The Critical Making Movement

How using critical thinking in technological practice can make a difference

Regina Sipos, Saad Chinoy and Ricardo Ruiz

29. December 2018

Abstract

This paper summarizes the session "The Critical Making Movement: How using critical thinking in technological practice can make a difference", held at the 35th Chaos Communication Congress between 27-30. December 2018 in Leipzig, Germany. It begins with a short history of the maker movement, summarizes current societal impacts achieved in makerspaces and criticism directed towards maker culture. The paper then offers critical thinking as a way to rethink technical practices conducted in makerspaces to achieve a more reflective practice and enable the utilization of the resources available in makerspaces for a society-oriented and citizen-driven practice. The origins of such critical making practices are touched upon, which lie in critical technical practice, critical design and critical engineering. All 3 - very briefly summarized in this paper - influence current critical making streams in academia as well as citizen-driven projects. To give a complete overview, the paper also offers a brief insight into current examples of academic syllabuses, research and citizens' bottom-up projects. Two cases are further elaborated in the hope to inspire more grassroots critical making research: EngineeringGood and the Hack-a-Toy workshops in Singapore and LabCOCO with Contos de Ifa in Brazil.

1 Introduction

Following the rapid burgeoning of making, makerspaces and maker culture, academics and grassroots communities alike are starting to engage in critical

making around the world. With roots in critical design and critical engineering, such activities can help people better understand socio-technical relations and achieve more and better societal impact with their work. Do-it-yourself activities (DIY) and making already allow for people to engage with technology and using critical thinking in the DIY culture can help look beyond the idealised picture of the maker and to "reintroduce a sense of criticality back into post-2010 maker culture to un-sanitize, un-smooth and re-politicize it [Hertz, 2015]. In this presentation we wanted to give an overview about the so-called "maker culture", explore the notion of using more societal reflection in technology through and the relevance of such practices for our future. We aimed to present such possibilities with two cases. In Singapore, EngineeringGood and the Hack-a-Toy workshops attempts to teach caretakers of people with disabilities to understand and rethink toys used in their work. In Brazil, LabCOCO, a critical making lab founded a gaming startup, Contos de Ifa, which focuses on breaking the habit of prejudice and discrimination towards Afro-Brazilian religions.

2 Short History of the Maker Movement

Firstly, we would like to point out that how making, maker spaces or the maker movement is defined is not yet final. If we define making as a hands-on creative process and maker spaces as community spaces or third places where people can make things, these have existed for a very long time: The American Libraries Magazine starts the timeline of the history of making with 1873 in New York with the Gowanda Ladies Social Society, which was formed to quilt, knit, sew, socialize, and talk about books [American Library Association, 2013]. That was almost 150 years ago, and rooms for making have been parts of libraries ever since. The phenomenon we call the maker movement began in the early 2000's with the re-upheaval of the DIY culture. The maker space has its roots in the Massachusetts Institute of Technology's (MIT) Fab Labs. Gershenfeld, of MITs Center for Bits and Atoms, is an originator of the Fab Lab, which has had a significant influence on makerspaces: not only the learning environment and collaborative culture that emerged from Gershenfelds MIT course, How to Make Almost Anything [Gershenfeld, 2013], but also the digital equipment for designing products and the digitally driven tools to create them. The Make: magazine kickstarted the rapid growth of the movement in 2005 with its maker-related projects. The magazine, according

to Martinez and Stager, is the Gutenberg Bible of the burgeoning maker community [Martinez and Stager, 2013]. A further catalyst for the growth of the maker movement was the launch of maker faires by Make: magazine, a series of venues for makers to express themselves and share their creations" (as cited in [Burke, 2014]). This accessibility of maker- and hackerspaces or community spaces of digital fabrication and prototyping has led to them become a rapidly growing phenomenon: between 2006-2016 the number of such spaces worldwide has multiplied by 14 [Lou and Peek, 2016].

