad, she was also an important voice that supported Lifepatch in articulating their work as a form of knowledge production that challenged the common Global North/Global South dichotomy. In her teachings at EPFL, for instance, she would continually emphasize that Indonesian DIYbio had to be taken seriously in its own right, rather than as an international collaboration. Hirosue also actively distanced herself from the more common developmental narrative: "When I first came here [EPFL], there was interest to do a Master's program in the Global South. The program I visited was not rooted in collaboration with the local people. I felt like it was similar to tourism. It just seems like another neo-colonialist power that arise from American students going overseas and doesn't work with projects locally to make devices. Then I realize this is not what I want to do."

Hirosue often reflected on her own privilege in relation to her Indonesian collaborators. She emphasized that Lifepatch's approach to scientific work was one that was rooted in cultural values of interdisciplinarity and collective action. This, she argued, was something that scientists from other regions could learn from. The commitment to treating Lifepatch as an equal partner and a site of expertise in turn shaped the production of the protocol. The collaboration between Hirosue, her students from EPFL, and Lifepatch had centered on the sampling and analysis of E. coli bacteria. Together, they developed "software, hardware, and wetware," as Budiarto described it to us. For this work, Hirosue gave the team access to relevant scientific literature. While Hirosue's input informed Lifepatch's approach to E. coli, both sides continuously emphasized Lifepatch's central role in making the protocol standard specific to Indonesia so that it worked in line with the "Standard National Indonesia (SNI) Water Sampling Protocol". It was this decision to develop a local standard that brought Lifepatch the attention and continued collaboration from and with local universities and scientists. For instance, Dr. Donny Widianto, a scientist at Gadjah Mada University, began working with the team during the creation and deployment of the protocol. While the protocol was not universally deployable, it had high local relevance.

Together with the university, the team worked on improving the protocol's applicability. Some of the iterations, performed in partnership with the university scientists, included the increase of the distribution and types of water sampling spots relative to the water flow and pH level of the river.

The boundary work of the protocol, here, shifts from one that consolidates between lay and domain expertise, to one that generates visibility for Lifepatch in both local and international scientific communities. In other words, the water sampling protocol in part enacted Lifepatch's aspirations to demonstrate their own form of knowledge practice as legitimate, and in so doing break from the Global North/Global South and Science/DIYbio dichotomy. This was further solidified as the relationship between Lifepatch and the scientists turned into an extended partnership premised on DIYbio. Lifepatch began hosting a series of workshops that taught local participants how to make culture mediums and cultivate E. coli. Initially, these experiments were performed in a DIY wetlab at the Lifepatch space. Later, Lifepatch turned to their university collaborators who gave them access to their university lab for analyzing E. coli. The partnership with the university laboratory was an important step in demonstrating the relevance of DIYbio. The water sampling protocol, here, functioned as a boundary object that facilitated Lifepatch's entry into professional scientific circles.

Star and Griesemer argued that standardization is fundamental to the functioning of boundary objects as it allows information to be made compatible and as such, extends its 'reach' across different social worlds [59]. The making of standardized forms enables involved parties to "find a common ground" in "clear, precise manual tasks" [59]. What we have shown so far is that the water sampling protocol has undergone continuous transformations by bringing together various actors including DIY biologists, university scientists, the Swiss collaborators and their journals, citizen participants, river data and bacteria. The protocol standard, in other words, was continuously in the making and constituted a medium of translation between diverse stakeholders. It was exactly because of these constant negotiations that Lifepatch was able to advocate for the importance of making scientific knowledge relevant to a broader public *and* in turn, legitimize their own central role in its accomplishment.

4.2 (Re)drawing A Coincident Boundary: Digital River Mapping

A crucial step in communicating to a variety of stakeholders the relevance of the water-sampling project was to make visible the data collected. Alongside the river walking and protocol work, Lifepatch members began producing a digital river map, spearheaded by Lifepatch member, programmer and artist Budi Prakosa. What to include in the map was the outcome of a collective decision-making process between river residents, foreign and local scientists, and the transnational DIYbio community. The goal was to make data legible and relevant for each of the actors involved.

