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Making (in) the smart city: The emergence of makerspaces

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ABSTRACT

Critical approaches to the smart city concept are used to begin highlighting the promises of makerspaces, that is to say, those emerging urban sites that promote sharing practices; exercise community-based forms of governance; and utilize local manufacturing technologies. A bird's-eye-view of the history of makerspaces is provided tracing their roots back to the hacker movement. Drawing from secondary sources, their community-building, learning and innovation potential is briefly discussed. Makerspaces, this essay argues, can serve as hubs and vehicles for citizen-driven transformation and, thus, play a key part in a more inclusive, participatory and commons-oriented vision of the smart city.

1. Introduction

Urbanization is a trend of our times, with the largest share of the human population globally living in cities; a trend that is only increasing (United Nations, 2014). Cities are economic centers that through the consumption of massive resources lead to heavy environmental impact (Glaeser, 2011) as well as to social contestations and conflicts (Foster and Iaione, 2016). This creates the need for new conceptualizations for a city that will be able to deal with the current issues in more imaginative, inclusive and sustainable ways.

In this context, the term "smart city" has emerged. This concept, however, is vague to say the least, since there is neither a single template of framing it nor a one-size-fits-all definition (Albino et al., 2015). The dominant narrative hails from those private enterprises which produce advanced information and communication technologies (ICTs) (Bulu, 2014; Townsend, 2013). The "smart city" idea has crystallized into an image of a technology-led urban utopia permeated with centrally controlled technological infrastructures, with the aim to improve the urban environment in terms of efficiency, security and sustainability (Niaros, 2016; Bulu, 2014).

This has led to a growing role of commercial activities through firms, such as Cisco Systems, IBM and Siemens, which promote themselves as "stakeholders" in the public consultation processes (Hollands, 2015). These large ICT powerhouses, having made massive investments, are the major companies involved in the smart city and the Internet of Things (IoT) cluster of technology. Through the installation of countless wireless sensors and the utilization of the IoT, the networked/sharing technologies installed usually target better energy and garbage management; reduced water consumption; improvements to citizen mobility; and crime prevention (Albino et al., 2015; Walravens, 2015).

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Nevertheless, the aforementioned practices have drawn some criticism during the last few years. For instance, it has been argued that the notion of problem-solving ICTs does not acknowledge the needs and desires of city-dwellers, mainly because they are not attuned to the ways that people use technology (Sassen, 2012) as well as due to the messiness and diversity of urban reality (Ylipulli et al., 2013). Also, issues related to privacy and citizen participation are often raised (Carvalho, 2015; Greenfield, 2013; Kitchin, 2014). Further, Hollands (2015) claims that the unrestrained deployment of these technologies is shaped around the motives of suppliers, i.e. the commodification of their existing products and services. Therefore, an environmentally harmful consumption of ICTs increases without serving the true needs of the citizens or even addressing actual problems (Niaros, 2016). It is therefore evident that this standard conceptualization of the smart city is troublesome, primarily due to issues embedded in the design and implementation of the technological infrastructure.

In this paper, critical approaches to the smart city concept are used to begin highlighting the promises of emerging urban sites that promote sharing practices and commons-based peer production. In short, commons-based peer production (CBPP), a term coined by Yochai Benkler (2006), has brought about a new logic of collaboration between networks of people who freely organize around a common goal using shared resources, and market-oriented entities that add value on top of or alongside them. Prominent cases of CBPP, such as free and open-source software and Wikipedia, inaugurate a new model of value creation, different from both markets and firms. The creative energy of autonomous individuals, organized in distributed networks, produces meaningful projects, largely without traditional hierarchical organization or, quite often, financial compensation (Bauwens and Kostakis, 2016).

Hence, in light of the rise of the collaborative commons, i.e., shared resources (Benkler, 2006; Rifkin, 2014), the concept of urban "makerspaces" is discussed. The latter are community-led, open spaces where individuals share resources and meet on a regular basis to collaboratively engage in creative commons-oriented projects, usually utilizing open source software and hardware technologies. Through the intersection of digital technologies and urban life, several initiatives have emerged that attempt to circumvent the dependence on private firms or governments to provide solutions. Individuals of varying backgrounds and goals have access to prototyping tools in makerspaces, allowing them to collaborate in order to produce small-scale solutions for problems of daily life (Kohtala and Hyysalo, 2015; Kostakis et al., 2015d). They produce their own solutions in co-working places which may go by various names like microfactories, hackerspaces, fablabs or media labs and others (Gandini, 2015). In this paper, some of these terms are employed at several stages, but the term "makerspace" is used as an umbrella for all of them.