3 Societal Impact in Makerspaces

Thousands of maker spaces in libraries, universities, privately owned spaces bring together hundreds of thousands of makers worldwide today. This means that a number of society members are engaging in this activity, but do the spaces engage in changing society? It is inherent that at such adaptation, the societal impact could be far reaching. There are a lot of maker spaces already aiming to create communities for their members, contribute to the improvement of the lives of people, or help them understand that technology does not need to be an inaccessible black box. Makerspaces dont necessarily self-identify as spaces of social innovation, but some specialize in solving societal issues by engaging in activities linked to:

- Education: making knowledge about technology available for the masses through local events, workshops and online materials
- Strengthening democracy: they offer third places for communities and support civic engagement through notions of activism and critical thinking, unlocking grassroots capabilities
- New models of production: access to personalized manufacturing and rapid prototyping, mass customization practices
- Contributing to the commons: by open source software, hardware and peer production; making blueprints available online,
- Innovative artefacts: by using different (inclusive) design methods, they support the creation of socially relevant prototypes, some of which can be innovative solutions (e.g. appropriate technologies) to societal problems

- Awareness raising on Sustainability: by hosting repair cafes, operating as eco-fablabs or simply by allowing local manufacturing instead of long delivery routes.

It is yet to be researched, what the true societal impact of such activities might be. Currently, most solutions are not yet sustainable, long-lasting or impactful and such artefacts represent the minority of prototypes made in maker spaces. What the reasons could be will be explored in the following section.

4 Criticism of Maker Culture

Maker culture has entered the mainstream and it is yet unclear whether this will have a positive or a negative impact on its practices. In the subtitle of his book, Makers, Chris Anderson calls it the The New Industrial Revolution, giving it a potentially exaggerated importance which might create expectations that are too high. The 44th President of the United States, Barack Obama used it to engage with citizens by endorsing making and hosting a Maker Faire at the white house. Making is more and more included in policies and politics. Makers were disillusioned when other institutions entered their spaces, like when the Defense Advanced Research Projects Agency (DARPA) gave funding to OReilly Media for its educational program [Finley, 2012], because the funders' agenda will more often than not have an effect on the practices. As Smith puts it, "Hacker visions and values for autonomous social innovation and critical involvement in open technology is co-opted by an agenda to educate, train and entertain people, and where the fear is that it reinforces compliance with conventional innovation agendas. Responses to this criticism point to the mainstreaming of makerspaces but gloss over the asymmetric power relations between 'partners. In terms of innovation democracy, the critical question becomes the conditions under which makerspace participants can really challenge, and even reshape, the agendas of sponsors and partners." [Smith, 2017]

The movement becoming mainstream has also brought with itself a "Silicon Valley ethos", which became visible e.g. when the MakerBot, "the darling of the Open Source Hardware movement" became closed-sourced [Benchoff, 2016]. Amongst others, Garnet Hertz is an opponent of this direction in the maker culture, which has become a particular, market-driven segment of do-it-yourself (DIY) while the original countercultural aspects of

the DIY-movement seem to have vanished. Hertz created a front page for a fictional Made: magazine, which gives some very clear examples of current problems with mainstream making. Amongst others, he points out the importance of readers staying away from any political activities (Join the Arduino Revolution but Avoid Civil Disobedience), highlights the exclusive nature of maker culture (101 DIY Gadgets for White Males) or how such innovative technology like the 3D printer is used for useless and unsustainable activities (How to Use a MakerBot to Make a Three Cent Piece o' Plastic) [Hertz, 2012]. As Hertz defined in a presentation at the FutureEverything Conference in 2014 [Hertz, Levin, McGuirk 2014], this version of maker culture is:

makers = hackers - controversy

When practitioners take part in predefined activities and only build seemingly life enhancing artefacts out of kits, there is little space left for creativity, speculative processes or reflection.

5 Rethinking Making with Critical Thinking

What academics and practitioners start to see is that an alternative is needed to the Silicon Valley-type ways used to innovate socio-technical systems. Due to their educational backgrounds, makers often use standard engineering practices and this might limit their societal impact. If innovating for society is the goal, it is required for practitioners to rethink how they innovate: reproducing industry practices has been criticized for a long time and has proven to be insufficient when it comes to societal change. Critical making as a term was initially developed about 10 years ago by Matt Ratto, who was focused on developing innovative scholarly practice. As he and Hockema put it in FLWR PWR Tending the Walled Garden: "Critical Making is an elision of two typically disconnected modes of engagement in the world: critical thinking,' often considered as abstract, explicit, linguistically based, internal and cognitively individualistic; and 'making,' typically understood as material, tacit, embodied, external and community-oriented." They also elaborate the 3 iterative stages of the critical making process:

1. Review of relevant literature and compilation of useful concepts and theories: specific ideas are identified that can be turned into material

prototypes.

