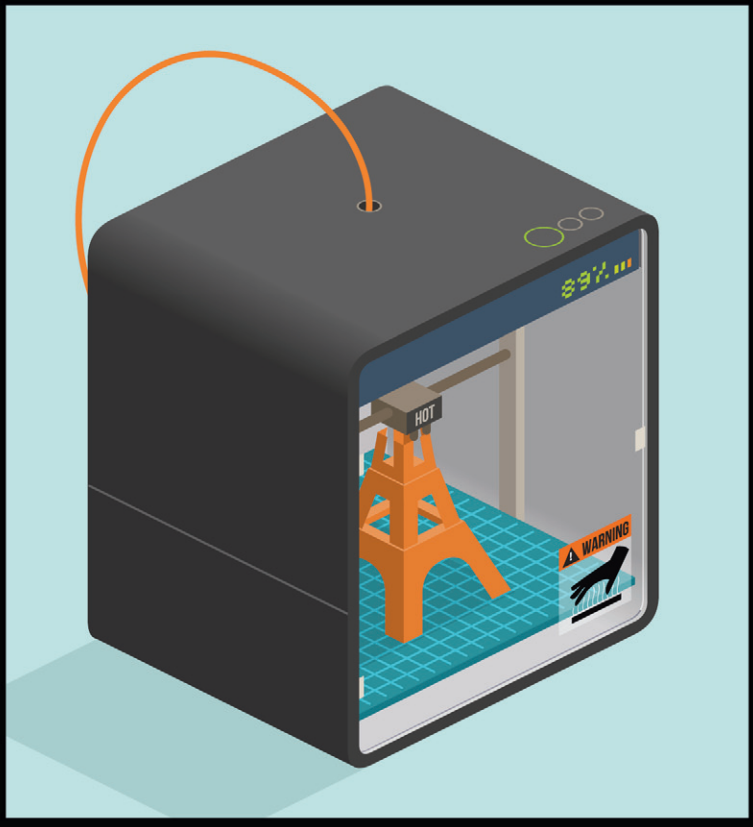
3D Printing Cultures, Politics and Hackerspaces



Leandros Savvides

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3D Printing Cultures, Politics and Hackerspaces

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3D Printing Cultures, Politics and Hackerspaces

BY

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INVESTOR IN PEOPLE

To all those people who tirelessly work to redefine the world toward the interests of the vast majority.

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List of Abbreviations

AM	Additive manufacturing
CAD	Computer-aided design
CBPP	Commons-based peer production
CEO	Chief executive officer
CLIP	Continuous liquid interface production
CNC	Computer numerical control
DARPA	Defense Advanced Research Projects Agency
DIY	*Do it yourself*
EU	European Union
FDM	Fused deposition model
IP	Intellectual patent
IT	Information technology
LOM	Laminated object manufacturing
MTC	Manufacturing Technology Centre
NASA	National Aeronautics and Space Administration
NSF	National Science Foundation
OSAT	Open-source appropriate technology
PLA	Polylactic acid
PVA	Polyvinyl alcohol
R&D	Research and Development
REMAP	Rehabilitation Engineering Movement Advisory Panels
SL	Stereolithography
STEM	Science, Technology, Engineering, Mathematics
STS	Science and technology studies
USB	Universal Serial Bus
UT	University of Texas
WEF	World Economic Forum

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Abstract

This book examines the emergence of 3D printing culture outside the professional lab, predominantly in Hackerspaces, Makerspaces, and Fab Labs. Such spaces constitute important sites in the development of open-source, desktop 3D printing and provide conducive conditions for the spread of the technology to and often beyond technologically informed publics. Specifically, this research addresses the convergence of activism and the maker culture with prevalent cultural imaginaries such as the visionary creator within decentralized and distributive manufacturing, the vision of autopoietic social systems, or the imaginative leap to space colonization. In addition, it explores the emergence of grassroots innovation and how it is configured through 3D printing. In order to observe the aforementioned social phenomena, I conducted multi-sited ethnography in several experimental spaces in the United Kingdom, Germany, and Cyprus. The selection of the sites represents different types of Hackerspaces, Makerspaces, and Fab Labs: some of them bring hobbyist maker communities together, while others were explicitly conceived as political interventions and others operate as informal startup incubators. In my fieldwork I followed users of 3D printing technology as they navigate their activities through grassroots workshops, multiple associated communities, and broader hacker networks.