Surveying and synthesizing secondary sources, this essay attempts to answer the following research question: What is the community-building, learning and innovation potential of makerspaces, i.e. an emerging civic infrastructure, towards a more inclusive, commons-oriented smart city?

The rest of the paper is organized as follows. Section 2 presents the concept of makerspace by providing a short historical account. Section 3 is then set to discuss the community-building, innovation and learning potential of makerspaces, considering them as hubs and vehicles for citizen-driven transformation. Section 4, finally, summarizes the main findings and arguments and includes proposals for future research and action.

2. A historical account of makerspaces

Makerspaces, hackerspaces, fablabs are in a flux: there is no single definition that perfectly captures all such spaces (Sleigh et al., 2015; Smith et al., 2015). This paper departs from a rather simple and inclusive definition, using the term "makerspaces" as an umbrella for community-run physical places where people can utilize local manufacturing technologies[1]

This broad definition of the makerspace concept does not imply that, for example, every media lab or microfactory is necessarily a makerspace because the former might not meet one of the following criteria. The makerspace term is adopted here because, normatively speaking, it is welcoming and inclusive (Smith et al., 2015) as well as related, but not limited, to manufacturing, a diverse sector that promotes innovation and productivity (Reinert, 2011). Hence, this definition introduces two basic criteria that qualify a space as a makerspace: first, to exercise community-based forms of governance; second, to utilize local manufacturing technologies. A bird's-eye-view of the history of the concept may shed light on it and justify the choice of these two criteria.

In the beginning, there was the hacker, a controversial term that is only now entering mainstream usage (Hunsinger and Schrock, 2016; Smith et al., 2015; Kostakis et al., 2015a). The connotation depends on the community still, and in general parlance the term is associated with doing something bad and/or illegal, whereas now this is changing. There are various types of hackers: the benevolent, white-hat hacker who, in Wark's (2004, 2013) and Levy's (2001) vein, experiments, tinkers, modifies, creates and/or participates in collaborative projects. There also is the malicious, black-hat hacker (also known as cracker) who has criminal intentions, causes damage and carries out criminal acts (Kostakis et al., 2015a). Then there is the grey-hat hacker who tends to hold a morally ambiguous role (Parker, 2005). For example, a benevolent, white-hat hacker would upgrade the functions of a wireless router's firmware with updates other than those that have been signed by the device's manufacturer; modify a sampling keyboard to create unusual sounds by doing circuit bending; or transform the plastic 500 cc bottle into a spacer for asthma medications.

[1] Anything from three-dimensional (3D) printers, to computerized numerical control routers and laser cutters (i.e., hi-techs), to simple cutting tools and screwdrivers (i.e., low-techs) can be considered local manufacturing technologies.

In this paper, hacking is understood as a creative process, immersed in the hacker ethic of problem-solving (Erickson, 2008) as well as of producing novel artifacts (Söderberg, 2007; Wark, 2004). According to several scholars (Dafermos and Söderberg, 2009; Himanen, 2001; Levy, 2001; Maxigas, 2012; Wark, 2004), who have taken a close look at the phenomenon, fundamental aspects of the hacker ethic include: i. sharing, solidarity and cooperation; ii. distrust of authority, that is opposing the traditional, industrial top-down style of organization; iii. freedom, in the sense of autonomy as well as of free access and circulation of information; and iv. embracing the concept of learning by doing and peer-to-peer learning processes as opposed to formal modes of learning (Kostakis et al., 2015a).