2. These prototypes are built together by scholars, students, and/or stakeholders. The focus here is on extending knowledge and skills in relevant technical areas and providing the means for conceptual exploration, not perfectly designed artefacts.

3. The third step is an iterative process of reconfiguration, conversation, and reflection: this step "involves wrestling with the technical prototypes, exploring the various configurations and alternative possibilities, and using them to express, critique, and/or extend relevant concepts, theories, and models." [Ratto and Hockema 2009]

5.1 Critical Technical Practice

Ratto was inspired by Agres paper on Critical Technical Practice: Lessons learned from trying to reform AI from 1997. Agre wrote about Critical technical practice in 1997, which is a critical theory based approach towards technological design. Agre aimed to increase awareness and critical reflection on the hidden assumptions, ideologies and values underlying technology design. [Agre, 1997]

5.2 Critical Engineering

In critical engineering we see two directions today: the pedagogical direction, used in engineering studies at universities, and the activist direction. In pedagogy, critical engineering is about incorporating critical thinking into engineering studies and the teaching process. It aims to help students ask questions about engineering itself. Discussions of critical thinking in problem solving, conducting experiments, ethical decision making, open-ended design, and assessing the social impacts of technology are utilized. However, critical thinking in this case is only applied within these focused elements of engineering but not about engineering itself. In Situation Critical: Critical Theory and Critical Thinking in Engineering Education Claris and Riley advocate for "asking questions about the production of technology and our relationship to it: Who does engineering, and for whom? Who decides what is and is not engineering, and what ways of knowing (epistemologies) are appropriate to the discipline? Who benefits and who loses from engineering?

How do social, political, cultural, and economic structures create our present understanding of scientific knowledge and the technologies we engineer based upon that knowledge?" [Claris and Riley, 2013]

The Critical Engineering Manifesto by The Critical Engineering Working Group is a framework for the critical engineering practice. Recognizing that engineering is "the most transformative language of our time, shaping the way we move, communicate and think", they raise 10 key and concise points regarding socio-technical issues and what steps the critical engineer can take. Examples are raising awareness about techno-political literacy, how each work of engineering engineers its user, proportional to the users dependency upon it, or that the Critical Engineer notes that written code regulates behaviour between people and the machines they interact with - by understanding this, the Critical Engineer seeks to reconstruct user constraints and social action through means of digital excavation [Oliver, Savicic and Vasiliev, 2017]. One of the Critical Engineering Working Group members, Julian Oliver illustrates these points in his critical engineering and computational climate art, Harvest: using wind-energy to mine cryptocurrency, the earnings of which are used as a source of funding for climate-change research [Oliver 2018], raising awareness on issues like climate change or the effects of cryptocurrency-mining on our environment.

5.3 Critical Design

Critical design has been around since the mid-nineties. As Dunne and Raby write in Speculative Everything: critical design uses speculative design proposals to challenge narrow assumptions, preconceptions, and givens about the role products play in everyday life [Dunne and Raby, 2013]. The example of Designs for an Overpopulated Planet: Foragers by Dunne and Raby, is a speculative design project dealing with the question of the world running out of food due to overpopulation. Governments and industry are incapable of dealing with the situation in this speculative vision so a group of people take their fate into their own hands and start using their knowledge to build DIY devices to "extract nutritional value from non-human foods using a combination of synthetic biology and new digestive devices inspired by digestive systems of other mammals, birds, fish and insects." Foragers is about the contrast between bottom-up and top-down responses to a societal problem and the potential role that could be played by grassroots in solving this. Taking the next step in speculative design, DiSalvo and his colleagues raise the

question during their GrowBot Garden project: what should come after these imaginations of possible futures? How can we collectively make speculative representations and prototypes of possible futures? [DiSalvo et al., 2010]

6 Critical Making

Critical making, as mentioned before, is a relatively new and somewhat broadly used term, as different practitioners use it to define different activities. It is used in academia in teaching and in research, but also to describe citizen-driven grassroots movements, such as "DIY Citizenship" (see Ratto and Boler below).