For the making of the map, findings from the river sampling were paired with Global Positioning System (GPS) tracks of Lifepatch's field trips to the rivers. The digital map rendered visible not only river pollution and how it varied across sites, but also Lifepatch's work that had gone into producing the map's very content. By mapping Lifepatch's river walking tours dating back to 2011 alongside the data collected during the walks, Lifepatch was able to depict the many years of work that had gone into the project, even if seemingly casual at first, or as Budiarto has expressed: "It's happened so organically. Initially, we also wanted to see visually what or where contamination come from so we documented all the water sewers that run to that river [...] Since our first walk at River Code we took pH and temperature data because that is what we can do easily to gather data to know river condition. Even in our first walk, we also took samples for E. coli analysis. Ideas [on mapping] come up after second and third walk."

When creating the visuals for the map, Lifepatch members made an effort to use programming languages that were familiar and accessible to Indonesian developers. Prakosa, a Lifepatch member who had implemented the software of the mapping project, was eager to program the map such that it could be appropriated by others less tech-savvy: "While fairly new, the open-source PHP web application framework Laravel has seen vast growth in popularity due to its ease of use, with a large part of users coming from developing countries where PHP remains the most affordable and commonly available server-side language" [11].

Many, similar to Prakosa, were acutely aware that their design choices for the map had the power to either include or exclude others from participation. They reflected on the power of maps to draw boundaries that did not necessarily correspond with lived experiences. Lifepatch member, photographer and architect Wawies Wisnu Widianto decided to add a panoramic 360-degree photograph to each location of the sampled data. With this, Widianto added cultural context to the digital data, extending the value of the map beyond scientific data, numbers and their interpretations. Both Prakosa and Widianto stressed that their choices for particular software tools and visualizations were shaped by their commitment to make the map reflect local cultural practices. They distanced their work from foreign developers and system builders, who they characterized as caring more for the innovative capacity of the code rather than the local context of Indonesia. The goal of the map, for Prakosa and Widianto was to make visible not only scientific data, but important cultural facets that shaped data collection and use.

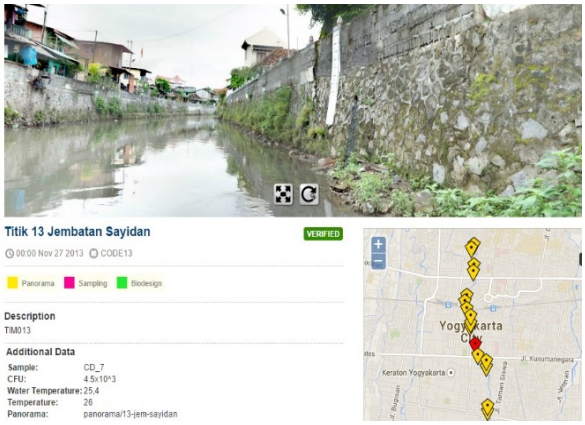

Figure 1 Panoramic Photo and the Digital River Map

Was their approach successful? Was the digital map taken up by local residents and lay audiences? To this date, the river residents have not made use of the protocol or the map to detect river contamination. While on first glance the project seemingly failed as a full-on participatory citizen science project, it delivered something else, perhaps even more important for the long-term effort of Lifepatch. What extended from the project was an attitude of scientific tool making. For instance, some river residents have responded to the *making* of the digital river map by inquiring how and where can they "learn to map like Prakosa". The digital river map was not successful in constituting in and of itself a translational artifact between scientific expertise and lay concerns. It was successful, however, in establishing Lifepatch members as knowledgeable citizens who could be consulted by local residents.

The digital map also helped Lifepatch to demonstrate its expertise in scientific practice. The digital river map resembles Star and Griesemer's notion of "coincident boundaries," objects that people can utilize in ways suitable to their unique sites and perspectives. More specifically, the map became a site to deliberate uneven power relations and histories of colonization. Cartographic practice and the act of mapping are deeply rooted in the colonial project to conquer and expand in Indonesia as much as elsewhere in the postcolonial world [e.g. 44, 65, 66]. Drawing boundaries and mapping out territory constituted an exercise of power rooted in naming and categorizing things, people, and places – often on Western terms [65]. The transnational team was well aware of the legacies of such histories. In a 2014 blog post, for instance, Hirosue detailed her concerns about how mapping was not an innocent move, and needed to be done carefully by rooting it in "the narratives and relationships Indonesians have with the river". Similarly, Lifepatch insisted that their international partnerships were about mutual learning and partnership. Both positioned their work as challenging any hierarchy that came with traditional understandings of what counts as the center of knowledge production and innovation. For both sides, the map constituted the means to demonstrate that culturally diverse and complex systems cannot be easily reduced to a string of data or a single map.