The hacker subculture appeared in the 1960s and took off in the 1970s from the MIT Artificial Intelligence Laboratory and other research institutes in the US, as well as from the phreaker scene through the magazine TAP (Technological American Party) (Maxigas, 2012). The hacker ethic is also considered to share some common characteristics with the hippie culture dating back to the 1950s and 1960s and evolving over the decades through different generations (Hogge, 2011; Levy, 2001) and socio-economic transformations (Bauwens, 2005; Benkler, 2006; Castells, 2000, 2003). It is in the context of the networked society that hackers started to form online and offline communities, sharing knowledge, tools and ideas. Arguably there was a need to organize, in a more systematic way, these conversations among hackers in physical spaces, which led to the creation of communities such as the Homebrew Computer Club in the mid-1970s, the Chaos Computer Club in 1981 or the first hackerspaces, as we know them today, in Berlin (C-base) and Cologne (C4) in the mid-1990s.

During the last two decades, the wide distribution of ICTs and the dropping costs of local manufacturing technologies have sparked global interest and experimentation with grassroots creative possibilities. Individuals and groups immersed in a hacker ethic, as described above, have been building community-run physical places to pursue their common interests. In other words, we have been observing the emergence of makerspaces. Makerspaces have commonly been used as a local, physical platform for the sharing of resources and the provision of local manufacturing technologies that are not yet as distributed as computers or Internet connectivity (Kostakis et al., 2015b). For instance, there is a rapidly increasing global network of hackerspaces, which is documented in the hackerspaces.org wiki and spans all over the world; or fablabs, which began in 2001 as a research project of MIT with the aim to investigate how underserved communities could be empowered by digital technologies at the grassroots level (Mikhak et al., 2002). Another example is that of men's sheds that originated in Australia in 1990s to promote psychosocial health and wellbeing in older men through their engagement in woodwork and other practical activities (Ballinger et al., 2009). Last, there are municipality-supported media labs such as Madrid-based MediaLab-Prado (Niaros, 2016), which was established in 2002 and has been active in the production, research, and dissemination of digital culture (MediaLab-Prado, 2016).

Makerspaces may be seen as the development of a new form of "third place" (Moilanen, 2012). Oldenburg (1999) coined this term to highlight urban social settings or surroundings that provide "social experience outside of the home or workplace/school" (Lawson, 2004: 125). Since the introduction of the concept, different types of third places have been listed, from cafés, clubs, parks, libraries, barber shops, churches, cookouts (Jeffres et al., 2009), to virtual places and online communities (Soukup, 2006). It is argued that such places are significant for the empowerment of community ties, the establishment of a sense of place, civic engagement and, therefore, democracy (Oldenburg, 1999, 2001). Their role becomes of utmost importance when one considers Putnam's (2000) claim of a decline in social capital within United States society during the last five decades, which has been undermining active civil engagement and thus democracy itself. Using the concept of third place and the community-building potential of the makerspaces as a point of departure, the following section describes how makerspaces can radically transform the idea of third place and serve as a new civic infrastructure.

3. Potential for citizen-driven transformation

3.1. Community-building potential

In order to provide a tentative mapping of makerspaces, we may start by addressing hackerspaces.org, perhaps the most popular virtual network of hackerspaces. It contains a wiki for anyone to share hackerspace-related stories and questions, mailing lists, a feed aggregator and many others. A central goal of this initiative is to support communication and collaboration among hackerspaces. Their homepage provides an inclusive definition of hackerspace as any community-run physical place where people can meet and work on creative projects. At the time of this writing, 2142 hackerspaces are listed in the wiki, with 1331 of them marked as active and 356 as planned, while the rest appears to be inactive or closed. By examining the hackerspaces.org list, it becomes obvious that makerspaces are spread all over the world (Hackerspaces.org, 2017). However, the majority is placed in the United States and Western Europe. Most of the hackerspaces supply members and visitors with access to local manufacturing technologies, such as 3D printers and open hardware (Lindtner et al., 2014; Moilanen, 2012; Moilanen and Vadén, 2013).

In addition to this, there are two recent studies on makerspaces conducted on a national level in the United Kingdom (Sleigh et al., 2015) and China (Saunders and Kingsley, 2016). Within the scope of these reports, commissioned by NESTA (National Endowment for Science, Technology and the Arts, the globally influential British iLab), a makerspace is understood as "an open access space (free or paid), with facilities for different practices, where anyone can come and make something" (Sleigh et al., 2015: 2; Saunders and Kingsley, 2016: 12).