6.1 In Academia: Teaching and Research

Teaching critical technical practices and critical making can mainly be found in the USA (Berkeley, Stanford, NYU) and Canada (University of Toronto and Emily Carr). Ratto aimed to critically explore the social issues inherent in technical systems, to acquaint students with some of the possibilities and problems of new physical and ubiquitous information technologies, and to help them develop basic skills in designing, making, and evaluating information systems that use these new technologies [Ratto, 2009]. The Critical Technical Practice course at the University of Colorado Boulder focuses on helping students with theory and methods to think more critically, creatively or radically about possible future human-technology relationships, engaging design as a means of provoking discussion, ideas, and questions about technology and culture as opposed to finding the ideal solution for a well defined problem [Devendorf, 2017]. Let's Make a Monster: Critical Making at Stanford points out the notion of technology-out-of-control", a constant worry of modern societies and defines critical making as a practice that utilizes technologies to think about humans constitutive entanglements with technology, while recognizing that insight often comes from errors, glitches and malfunctions [DeMarinis and Denson, 2018]. Interestingly, examples of critical engineering practice in post-soviet countries like Kasakhstan can also be found, where critical thinking is already cultivated by the Ministry of Education [Burkhalter and Shegebayev, 2010].

In terms of research, there are also two distinct directions: art/design and grassroots research. Conducted by a Dutch critical making consortium,

a 4-year project titled Bridging Art, design and Technology through Critical Making asks questions such as: "How can 21st century creative practices art, design, making overcome the industry logic of techno-optimistic makeability and aestheticized products of creative industry?" [Cramer et al., 2018]. In Switzerland, the Critical Media Lab is an integral part of the Institute of Experimental Design and Media Cultures (IXDM) at the Academy of Art and Design FHNW in Basel. This is a physical lab space and a conceptual vehicle "to develop a contemporary notion of criticality towards design, media practices and their cultures, but also aims for a playful and experimental proximity of practice and theory" [Critical Media Lab, 2014].

Looking at citizen-driven development and maker culture, Research Group 2 at the Weizenbaum Institute in Berlin focuses on the production opportunities of maker culture. They research makerspaces and open labs with a societal impact in industrialised nations (USA, South Korea), in emerging economies (Brazil, China) as well as in developing countries [FG2, 2018].

6.2 Citizen-driven Projects

With the wide availability and accessibility of maker spaces, but also social media that allows for likeminded people to gather and create together, active citizenship is growing and can be seen in activism, grassroots movements and citizen-driven practices.

It has been the objective of Hertz to expand the term critical making as an appeal to hands-on makers to be more critically engaged with technology and has gathered two great collections of partially citizen-driven projects that were published in a number of zine-like booklets. "Critical Making", released in 2012 consists of 10 pocket-sized booklets and includes interviews amongst others with Phoebe Sengers, who develops new kinds of interactive technology that respond to and encourage critical reflection on the place of technology in culture or with Natalie Jeremijenko, who blends art, engineering, and environmentalism to create real-life experiments that enable social change. It also contains short descriptions of critical making projects, such as Soft Publics by Mike Manalo, facilitating temporary sites for legally protected speech or the Hazmat Kite by Ken Gregory, responding to the smog problem and the health issues linked to it in Windsor, Ontario, supporting the already existing civil complaint methods [Hertz, 2012]. These booklets were followed up by Disobedient Electronics: Protest, in 2016, a zine showing projects with the aim to point out amongst others that building electronic

objects can be an effective form of social argument or political protest and that the larger issues of what it means to be a human or a society today needs to be directly confronted. This booklet also consists of a number of project descriptions in zine-format, such as the 79 percent Work Clock by Party, calling attention to the gender wage gap or Probots, a protesting robot by Csikszentmihalyi, Aguiar and Azevedo [Hertz, 2016].

As Ratto and Boler summarized, "DIY citizens understand their work to be socially interventionist and ask themselves how do we engage with society politically through technology? [Ratto and Boler, 2014]. Individuals and groups who are self-organizing are enabled by social media networks to scale up and cross the borders of the state, as described in a case study about craft communities of knitters who form and express citizenship identities. These might be dismissed as simple groups of hobbyists, and not taken seriously, but their online networks provide opportunities for new forms of connective engagement to emerge and thus a more optimistic counterculture in current political climates.