In this process of "talking through the map", the various stakeholders involved in JRP could show their commitment to a reflexive and contextualized practice of mapping. The reflexive process furthered a critical inquiry into foreign public engagement, showing in practice how marginal actors can contribute and elevate their agendas through the act of mapping. Producing the map, then, was not only about creating an account of river pollutants, but also about demonstrating that Indonesia could relate to the West in ways other than as the colonized or the passive recipient of developmental aid.

4.3 Visceral Objects: Wine Fermentation Workshops

In the last stages of JRP in 2015, Lifepatch carried out a series of workshops to demonstrate DIYbio in action. More specifically, they conducted a series of wine fermentation workshops with local and international participants. A central part of these workshops was to understand the concerns and questions of the river residents. The goal was to transform a potentially alienating scientific procedure into something familiar and comfortable by translating scientific data into familiar forms of expression or what we call, *visceral* objects. By making visceral objects, scientific data is made visible, consumable and evocative and the complexity of science is made "feel-able".

The wine fermentation workshop typically started with boiling fruits. Workshop participants would work together on pureeing the boiled fruit and pouring them into sanitized 5-gallon water bottles or jugs. Yeast powder would then be mixed with lukewarm water and added to the fruit puree. The bottle would then be carefully sealed. Throughout the process, Lifepatch would explain the scientific process of yeast fermentation. Emphasis was put on detail, sanitation, and the self-made sealing process. The workshops ended with participants enjoying fermented wine from Lifepatch's previously self-made ferments. The goal was to engage lay audiences in a visceral experience of scientific processes. Budiarto describes this as: "I cannot tell them that 10 x 1000 E. coli is in their water, so what do I do? We make a workshop about fermentation for data sharing so that they can feel and know their environment." When workshop participants tasted, smelled, and felt science, so the vision was, they would learn what safe water means. The fermentation workshop, as such, was positioned to translate between experts and lay audience by developing a hands-on educational approach.

Hirosue saw significant value in the fermentation workshop for her own educational purposes as it demonstrated that "development projects don't have to be a product and it could be a workshop… I think that the [fermentation workshop] was quite shocking for the Swiss students... if you want to learn about how to avoid contamination of water, you have to learn what grows in the water…In Switzerland, you don't have to think about [it] every day because you don't have to deal with it."

To her students in Switzerland, Hirosue would describe the fermentation workshop as an example of Indonesia's "more evolved way of thinking about hacking [and making]." She contrasted this with making and hacking practices in the US and Europe, which to her felt less politically engaged, but centered more on commercial outcome. Hirosue's endorsement performed important work. The workshops centrally contributed to the collective's reputation in an international network of art-science enthusiasts. For instance, in 2013, Lifepatch was invited to the Jakarta Biennale to showcase their work entitled the "Dining Space Project". During the event, the team hosted a fermentation workshop that centered on issues of unsafe alcohol brewing practices common in Indonesia due to a rise of alcohol taxes. These workshops become moments of aspiration for other foreign stakeholders; Swiss scientists, for instance, saw them as new models to science education. Overall, the fermentation workshop was hosted more than 10 times outside of Indonesia in regions including but not limited to the Netherlands, France, Singapore, Malaysia, Thailand, with Lifepatch members receiving funding to both host these workshops and travel abroad.

Figure 2 Fermented Fruit wine workshop in Indonesia hosted by members from Lifepatch

Taken together, the river walks, the water sampling protocol, the digital map, and finally the workshops made Lifepatch known for their sociopolitical interventions and commitment to expose societal and environmental issues. In 2015, this culminated in the award of an honorable mention at the electronics arts Festival Prix Ars Electronica, crucial in making the collective's work visible in a much broader network of digital technology, art, and science.