According to the first one, the proliferation of makerspaces in the United Kingdom has been rapidly growing from a handful to 97 during the last decade (Sleigh et al., 2015). The same report states that most UK cities have at least one makerspace, however, the density and number of makerspaces differs by region. Specifically, London, Scotland and Wales have the most makerspaces per capita, while the North East, the East of England, and the East and West Midlands have the fewest (Sleigh et al., 2015). Moreover, most of them have small member communities, with 60% having 50 members or less while 5% have over 1000 members. In terms of visitors, 75% of makerspaces received up to 250 unique visits in November 2014 with almost 5% reporting over 5000 visits during the same month (Sleigh et al., 2015).

In China, where "making things is a national specialism" (Saunders and Kingsley, 2016: 5), makerspaces have spread rapidly over the past five years, from just 1 in 2010 to over 100 in 2015. Three-quarters of them are located in large cities on the developed East Coast, such as Beijing, Shanghai, Shenzhen, while the rest are in large northern and inland cities (Saunders and Kingsley, 2016). Moreover, the average number of members in China's makerspaces is 100.

Drawing from the above sources, it becomes evident that makerspaces are proliferating in the North-Western world with a recent expansion to the East and South. In addition, the following image is a screenshot from the MakerMap, a platform where anyone can add a makerspace and tag it according to certain criteria. Although the platform does not provide a definition of what is considered a "makerspace", the map serves both as another (soft) indication of the globality of the phenomenon, but also of the regional bias typical for ICTs and local manufacturing technologies (Benkler, 2014; Fuchs and Horak, 2008) (See Fig. 1).

So, how are these community-driven places governed? According to Kostakis et al. (2015a), which explored the governance mechanism of eight selected makerspaces (self-identified as "hackerspaces"), the latter seem to replicate governance structures and principles observed in online CBPP, as exemplified by the free encyclopedia Wikipedia or the free/open source software projects (Benkler, 2006; Bauwens, 2005). Hence, the chosen case studies could be considered a manifestation of online CBPP in the physical realm but not a direct or a precise transfer due to the scarcity and the subsequent allocation problems of the material world, as opposed to the digital realm, where replication requires a near-zero marginal cost. Although the projects within a single makerspace can be very different from those of another and much more different than the CBPP ones, it is understood that most of the CBPP characteristics also permeate the makerspace phenomenon (Kostakis et al., 2015a). For instance, in both online CBPP projects and makerspaces, issues of independence and autonomy arise when it comes to monetary support from an outsider. Even if the ability of the makerspace communities to develop the norms required for CBPP models is arguably put under more stress, it can be noticed that there are many instances that seem to embrace several CBPP aspects through adopting hybrid modes of governance. These modes, at least for the cases discussed in Kostakis et al. (2015a), share certain elements which exemplify CBPP governance mechanisms and characteristics, which are, after all, historically and essentially indistinguishable from the hacker ethic. Therefore, it has been argued that makerspaces' various hybrid modes of governance are actually an unfinished artifact that follows the constant reform of social norms within the community, as happens in CBPP.