A reverse engineering project - as a civic activity - where objects prompt critical reflection [Hertz, Levin, McGuirk 2014] is Golan Levin's (Carnegie Mellon University) Free Universal Construction Kit. Recognizing the problem of brand-based closed systems in toys, it creates a bridge between them: a grassroots interoperability remedy implements proprietary protocols in order to provide a public service unmet or possibly even unmeetable by corporate interests.

7 Researching Grassroots Critical Making

The next section is going to consist of two detailed examples of grassroots movements using critical thinking and making. As the critical making movement grows, interest in researching it will also increase. We deliberately decided to present two cases that have very different roots, come from countries that are very different (Brazil and Singapore) and the societal issues they try to solve and their approaches in doing this completely differ. We chose these cases to show that critical making as a practice is very heterogenous: as academic research continues to explore bottom-up movements, it needs to take into account that these are not homogeneous groups, and are generally decentralized, which means that they cannot and should not be researched as one, uniform movement. Further difficulty is that the taxon-

omy is also often scattered, and grassroots don't always self-identify with the words academics describe them with. Scientists might be inclined to research movements once they're more institutionalized, because they become easier to research, as they they start following official frameworks, but this often means that funding influences their practices and thus political-activist roles they play diminish. Societal impact is high in those grassroots spaces and movements that use critical making, but in a very local, Schumacherian perspective, where "Small is Beautiful"[Schumacher, 1973]. This means that while academic institutions often do not see the direct benefit in researching them as individual agents, such grassroots groups continue to strengthen democracy, attempt to change the status quo and raise awareness around societal issues invisible "from above". We believe that even though it might happen on a scale too small for some, the ingenuity of human creativity to hack and make for society is worthy of observation and research, and will present two case studies below.

7.1 Case from Singapore: EngineeringGood

The maker mindset, perhaps also thought of as sideways thinking, is a defining trait of makers and is often at the heart of innovation. EngineeringGood, is a Singapore registered charity, has adopted this maker approach to positive effect with their Hack-a-Toy workshops.

Accessibility devices designed for Persons with Disabilities (PwD) are expensive in spite of their simplicity. For instance, the AbleNet JellyBean Twist is a popular commercial accessibility device that is in high demand retails at approximately Eur 40. The JellyBean Twist is essentially a button that is well built and designed to be usable in a variety of scenarios that are often utilitarian and form a part of the infrastructure necessary for improving the accessibility of spaces, for example; as a switch for opening and closing doors. Using these commercial devices for playing with toys however is cost-prohibitive and often seen as excessive.

EngineeringGood challenges this with Hack-a-Toy by the ingenious repurposing of mass produced tap lights that are essentially big buttons that light up. Accessibility devices use earphone jacks as a ubiquitous standard for interchangeability and interoperability, therefore the DIY version of the accessibility switch is a tap-light that is hacked or modified with the functional addition of an earphone jack soldered into place to re-purpose the tap-light to behave as a button that performs the same function as its commercially

available alternative. The low-cost nature of these DIY switches makes them more suitable for playful applications and are easily replaced if damaged. These workshops adopt a participatory design process where caregivers learn how to solder, often for the first time. Enabling the repair and production of more DIY devices but more importantly unlocking the mindset of caregivers and practitioners to the idea of repurposing devices for customization. The process of making these devices places the impetus of design and usability in the centre of where its most needed: the user and/or primary caregiver.

Using toys as the desired output automagically imbibes a playful approach to what is often a deeply pragmatic endeavour, learning how to solder and repair. The immediacy of the tangible output of these hands-on workshops ignites a positive response in participants to the maker approach, challenging the consumerist behaviour that is all too synonymous with Singapore.

The Hack-a-Toy workshop is a hands-on learning experience to build a low-cost, DIY switch- adapted toy for children with special needs. Participants apply basic concepts of electrical circuits and technical skills such as soldering, wire stripping, and assembly / disassembly to build an accessibility switch from off-the-shelf materials. These accessibility switches are then paired with commercially available toys to convert them into switch-adapted toys.