Drawing on the findings of my research, I argue that the emergence of digital DIY and maker cultures was not only powered by 3D printing technologies but also played a vital part in creating, expanding, and disseminating knowledge of 3D printing further afield. Within this process, 3D printing users become developers themselves who simultaneously reinvent forms of consumption, processes of learning, and reconceptualizing the relationship between science and craft. Despite the apparent social and collective nature of these practices, there is also a parallel individualistic twist at the heart of the maker culture. The book contributes to a growing debate within science and technology studies, which is concerned with the emergence of citizen science and civil society interventions in shaping technology. Moreover, it touches upon challenges and motivations in the field of grassroots innovation by examining how it is organized and conducted in semi-informal contexts such as the Hackerspaces, Makerspaces, and Fab Labs.

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Chapter 1

Approaching 3D Printing

> Today we are seeing a return to a new sort of cottage industry. Once again, new technology is giving individuals the power over the means of production, allowing for bottom-up entrepreneurship and distributed innovation. Just as the Web's democratization of the means of production in everything from software to music made it possible to create an empire in a dorm room or a hit album in a bedroom, so the new democratized tools of digital manufacturing will be tomorrow's spinning jennies. And the guilds they may break may be the very factory model that grew up in Manchester and dominated the past three centuries.
>
> (Anderson, 2012, pp. 50–51)

3D printing as a technological possibility has been around for more than two decades. Indicatively, the first successful attempt to print objects using the now popular stereolithography method was made by Charles Hull in 1986. The first attempt to commercialize 3D printing technology and methods for manufacturing emerged in 1994, using print materials composed of wax (Jacobs, 1992). There are a variety of methods that constitute 3D printing technology, but the underlying general characteristic all methods utilize is to build objects in additive technique. That is in contrast to molding them using a subtractive method (Knill & Slavkovsky, 2013). This means that 3D printers can be quite efficient and more flexible than other methods of manufacturing, depending on the state of development of the specific methods in specific industries: efficient because the additive technique builds objects not by eliminating parts and so as a process entails much less waste and is a good choice for low volume manufacturing; and flexible because building objects additively offers greater creative freedom with flexible materials as well as more intricate geometric objects.[1]

With the commercialization and thus affordability of 3D printing, it was primarily field professionals and hobbyist practitioners that had access to prototyping, through industrial or semi-industrial professional settings. The technology remained virtually unknown to the vast majority of the population. This would appear to coincide with and even explain why, until very recently, literature that relates directly to 3D printing as technology and process was very scarce, apart from official industry and policy reports. Francis Jacob's (1992) early work on defining the key characteristics and competences of the technology when it was in

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its infancy is an example of such work published through industry. Indeed, after the turn of the century, research on 3D printing remained technical in the main. For instance, as a field of study, Additive Manufacturing has been systematically researched in terms of pure engineering and as a scientific advancement of manufacturing (Balc & Campbell, 2004; Burton, 2005; Hague, Campbell, & Dickens, 2003; Hopkinson, Hague, & Dickens, 2006; Reeves, Tuck, & Hague, 2011; Sells & Bowyer, 2006).[2]

From the beginning of the twenty-first century, 3D printing began to fire the imagination of public media and cultural groups with an interest in DIY and technology, consequently sparking creative narratives. Such narratives helped disseminate knowledge of the existence and practical capabilities of 3D printing among the general public, which gradually became aware of its existence. This was when the Makers movement started to gain momentum, so named because of "*Make* magazine," an American bimonthly publication founded by Dale Dougherty, a leading proponent of open software. The Makers movement had a very simple message: "Make. Just make. This is the key. Making, is actually fundamental to what it means to be human" (Hatch, 2013, pp. 11–12).