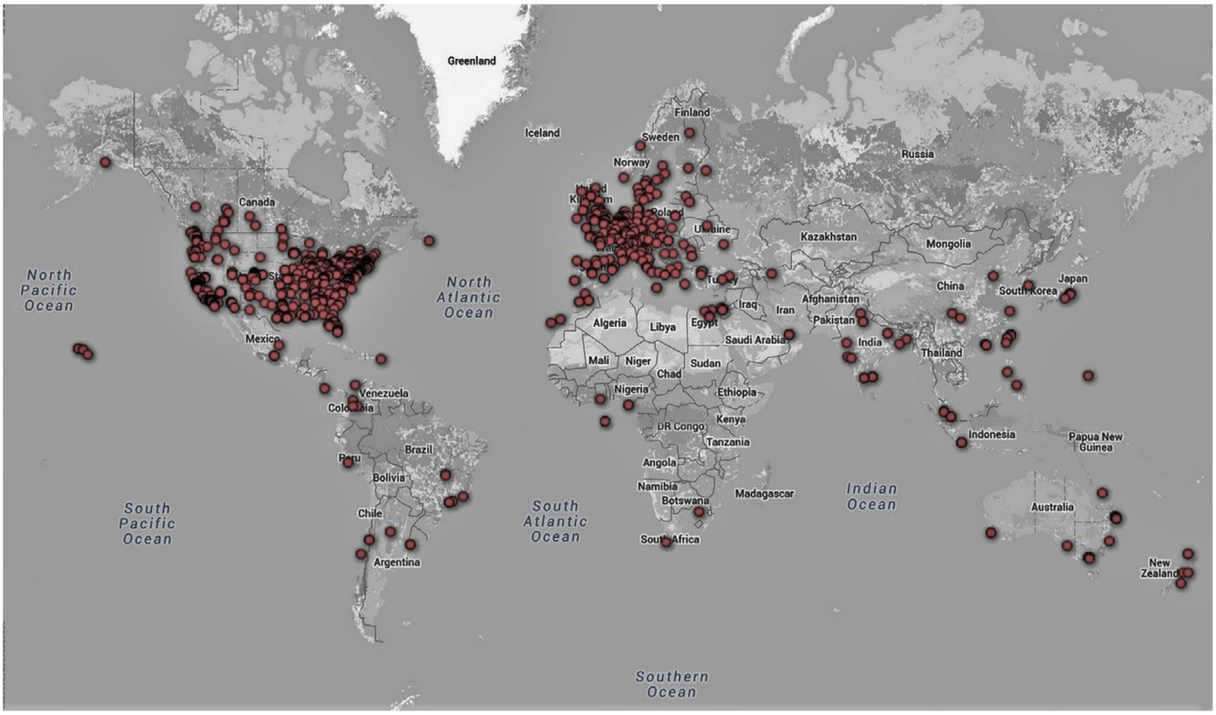

Fig. 1. TheMakerMap.com (last accessed on 17 February 2017).

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Nevertheless, while Kostakis et al. (2015a) focus on makerspaces which are self-identified as hackerspaces (thus putting an emphasis on ideological issues, such as do-ocracy and voluntarism), Saunders and Kingsley (2016) and Sleigh et al. (2015) study a much wider array of makerspaces. The latter found out that the UK makerspaces rely on a combination of informal and paid roles to operate. Voluntary staff and informal user support are important features of many makerspaces. Approximately 40% of the examined makerspaces also employ technicians on a full- or part-time basis. This might be explained by the fact that, whereas almost 50% of makerspaces were founded by informal groups (as was the case with all the examined makerspaces in Kostakis et al., 2015a), nearly 33% emerged from existing companies or organizations. In addition, the Chinese makerspaces are still experimenting with business models. One in five makerspaces is funded by a parent company, 34% have received some form of government support and 24% has no income and relies on the support of volunteers (Saunders and Kingsley, 2016).

To recap, because of the perpetual transformation of makerspaces and their diverse organizational structures, it seems wise to approach them on a case-by-case basis for a more detailed account of governance. Of course one should be aware of the fact that every makerspace and its community is unique (Mikkonen et al., 2007). After all, it is hard to say what a makerspace is exactly: "you know it when you are in one, but they are all unique because people are so unique" (Kostakis et al., 2015a: 569). From the perspective of the concept of third place (Moilanen, 2012; Oldenburg, 1999), makerspaces can be viewed as community-run hubs that connect citizens not only of the same city but also of other cities worldwide. According to Sleigh et al. (2015), approximately 66% of the UK-based makerspaces collaborate with other UK-based or foreign makerspaces on a regular basis, while 46% contribute to commons-oriented, open source projects which normally have a global orientation. Yet, Moilanen (2012) observed that individuals are more engaged and committed to one local makerspace. Further, of particular interest are the findings of Saunders and Kingsley (2016), Sleigh et al. (2015), and Moilanen (2012) that two of the top reasons people use makerspaces are socializing and learning. Hence, makerspaces can be platforms that cultivate relationships and networks, building social capital, i.e., "social networks and the attendant norms of trust and reciprocity" (Sander, 2002: 213).