The workshops also help to raise awareness about disability and how technology can enable and empower, if applied critically.

For children with special needs, the switch-adapted toys made during the workshops help to enhance their independence in activities of daily living. For instance, a switch-adapted toy enables a child with special needs to play independently and learn through play, his/her therapist is also able to use the same switch-adapted toy to motivate him/her during therapy, to improve his/her physical and cognitive development.

Children with special needs should not miss out the joy of playing with toys just because they have difficulty operating small ON and OFF buttons. The Hack-a-Toy workshops aim to teach participants how to DIY their own accessibility switches to adapt off-the-shelf toys for easy activation by children with special needs. This not only restores their joy in playing, but also encourages movement and the improvement of motor skills.

External links:

- Engineering Good: `http://engineeringgood.org`
- Local programmes in addition to Hack-A-Toy Workshops: `http://`

engineeringgood.org/local-programmes/

- DIY Accessibility switches: https://www.youtube.com/watch?v=d9_lAt7U7_8&list=PLf7VfyZ950aL80gDaYr2chY2S4maYVaAC
- Donate to the cause: http://bit.ly/giveengineeringgood

7.2 Case from Olinda, Brazil: LabCOCO

In late 2003, the Brazilian Congress approved the inclusion of History of Africa and Africans as mandatory disciplines at regular schools, to study the Afro-Brazilian cultural process and the role of black people in the evolution of national society. As a cause, distinct pedagogies related to African culture in Brazil emerged. However, many of these enterprises did not attract the youth to the debates, since the methodologies available couldn't handle the cognitive infrastructure that new technologies and networks provide to connected black youth. Coco de Umbigada Cultural Center is an NGO actively engaged in building a cultural digital Brazilian literacy while proposing methods which enable the youth to have fun along with learning, on how to break the habit of prejudice and discrimination towards Afro-Brazilian religions, in a playful cognition process. This cultural centre is based in Olinda, at the state of Pernambuco, in the northeastern region of Brazil.

LabCOCO is a critical making lab created at the cultural centre to promote the cultural identity of the young population from the community, applying agile projects development methods and using open technologies. LabCOCO runs a Free 150MHz FM Radio broadcasting on a daily basis, a music record studio, drum playing and building classes, bicycle repairing workshops and a digital game development startup, called Contos de Ifa.

Contos de Ifa is a web game which focuses on breaking the habit of prejudice and discrimination towards Afro-Brazilian religions. It is build together with the youngsters from the communities in workshops at LabCOCO. It uses Candomble religion mythology as background for the games and the meetings used to develope it. Its target audience are primarily children and youngsters, and the idea is that through the challenges of each game, the player (and the game designer) may learn the knowledge of each myth. Since the religion maintenance is through oral knowledge, and not based on holy scriptures, this technology supports manners to express this orality as sustained on the temples of Afro-Brazilian religion in Brazil.

Although Brazil has a fame of being plural on its culture, religious intolerance has been seen primarily in the context of Afro-Brazilian religions. According to the Brazilian Ministry of Human Rights, from 2011 to 2016 the Dial Direct Complaints service for Human Rights reported a constant rise in cases involving racism and religious intolerance [SEPPIR, 2015]. Furthermore, many cases are not registered. Contos de Ifa aims to reduce discrimination of colour, tradition and religion, impacting on people's empowerment based on their cultural identity, setting together technology, methods, youth and the knowledge of Afro-Brazilian religion and history.

Contos de Ifa have now eight years of weekly - and sometimes daily - meetings with hundreds of youngsters involved, developed dozens of web games on those meetings and more than 55 thousand users-players at its online platform. Its Facebook page gather 7.7 thousand users, and workshops happened also outside Olinda, in Goiana, Aracaju, Cachoeira, Ribeirao Preto, Sao Paulo, Santos, Zurich and Berlin, in schools, community centres, public markets, teachers' training programs and public events. In general, youngsters who take part in the labs understand the importance of their cultural identity and how they can be part of a digital-developed world. Beyond that, it brings fresh air to education, through practices capable of transforming the economy into more social and human.

LabCOCO ignites sustainable economic models engaging black youth in creative technologies development. Beyond capabilities on technical development and ancestral knowledge, the labs fulfill a gap in the on the maker movement on delivering results to communities, at the same time achieving distinctive results to low-income communities educational spaces.