Creative hobbyists and communities started to use such type of machinery for their own purposes, experimenting and in many ways adding to and advancing the technology itself. The iconic garage where the Apple seed was first planted and similar stories of mega concerns first seeing the light of day in small uncomfortable places where their creators had to hack their initial products and ideas until they took off became the stuff of legends that provided a motivational boost for those who otherwise might have packed it in after experiencing the inevitable setbacks associated with developing a new technology. Many stuck to it because of the romanticized image of a group of pioneering wunderkinds who achieved success, by defying the skeptics, proving that starting to make is the most difficult step (Bauwens & Kostakis, 2014; Turner, 2010). So, why approach 3D printing as a cultural phenomenon apart from a technological development?

As the momentum built and word spread about 3D printing culture, illustrious and established media were quick to get into the act pronouncing 3D printing as a phenomenon potentially "bigger than the Internet" (Morton-Clark & Garrahan, 2012) for businesses to exploit the new technology. On the other hand, from a grassroots perspective, as Chris Anderson contends, this is a crucial technology that could bring about a "third industrial revolution" (Anderson, 2012, p. 40) because it will allow people (not just workers) to "control the means of production" (Anderson, 2012, p. 5), a clear suggestion that the technology can bring about cataclysmic social changes.

Whatever the case, 3D printing seems to be exciting news for many fields of study and a technology capable of reconfiguring modes of production and consumption in the future. An obvious reason could be the development and integration of Internet and Internet-based hardware and software into the everyday life of millions of consumers. For others, it goes beyond a mechanistic understanding of the combination of Internet and a desktop machine. The technology and related hardware and software open up a whole new political economic paradigm. Carson has contributed to the field from the perspective of a mutualist

political economy (2010) albeit not focusing solely on 3D printer but on desktop manufacturing in general. In policy making circles, the idea of a circular economy meets some of these characteristics halfway by proposing new ways of using materials, collaborative consuming, and creating new value channels.

> In our business, we have regular discussions with our partners, coming up with new "circular" approaches, such as "second-life markets," where goods are refurbished and marketed to new customers, extending the life of the product and building new revenue streams. The fact is, climate change and resource scarcity won't go away unless we change things. More renewable energy usage and a smarter use of the planet's resources is at the heart of the circular model, in which re-manufacturing, recycling and re-use methods are adopted in greater number.
>
> (Stephenson, 2015)

The development and conversion of such technology into a brand new manufacturing technique and organization culture has generated an accompanying literature that explores 3D printing as it relates to intellectual property in terms of new exclusions and innovation processes that unravel (Bradshaw, Bowyer, & Haufe, 2010; Weinberg, 2010); how inexperienced users could achieve professional and functional designs (Campbell et al., 2007; Simpson, Siddique, & Jiao, 2006); and how this could alter the manufacturing industry in terms of mass customization (Baumberger & Baulcombe, 2005; Chin, 2005; Koren & Barhak, 2007). Despite the focus on its productive impact, the significance of 3D printing in cultural terms and more importantly in everyday life was perhaps overlooked or underappreciated until the Makers movement adopted and promoted 3D printers as important desktop technology for making. That this lent itself to science fiction and play proved to be attractive for makers and the wider public alike.

After the 1960s, when the space race brought new audiences to science fiction and then the 1990s, where the mass adoption of personal computers and the Internet created the cyberpunk genre (Bacon-Smith, 2000; Pierson, 1999), futurism came back into fashion.[3] This alluring futuristic imaginary is also what attracted me to the study of 3D printing not simply as a technological development but more broadly as a social and culturally induced phenomenon. Ubiquitous manufacturing and the ability to deliver finished products through 3D printing machines in networked and decentralized centers motivated communities and artists alike to start dreaming of a 3D printed future (Birtchnell & Urry, 2013). Following suggestions by cultural icons such as Anderson, for many years'

[3]Not only through the lens of 3D printing, it is evident that new technological and scientific developments have been reflected in social and political thought. One example is the advocacy of accelerationism, which has left and right wing variants. However, the differences of the different variants, the main tenet of accelerationism is that technological and scientific developments are exceeding the limitations of capitalism and lead toward post-capitalist futures. See, for example, Williams and Srnicek (2014).

editor-in-chief of *Wired* magazine and later founder and CEO of 3D Robotics, I approached this project in a manner allowing me to discern such cultural imaginaries while attempting to document its real-time development. I decided to look for 3D printers in these bottom-up spaces and juxtapose my observations, experiences, and interviews with official documents, newspaper articles, and policy documents.