However, claims around the potentialities of makerspaces are still speculative and depend on how individuals associate with such places (March 2016). While makerspaces have been built in ethnically and geographically diverse environments, there is yet a lack of racial and gender diversity within many of them (Dunbar-Hester, 2014; Toupin, 2014). Despite the ideal of openness in makerspaces, social inequalities that impede access and participation are often ignored, and privilege or domination over some groups of people are not acknowledged (Dunbar-Hester, 2014). For instance, membership is predominantly male in 80% of UK makerspaces (Sleigh et al., 2015) and 77% of China's makers are male (Saunders and Kingsley, 2016). Additionally, according to a study conducted by Make magazine and Intel (2012), 81% of U.S. makers are male with an average income of $106,000. These are indications that participation in the maker movement is heavily dominated by affluent men.

As an attempt to correct this lack of diversity, some feminist and people of color-led makerspaces have emerged, such as Mz Baltazar's Laboratory in Vienna and Mothership Hackermoms in Berkley (feminist spaces created in 2008 and 2012 respectively) or Liberating Ourselves Locally in Oakland (a "people of color -led" space created in 2012). However, such strategies have been met with controversy, since they are deemed to go against the principle of openness (Toupin, 2014).

Next, we discuss how makerspaces can produce collective value in the form of learning as well as of innovation.

3.2. Learning potential

An increasing amount of literature coming from various disciplines (e.g., cognitive psychology, experiential learning, design theory, computer science, science and technology studies) explores the educational and pedagogical potential of making (Schrock, 2014). Two lines of scholarship in the field of pedagogical studies with a focus on making are of particular interest in the current context: constructionism and critical making. To begin with, the learning theory of constructionism (Papert, 1980a, 1980b, 1993, 1997; Papert and Harel, 1991) highlights the personalized production of knowledge artifacts as well as the social nature of the learning process.

In line with many prominent scholars in the philosophy of education (e.g. Jean Piaget, Lev Vygotsky, Paulo Freire and John Dewey), constructionism maintains that an individual's intellectual growth must be rooted in his/her experience (Ackermann, 2001; Papert, 1980b; Wertsch and Tulviste, 1992). Knowledge is not seen as a commodity to be transmitted but as a personal experience that has to be constructed (Ackermann, 2001):

> constructionism – the N word as opposed to the V word – shares constructivism's connotation of learning as 'building knowledge structures' irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it is a sand castle on the beach or a theory of the universe (Papert and Harel, 1991: 3).

While both constructionism and constructivism consider socially embedded experience key to the learning process, the former puts an emphasis on the significance of actively making things (Ratto, 2011). So, "constructionism extends the theory of constructivism to focus explicitly on how the making of external artifacts supports learners' conceptual understanding" (Sheridan et al., 2014: 507).

Drawing upon constructionism, Matt Ratto has been developing the concept of "critical making" (Ratto, 2011; Ratto and Boler, 2014). He defines critical making as "a mode of materially productive engagement that is intended to bridge the gap

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between creative physical and conceptual exploration" (Ratto, 2011: 252). Critical thinking is often understood as a conceptually and linguistically based process, whereas physical "making" is allegedly related to goal-based material work (Ratto, 2011: 253). Through empirical examples and within the constructionism context, Ratto shows how two seemingly different modes of human engagement with the world can creatively be connected and not only deepen conceptual understandings, but also inaugurate venues for technical innovation (Ratto, 2011: 259). Ratto's findings are in line with the conclusions of Kostakis et al. (2015c) where, through a participatory-action research project, it was shown how 3D printing and design can electrify various literacies and creative capacities of students in accordance with the spirit of the networked, interconnected, information-based world. It was also argued that the ethics of the commons/sharing movement, which has produced several media technologies of educational value (from free/open source software, say Moodle or Sugar, to the free encyclopedia Wikipedia to open hardware such as the Arduino micro-controller or low-cost 3D printers), could provide a context for experimentation, communication, collaboration, sharing and learning (Ratto, 2011; Suoranta and Vadén, 2010).