External links:

- Coco de Umbigada: `http://sambadadecoco.wordpress.com`
- Contos de Ifa: `http://contosdeifa.com`
- Contos de Ifa Blog: `https://contosdeifa.wordpress.com`

8 Conclusion

The potential inherent in makerspaces, the cumulative knowledge of its members and the technical possibilities that rapid prototyping offers is currently not used well enough to be impactful. Even though there are thousands

of makerspaces, both private and public, with untapped potential in their hundreds of thousands of members, the societal impact they create often remains minimal. Can critical thinking inspire makerspaces' members to design and implement people-centered, reliable and sustainable solutions to societal problems - as they often are best positioned to recognize and potentially tackle such problems within their own communities? How can inspiration provided by practices of critical technical practice, design and engineering change the way socio-technical developments are addressed within academia and in citizen-driven projects? This is yet to be seen, as we are at the beginning of this journey. Critical making is as diverse and colorful as the actors currently establishing what it could look like: from enabling everyday citizens to understand better the "black box" of technology and its societal implications to how it can be used to make a difference in today's development.

References

[Hertz, 2015] G. Hertz, What is Critical Making? In: Conversations in Critical Making, Blueshift Series, CTheory Books. Accessed on 2. March 2018. http://ctheory.net/articles.aspx?id=759&fbclid=IwAR1EVSOsz0PK6127kY9hJ8jhnZ6Zh1ZUbGEmslvvuPP0LXd_pWf0BZWsyUU

[American Library Association, 2013] American Libraries Association: Manufacturing Makerspaces https://americanlibrariesmagazine.org/2013/02/06/manufacturing-makerspaces/ accessed on 16. December 2018.

[Gershenfeld, 2013] N. Gershenfeld, How to Make Almost Anything, The Digital Fabrication Revolution. In: Foreign Affairs, Volume 91, Number 6., 2013.

[Martinez and Stager, 2013] S. L. Martinez and G. Stager, (2013). Invent to learn: Making, tinkering, and engineering in the classroom. Torrance, CA: Constructing modern knowledge press, 2013.

[Burke, 2014] Burke, J. J. (2014). Makerspaces: a practical guide for librarians (Vol. 8). Lanham, MD: Rowman Littlefield, 2013.

[Lou and Peek, 2016] N. Lou and K. Peek, (2016). By The Numbers: The Rise Of The Makerspace. In: Popular Science, March/April 2016 issue.

[Finley, 2012] K. Finley (2012) The Military-Maker Complex: DARPA Infiltrates the Hackerspace Movement. Accessed on 17. December 2018. http://www.technoccult.net/2012/02/24/the-military-maker-complex-darpa-infiltrates-the-hackerspace-movement/

[Benchoff, 2016] B. Benchoff (2016) The MakerBot Obituary. Accessed on 17. December 2018. https://hackaday.com/2016/04/28/the-makerbot-obituary/

[Hertz, 2012] G. Hertz (2012), Made: Technology on Affluent Leisure Time. Insert in Critical Making (first edition), in sticker format. Published by Garnet Hertz (AKA "Telharmonium Press, Hollywood, California"). Accessed on 19. December 2018. http://conceptlab.com/made/ and http://www.conceptlab.com/criticalmaking

[Smith, 2017] A. Smith (2017) Social innovation, democracy and makerspaces. University of Sussex, Science Policy Research Unit Working Paper Series SWPS, 2017-10

[Hertz, Levin, McGuirk 2014] G. Hertz, G. Levin and J. McGuirk (2014), Critical Making. Session at the FutureEverything Conference. Accessed on 19. December 2018. https://vimeo.com/100631185

[Ratto and Hockema 2009] M. Ratto and S. Hockema (2009), FLWR PWR - Tending the Walled Garden. Virtueel Platform, Lecturis, Einhoven, 2009.

[Agre, 1997] B. Benchoff (2016) P. E. Agre (1997) Toward a Critical Technical Practice: Lessons Learned in Trying to Reform AI in G. Bowker, L. Gasser, L. Star, and B. Turner, eds, Bridging the Great Divide: Social Science, Technical Systems, and Cooperative Work. Erlbaum, 1997.