5. DISCUSSION

This paper began with the articulation of making's central appeal to concerns of participatory design (PD). Making reinvigorates long-held values of PD including the commitment to democratize technology production and design, to the inclusion of diverse viewpoints and marginal actors, and to

alternate ways in which technology can be conceived, designed, and used. Whereas PD has been tremendously powerful in opening up the black box of technology, how do we engage practices, like the ones covered in this paper, that share the same commitment to demystify science and technology, to engage with situated knowledges, and to build civic technologies? What is the relevance of PD when it is confronted with DIY communities that bring users into the process of technological and scientific production rather than leaving it up to the researcher or professional designer?

We believe the answer lies in a reflexive engagement with how we, as researchers, scholars and designers in PD and other related fields have construed the relationship between making/designing and political action/critical computing [35, 37, 38, 56]. Let us elaborate. As making is being endorsed as a site of PD in action, a primary focus has been on values and practices that appear familiar and compatible with (largely Western) understandings of design: open source platforms, digital fabrications tools, and community building efforts. Taking seriously the diverse making efforts and cultures in existence today requires, however, acknowledging diverse practices of design and making [37, 38, 56]. We have shown, in this paper, how DIYbio in Indonesia was a site of contestation over where good technology design or proper science was to be located. DIYbio was not only a lived practice of concerns central to PD, it also challenged who gets to call upon others to participate. The three objects we examined in this paper enacted both DIYbio in practice *and* a political intervention into views that portray regions like Indonesia as merely the receiver and the West as the originator of new methods, innovation, and critical intervention. By a reflexive PD, we argue for the importance to be held accountable, as researchers and designers, with regards to our own presumptions of good research and design. A reflexive PD demands of us to open up our own conceptualizations of design and where we locate it [2]. In what follows we offer a couple of ways to forward reflexive PD. We do want to stress that these should not be understood as an exclusive list, but merely as a starting point to further expand a reflexive PD practice.

5.1 Making as Boundary Object & working with frictions

Throughout this paper we have employed the lens of boundary objects [59]. This approach has allowed us to analyze making, and in our case DIYbio, as embodying dynamic, shifting significations, being "weakly structured in common use" rather than set in eternally static essences [59]. We have shown how a water sampling protocol, digital river map and fermentation workshops constituted acts of translation; across and between science and civic engagement on the one hand, and to reposition and legitimize alternate modes of doing science on the other. Making itself is a translational project, rather than a stable entity that works the same across regions and borders. Recognizing this multiplicity allows us to track making's interpretive flexibility, which we believe is key to envision how making could intervene in creating alternative futures worth pursuing. In other words, recognizing making's interpretive flexibility allows us to see how situated making projects enact specific political interventions, rather than assuming that making's political act is always inherently aligned with more familiar values such as the democratization of technology production or the empowerment of individual users.

The DIYbio we followed were driven to engage citizens into science and technology projects. And yet, at same time, it also constituted a potentially more radical political act: the contestation of common binaries such as Global North/Global South and innovator/receiver of technology. The act of criticality, here, was not performed through scholarly writing, but through negotiations in transnational partnerships and alliances. It is analytically productive, then, to see making as a process that carries the means for translation, rather than ascribing it a stable meaning across diverse sites. Making does not inherently enable democratization of technology production as we have shown here, and others have before us [25, 28, 39, 53, 55]. Rather, democratizing technology design and production takes work and while making carries the potential to enable it, it is not a guarantor for success.

Our work, here, closely aligns with anthropologist Anna Tsing's notion of friction, i.e. "the awkward, unequal, unstable, and creative qualities of interconnection across difference" [64]. The boundary objects we documented were manifestations of such differences across expertise and cultures. They were ever evolving according to its uses, contexts and mobility. While they bridged the domains of scientific professionalism with amateur citizen science, they also repositioned Indonesia, specifically when expert domains interacted across national borders.

We argue for the importance to work with such frictions rather than seek to avoid or dismantle them. The work that boundary objects facilitate when bringing together different social worlds is not always seamless; it is messy, unequal and full of friction. For instance, in the case of our fieldsites in Indonesia, DIYbio was in and of itself a site to work through frictions that arise in transnational encounters and collaborations, from postcolonial legacy to negotiations over technological and scientific origin stories. Legitimizing DIYbio and Indonesia as sites of knowledge production was not straightforward or easily accomplished – it constituted work and constant negotiation between diverse actors.