In this manner, my hope is that this book gives an insight and shapes the understanding to some degree of a broad social phenomenon that encompasses work, hobbyism, and political activism through the lens of 3D printing. 3D printing is closely related to the hacker ethic (Levy, 1984; Söderberg, 2008) as much as it is associated with networked modes of alternative production and sharing of information (Bauwens, 2005; Benkler, 2006; Bowyer, 2007; Carson, 2010; Castells, 2000; Kostakis, 2013; Powell, 2012). The hacker ethic has proven to be a key component in innovation strategies, which suggests that just being a hacker or a maker does not necessarily mean alternative ways of doing and living. Other factors have to be taken into account to explain the alternative modes of production and distribution – e.g., motivations, infrastructure, and cultural imaginary. This book is the product of my initial attempt to engage with STS. The choice of STS seemed to be the most appropriate, as it allows an interdisciplinary approach to technological phenomena, looking at 3D printing through society, politics, and culture.

My interlocutors in this endeavor to find links between grassroots communities and the technology itself range from experts, university students, and researchers to hobbyists, artists, and political activists. Each had something to talk about when asked about 3D printing and each helped position a piece in the puzzle of the phenomenon for this study. Indeed, some of the arguments I make throughout the book are triangulated in order to show how individual perspectives connect to a broader cultural phenomenon. Some people have identified themselves as part of the Makers movement while others, although not identified as such, revolved around for completing their projects. Although not all of those involved in this study necessarily identify themselves as being part of this movement, the movement's swift rise to prominence had significant impact on the technology, the people who are involved, and the spaces they conduct their practice.

The Makers movement that started to increasingly expand over the past 10 years emerged within an environment which contained three historical developments: firstly, the collective experience and cultural legacy of the urban working class of previous generations, whose radical science movements for democratic decision-making (Arditti, Brennan, & Cavrak, 1980) challenged the direction of scientific explorations taken by government administration (Rose & Rose, 1972, 1979); secondly, industrial production upgrades like digitizing manufacturing (Wu, Rosen, Wang, & Schaefer, 2015), the question being did they constitute a new paradigm or are they simply an addition to old structures; and last but not least, shifts in educational trends which expanded traditional learning practices to include informal playful practices while retaining basic educational values. These innovative educational practices use collaboration to unsettle the balance of power between those being educated and the educator, resulting in a more democratic learning experience (see Tanenbaum, Williams, Desjardins, &

Tanenbaum, 2013). In addition to these informal practices, new methods of learning place greater importance on the methodology of searching for answers than on the answer itself. There is also the growing, necessity-based collaboration between industrial workers whose skills are outmoded (due to redundancy and/or industry changes or the availability of cheaper production and bigger profits elsewhere) and skilled university graduates who find it increasingly difficult to find secure jobs.[4,5] As such, the field covers a wide range of often overlapping practices, technologies, lifestyle, and ways of thinking, including art and small startup enterprises, all of which find it increasingly beneficial to collaborate in some way or another. For this matter alone, grassroots community workshops add a physical dimension to the previous online collaborations of the open software movement, which now seem to be the favorite physical platforms where they can engage.

With this emergence of new forms of collective community workshops in the heart of cities, 3D printers have become a common tool for makers and hackers. Despite the efforts of Johan Söderberg (2013a, 2013b), Vasilis Kostakis and Michel Bauwens (2014), the available literature exploring the technology of these emerging movements and the field for integrating user perspectives with broader social developments is very limited. This is to some degree expected, since the hype surrounding the particular technology and the Makers movement has only been addressed recently. Another research example from this perspective is the study conducted by Jones et al. (2011) which specifically brings up matters that could only have been learned by insiders and people spending a considerable amount of time delving into forums and blogs that explained the birth and development of RepRap. RepRap sought to create a general-purpose machine with self-replicating and mass customization capabilities through open design, under the license of free software (see Sells, Bailard, Smith, Bowyer, & Olliver, 2009). In their book "*Fabricated*: *The New World of 3D Printing*," Lipson and Kurman (2013) provided an insight from the perspective of the mainstream economy and industry urging that they utilize the technology by resorting to futurology.