[Dunne and Raby, 2013] A. Dunne and F. Raby (2013) Speculative Everything. Design, Fiction, and Social Dreaming, The MIT Pres, Cambridge, MA., 2013.

[Dunne and Raby, 2009] A. Dunne and F. Raby (2009) DESIGNS FOR AN OVERPOPULATED PLANET: FORAGERS, 2009. Artwork Commissioned by Design Indaba as part of Protofarm 2050 for the ICSID World Design Congress in Singapore. Accessed on 14. December 2018. http://www.dunneandraby.co.uk/content/projects/510/0

[DiSalvo et al., 2010] Ca. DiSalvo, L, Fries, T. Lodato, B. Schechter, T. Barnwell (2010) GrowBot Garden, workshops and exhibition as part of the 2010 01SJ Biennial in San Jose, CA. Accessed on 14. December 2018. http://carldisalvo.com/posts/growbot-garden/

[Claris and Riley, 2013] L. Claris and D. Riley (2013) Situation Critical: Critical Theory and Critical Thinking in Engineering Education [Career Advisor]. In IEEE Women in Engineering Magazine, Volume:7, Issue:1, PP: 32 - 36, 2013.

[Oliver, Savicic and Vasiliev, 2017] J. Oliver, G. Savicic and D. Vasiliev (2017) THE CRITICAL ENGINEERING MANIFESTO https://criticalengineering.org/en

[Oliver 2018] J. Oliver (2018) Harvest. Artwork commissionned by Blackwood Gallery for The Work of Wind: Air, Land, Sea. https://criticalengineering.org/en

[Devendorf, 2017] L. Devendorf: Critical Technical Practice course syllabus, Fall 2017, ATLAS and Department of Information Science. Accessed on 22. December 2018. https://ctpf17.wordpress.com

[Ratto, 2009] M. Ratto: Critical Making: critical information studies meets design oriented research, syllabus, Winter 2009, Critical Making Lab, University fo Toronto. Accessed on 22. December 2018. https://ctpf17.wordpress.com

[DeMarinis and Denson, 2018] P. DeMarinis, S. Denson (2018) Lets Make a Monster: Critical Making, syllabus Spring 2018, Stanford University. Accessed on 22. December 2018. https://explorecourses.stanford.edu/search?view=catalog&filter-coursestatus-Active=on&page=0&catalog=&q=ARTSTUDI+233%3A+Let%27s+Make+a+Monster%3A+Critical+Making&collapse=

[Burkhalter and Shegebayev, 2010] N. Burkhalter and M. Shegebayev (2010) The Critical Thinking Movement in Kazakhstan: A Progress Report. Research in Comparative and International Education, 5(4), 434445., 2010.

[Cramer et al., 2018] F, Cramer, L. Evers, A. Helmling, K. Kuitenbrouwer, M. Sondeijker, J. Wesseling: Position Paper Critical Making. Accessed on 14. December 2018. http://www.criticalmaking.nl/publications/critical-making-position-paper

[Critical Media Lab, 2014] About the Critical Media Lab, Basel. Accessed on 14. December 2018. https://www.ixdm.ch/critical-media-lab/?fbclid=IwAR1TU2tdZyjmPDqIBk62HFJAorAb3aTHDh5Qy9_rphjtGhwEsA8SHSPB_U4

[FG2, 2018] Research Group 2 on Production Ooportunities of the Maker Culture, Weizenbaum Institute https://vernetzung-und-gesellschaft.de/fg2/. Accessed on 22. December 2018. Translated by Regina Sipos.

[Ratto and Boler, 2014] M. Ratto and M. Boler (eds), DIY Citizenship: Critical Making and Social. Media, Cambridge: MIT Press, 2014.

[Hertz, 2016] G. Hertz (2016) Disobedient Electronics: Protest. Accessed on 2. March 2018. http://www.disobedientelectronics.com

[Schumacher, 1973] E.F. Schumacher, Small Is Beautiful. Economics as If People Mattered. London: Blond and Briggs, 1973.

[SEPPIR, 2015] SEPPIR BRAZIL, Ouvidoria Nacional da Igualdade Racial. Accessed on 5. Jan 2019. http://www.seppir.gov.br/ouvidoria