Therefore, the learning potential of making coupled with open learning environments (Hannafin et al., 2013); project-based learning (Blumenfeld et al., 1991); informal tinkering (Hunsinger, 2011); and peer collaboration (Moilanen, 2012) can motivate the social learning and personalized involvement of participants (Baichtal, 2011; Blikstein, 2013). Makerspaces exhibit the aforementioned characteristics and, thus, show great promise as emerging learning hubs (Blikstein et al., 2015; Koh and Abbas, 2015; Litts, 2015). That is why makerspaces have recently generated much interest in diverse educational circles (Halverson and Sheridan, 2014; Sheridan et al., 2014). For example, several libraries and museums have created spaces with the aim to empower creative activity, resource-sharing, and active engagement with making, materials, processes, and ideas in relation to their collections and exhibits (Britton, 2012; Honey and Kanter, 2013). Another instance is Buechley et al.'s (2013) study of making activities with learning value that take place in makerspaces, such as building circuits into textiles, or Honey's and Kanter's (2013) documentation of real-world examples of learning activities that occur in makerspaces, amongst other places.

It appears that makerspaces offer the capacity for informal community activity as well as a proper learning environment with a focus on productive processes rather than skill-set building (Blikstein, 2013; Litts, 2015; Sheridan et al., 2014). Varying activities may be combined (like programming and hardware building and even manufacturing tools development), following the approach of constructionism. Sheridan et al., in their study of three makerspaces, conclude that as educational spaces they enable makers to be involved in "participating in a space with diverse tools, materials, and processes; finding problems and projects to work on; iterating through designs; becoming a member of a community; taking on leadership and teaching roles as needed; and sharing creations and skills with a wider world" (Sheridan et al., 2014: 529).

Nevertheless, it could be argued that inclusivity and participation in such educational activities is not assured. Although more than 50% of UK makerspaces offer support, courses and tool inductions, the majority of makers are well-educated and technologically-confident (Sleigh et al., 2015). Likewise, according to the Make magazine and Intel's (2012) report, 97% of makers in the U.S. have attended or graduated from college, while 80% say they have post-graduate education (Make/Intel, 2012). Thus, to facilitate learning for diverse users, makerspaces should be staffed by qualified educators who are knowledgeable about theories of teaching and learning as well as about user needs and behaviors (Koh and Abbas, 2015). Despite this potential of makerspaces, educators must remember that, "the real power of any technology is not in the technique itself or in the allure it generates, but in the new ways of personal expression it enables, the new forms of human interaction it facilitates, and the powerful ideas it makes accessible to children" (Blikstein, 2013: 18).

Recognized as sites of community-building, creativity and learning, makerspaces could be game changers towards new forms of educational venues and (social) innovation.

3.3. Innovation potential

Makerspaces are often considered hubs that may act as incubators for both innovation and entrepreneurship. This article adopts the classic Schumpeterian understanding of innovation as the use of new ideas (inventions, discoveries or a new combination of known items or processes) that are turned into market successful products, services or organizational processes (Drechsler et al., 2006: 15–16; Schumpeter, 1912/1982). Nevertheless, other concepts of innovation have risen in popularity such as social/grassroots/free innovation (see respectively Borzaga and Bodini, 2014; Smith et al., 2017; von Hippel, 2017). According to the Center for Social Innovation at Stanford Graduate School of Business: "a social innovation is a novel solution to a social problem that is more effective, efficient, sustainable, or just than current solutions. The value created accrues primarily to society rather than to private individuals" (Phills et al., 2008). As we will see later, a few commons-oriented initiatives strive to innovate both for the market and the society, being thus related to both aforementioned concepts.

In makerspaces people innovate and learn together by making things and using the Web to globally connect and share designs, tutorials and code (Schuurman et al., 2011). They offer creative environments where sustainable entrepreneurs, potentially with diverse motives and backgrounds (Pinkse and Groot, 2015), can meet and interact and thus benefit from synergies and the cross-pollination of ideas (Capdevila, 2015). Moreover, in makerspaces designers can come together and collaborate in participatory explorations during the use phase by prototyping, adding small-scale interventions and, therefore, moving from a "design-in-the-studio" to a "design-in-use" strategy (Seravalli, 2012).