The Hackerspaces, Makerspaces, and Fab Labs that were springing up near the UK's Midlands industrial area offered extra easy access to look into what makes this spreading culture so attractive to hackers and makers alike. But it was not confined to the traditional core of Midlands manufacturing around cities like Birmingham, Derby, Coventry, and Leicester. The opening of these spaces inspired others, not necessarily from industrial towns or backgrounds, to create their own workshops. These workshops had to find legal ways of establishing themselves just as they had to find more interested people in order to increase prospects for collaboration and expansion of their networks. In a few brief years, they grew from isolated pirate-like organizations within cities to

[4]See, for example, a "SPERI British Political Economy brief" commenting on the decline of manufacturing industry in the United Kingdom during the past two decades.

[5]The inability of youngsters to find jobs coupled with the increasing capabilities of desktop technologies have had some effect, turning many toward DIY projects on their own.

large communities integrated within the fabric of their respective local societies, some even with national appeal. Some collaborated with companies, others less so. Some actively encouraged startups, and others preferred to create inclusive communities, a way of showing they were concerned with more than just creating projects. Susana Nascimento (2014, p. 1) writes on their importance:

> These new settings are promisingly opening up concrete opport unities for decentralized and collaborative engagements with technology, not only related with material and technical experimentations, but also with economic, cultural, social and political consequences, and ultimately with conceptual and epistemological changes. With due attention to their differences, there is a common and shared rationale attached to these emerging spaces that supports an openness when approaching and thinking about technology. This powerful and captivating rationale expresses that any user, consumer, or citizen should be ultimately able to produce, use, share, copy and improve technologies, with little to no help or backup from traditional technological experts, organizations or institutions. And from this standpoint, derives a multiplicity of potential pathways for empowerment through technology and democratization of technology for broader social groups.

Decisions such as how to organize or the name the community should adopt, are usually a matter for those who set up each community. The importance of this culture has two basic tenets: ways of organizing and access to tools. Some communities adopt a democratic framework, presuming the community to be as important as the sharing of tools and machines. Others focus more on sharing resources and apply a managerial style to daily care. The decision on what organizational style each community prefers is usually affected by operational costs and the direction it wants to follow. For example, a shared machine shop for commercial purposes is not likely to follow democratic style management. At the same time, a community which seeks to operate as a hobbyist group usually promotes cultural values such as participation through collective decision-making. Although rather different in some aspects, in this dissertation, I group these noncommercial spaces on many occasions as community workshops, since I think they share similar core attributes. People within the Makers movement often act in the same way despite the label chosen.

The book explores the dynamic interplay between these spaces, the Maker community and 3D printing technology, not as isolated issues but in context. In other words, by challenging popular notions of hype-driven technological narratives, Technoscience and grassroots communities, this study aims (after a historical outline of 3D printing development) to explore a 3D printing ecology – 3D printers' habitat, uses, and the actors involved while at the same time capturing its latest developments. A vital part of my analysis of the development of 3D printing is the wider context, i.e., the social and economic environment as reflected in this phenomenon after the global financial meltdown (Albo, Gindin & Panittch, 2010)

as well as the debates on innovation, science, and technology (Kline & Rosenberg, 2010). The post-financial meltdown landscape is characterized by increasingly precarious (Ross, 2008) and self-employment work (especially in the creative industries), the prevalence of social media (see O'Keeffe & Clarke-Pearson, 2011), and the increasing importance of STEM education (Bybee, 2010). Such an environment hosted favorable conditions for the reemergence of a DIY attitude, as advocated by the Makers movement.