5.2 An Ethics of Multiplicity

Tracing DIYbio through the production of boundary objects allowed us to examine not only sociological and designerly frames, but also the cartographic. The cartographic notion of borders can be productive to think with. While making is often envisioned as a global movement, cutting seamlessly across diverse regions, the mapping project we have documented in this paper speaks of desires to demarcate Indonesia as a unique site of maker practice and in so doing, draw a distinct boundary that challenges foreign intervention and superiority claims. Cartographical practice in Indonesia can't be divorced from colonial histories and mapping projects that "cut up" regions and cultural practice into entities for the West. When DIY biologists drew maps that challenge foreign intervention, other borders were also drawn. While Indonesia's DIY biologists – by making digital maps and hosting participatory workshops – garnered significant attention of influential actors both locally and abroad, little citizen science was actually accomplished. While the local river residents were at the center of the project's democratization efforts, it was the DIY biologists whose stature in international relations transformed. While the DIYbio projects we described in this paper were political, in that they intervened in the West/the rest and similar binaries, they have not (yet) delivered on their promise to democratize participation. While JRP helped reposition Lifepatch and their DIYbio practices as legitimate members of an international art-science network, DIYbio has not become a sustained practice amongst the river residents. It is, here, where we begin to see the importance of interrogating, as we set out in the beginning of this paper, how the political and the participatory are achieved in practice. We argue that only now that we have opened up the question of how the making of making unfold can we conceive of engagements between scholars and maker practitioners that takes us beyond the common binary of either enthusiastically endorsing making's utopian project of

democratizing production or to critique it because of its elite or exclusionary tendencies [41]. What this requires, we argue, is an ethics of multiplicity.

Indonesian science and technology practice today is a result of numerous transnational encounters that unfolded before, during, and after Indonesia's colonial histories, e.g. [12, 23, 64]. Scholars of postcolonial studies have shown that these translocal encounters challenge simple binary of colonized vs. colonial, exploiter vs. exploited, Western science versus Eastern traditions, modern vs. backwards [17, 18, 58, 60]. Andrew Goss, for instance, shows in great detail how knowledge productions in Indonesia and the Netherlands informed one another during colonial intervention [23], building on a large body of postcolonial and feminist studies that has shown that colonized people and places, though seemingly remote and pristine, were already an intimate and integral part of European cultural production [e.g. 17, 58, 70]. This prior work supports our emphasis to recognize nations as non-isolated organisms that constantly react and respond to one another, however unequal. Such encounters of science and knowledge production also exemplify what Mary Louise Pratt (1991) calls "contact zones" - "social spaces where cultures meet, clash, and grapple with each other, often in contexts of highly asymmetrical relations of power, such as colonialism, slavery, or their aftermaths as they are lived out in many parts of the world today" [50]. Tracing boundary objects in and through transnational encounters, as we did in this paper, makes visible how the making of DIYbio constituted one such contact zone in continuously negotiated transnational relations.

Following this, there is no pure subject position such as the revolutionary maker, the citizen scientist, or the foreign imperialist. There is only multiplicity. An extensive body of work from the field of science and technology studies has challenged notions of essence and firm binaries such nature/science, society/technology, object/subject, and so on [26, 34, 46]. This work has shown, that in contemporary practice the natural and the social are fundamentally entangled [26, 34, 46, 60]. To analyze such entanglements, we need to account for the "multiplicity of reality" [46], the multiplicity of use, including non-use, in order to critically assess how user and technology are co-constructed [4, 49]. This ethics of multiplicity, we argue, can help embrace the multiple meanings that emerge from encounters between individuals and collectives positioned differently in relation to existing systems of power. To recognize that there is no pure category, but hybridity of many sorts, further affirms the importance of straddling margins and adaptive boundary objects [17, 18, 58]. An ethics of multiplicity acknowledges how Lifepatch and their collaborators challenged firm categories of knowledge, innovation and design, all the while accounting for their position of relative privilege to speak for others in Indonesia. While the self-fabricated objects we documented here might not necessarily lead to unequivocal democratization of science and technology, they do exemplify how making itself is ambiguous, multiple and continuously in the making.

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