During a preliminary reading in 2012, although the academic landscape on 3D printing was much different from today, I was aware of some studies already being done on its development.[6] During the years of study, there has been an increased availability of much faster and more reliable 3D printers as well as the development of a distinct culture along with the expansion of grassroots community workshops. Literature that relates directly to this specific technology and process is essentially very scarce other than official industry and policy reports. Francis Jacob's (1992) early work attempted to define the key characteristics and competences of the technology at the time of its infancy. Considered as a natural continuation of Jacobs' work, Hopkinson, Hague, & Dickens' (2006) record the developments in the field for over the past two decades. Neil Gershenfeld's (2006) work on the emerging desktop manufacturing situates 3D printing within a background of the MIT Media lab as well as providing extensive descriptions on the existing situation endeavoring to reflect on social and technical paradigms that might emerge. As with any technology, the degree of its popularization and by extension demand for development can be measured by its presence in popular culture literature. In terms of science, fiction "*Makers*" (Doctorow, 2009) and nonfiction such as "*Shaping Things*" (Sterling, 2005) have gathered some popularity in academic and nonacademic public. The development of 3D printing has compelled Ratto and Ree (2012) to attempt to restate the question of the material versus the digital in the light of social change.

The reemergence of the concept of ideas materializing through altering production paradigms and shifting the way of thinking proves it is no coincidence that old questions about the primacy of the material are returning (Latour, 2007). 3D printer is a technology that sparks such imaginations about potentialities. What is real in terms of 3D printing production (Van den Berg, Van der Hof, & Kosta, 2015): ideas preceding thoughts or material conditions preceding ideas? A radical change in production practices culminated in the development of this technology will force researchers and practitioners to answer again and again the question of materiality and its fusion with the digital, the blurring of clear distinct lines (Loy, 2014). However insightful, many previous studies have tried to focus on certain aspects of the technology yet failed to include the political disputes as well as the ideological dimension that takes place within social, economic, and political landscapes. Hence, this book is

[6]The proliferation of studies conducted during 2012–2017 expanded the literature on the subject. By 2020, 3D printing literature has increased as well but the hype has largely deflated.

a product of that missing link, an attempt to understand this dynamic interplay firsthand but having in mind its social, (geo)political, economic, technological, and environmental implications in an integrated totality as Fredric Jameson (1992) put it, rather than isolated and fractured way.

Innovation: Economic, Nonprofit, and Informal

What is technology? What drives technological change? These are the fundamental questions concerning the issue of technology and innovation. There is no general agreement as to what constitutes an objective reality or factor that drives technological change. Increasing productivity, creating new objects, and altering social relations through new ways of integrating society with technology are integral characteristics of what it means to innovate. However, in themselves, such characteristics do not seem to constitute enough reasons to be called innovations. This is because innovation seems to be an elusive term. What constitutes an innovative practice or technique? Perhaps the most certain feature of innovation is that since the first industrial revolution, it seems to be closely linked with economic growth. Moreover, the innovation process owes some credit to instincts that the entrepreneurial attitude entails, a feature that recently has gained attention (Chiapello & Boltanski, 2005; Van Oost, Verhaegh, & Oudshoorn, 2009; West & Lakhani, 2008). Hence, this seems to be a barrier in attempts to count in a formulaic fashion the factors affecting innovation (Rogers, 1962, 2003). With the rise of the capitalist mode of production, one thing is certain; under this mode, the world has seen an unparalleled technological advancement and increase in productivity. For example, social thinker and economist Karl Marx (1990) specified the need of the entrepreneurial bourgeois class within capitalism to constantly innovate in order to ensure profitability and thus their existence as a class. However, despite his thorough analysis and critique of capitalism, he did not point out a definite theory or a path on how innovation is achieved; only some aspects scattered between his texts.

Economist Joseph Schumpeter, building on the work of Marx, was perhaps the first economist to give great importance to innovation as a powerful force of economic as well as social and political transformations. As a fundamental contribution, he suggested that we should comprehend innovation beyond a narrow spectrum of technical change, but rather as a shift that can happen in production after a variety of causes that may include new markets, new raw materials, or new structural changes in industries (Schumpeter, 1934, p. 66). Thus, for Schumpeter (1935, p. 7), it is impossible to methodologically reduce innovation of component factors, but rather see innovation as a holistic approach.[7] Perhaps the biggest difference between Schumpeter and Marx was that while Marx thought that the

[7]Schumpeter (1935, p. 7) states that "the historic and irreversible change in the way of doing things we call innovation and we define: innovations are changes in production function which cannot be decomposed into infinitesimal steps. Add as many mail-coaches as you please, you will never get a railroad by so doing."