Several innovative entrepreneurial endeavors and start-ups have emerged through makerspaces. This article refers to some prominent cases with the aim to provide an overview of the most mature examples that cover a wide spectrum of areas, from ICT and local manufacturing technologies to farming, culture and neuroscience.

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To begin with, the low-cost 3D printer producer MakerBot Industries is one of the most prominent start-ups whose history unfolded within two makerspaces: Austria-based Metalab, where the project was conceptualized, and US-based NYC Resistor, where it was prototyped (Pettis, 2011). MakerBot started as a successful open source project to turn into a traditional closed-source company and subsidiary of Stratasys, a leading manufacturer of 3D printers. MakerBot used to dominate the market of low-cost 3D printing (<3000€), however, according to a Fortune article (Zaleski, 2015), it is losing the market to smaller manufactures. For instance, Ultimaker BV, a company that is coming up the ranks, produces open source 3D printers whose prototypes were first built in a Dutch makerspace (Utrecht ProtoSpace) (van Geelen, 2015). Both MakerBot and Ultimaker along with dozens of commercially successful start-ups are built upon the designs of the first open source 3D printer, RepRap. The RepRap project began as a state-funded research endeavor which has greatly benefited from experimentation and incremental innovations occurring in makerspaces globally (de Jong and de Bruijn, 2013). Moreover, 3Doodler, one of the most successful Kickstarter projects of all times (Hurst, 2015), is a 3D printing pen which was first built by two friends in early 2012 at the US-based Artisans' Asylum makerspace (Denison, 2015).

Moving from local manufacturing technologies to sensors and microcontrollers, makerspaces have also served as incubators for relevant start-ups and innovations. To begin with, Arduino is the popular open source computer hardware and software company as well as user community that designs and manufactures microcontroller-based kits for building senseable devices in the physical world. Arduino has extensively been used in makerspaces to create various objects, from simple toys and musical instruments to sophisticated devices and manufacturing machines. Moreover, in London Hackspace, the start-up Nanobe emerged, which, inspired by and based on Arduino, develops and sells a micro-controller which can interact with cloud based applications and events in the online environment.

Further, the Public Lab, an open community network, collaboratively develops open source technologies and practices that explore and address environmental issues. The project was created in the wake of the Deepwater Horizon oil spill in the gulf of Mexico in 2010 with the aim to "increase the ability of underserved communities to identify, redress, remediate, and create awareness and accountability around environmental concerns" (Publiclab.org, 2017). The network is virtually coordinated with the help of a wiki while physically participants meet in local makerspaces and workshops. The Public Lab network has collaboratively produced low-cost, open source, community-supported products such as the Roomba indoor air quality monitoring system, the Riffle water monitoring system, the Dustuino monitoring system, and desktop and mobile spectrometers. These products produce meaningful, understandable and high quality environmental data. Public Lab also has a shop where one can buy some of the do-it-yourself kits.

Another example of a novel approach to environmental data gathering has been suggested by the Open Source Beehives project. At its beginning, the project involved a diverse network of makerspaces (Fab Lab Barcelona, the Belgium-based OKNO and the Open Tech Collaborative in Denver) which prototyped an open source, senseable beehive that could be made with local manufacturing technologies (Romano, 2014). The team has now grown into a citizen-led beehive network with the ultimate goal to discover what is causing Colony Collapse Disorder (Romano, 2014). The core group behind the project has now launched a company, AKER LLC, which, in addition to the Open Source Beehive, produces and sells open source kits for urban farming (AKER, 2016).

More diverse fields in which makerspaces have served as platforms for innovation are following. To start, the Open Access Control project began in the US-based 23b Shop makerspace to satisfy the need for a customizable and low-cost electronic access control at the makerspace (Baichtal, 2013). After a first prototype was built and successfully operated, several commercial boards were commissioned from Flashline Electronics. Recently, the ACCX Products store was created where one can buy an up and running open source security system (Baichtal, 2013).

Next, the KiloBaser project, self-titled the "Nespresso machine of DNA synthesis" (Kilobaser.com, 2016), emerged in the Austria-based realraum makerspace. Kilobaser is now a product of the start-up company Briefcase Biotec GmbH, founded in 2014 and related to a biotechnology-oriented makerspace, which develops life science equipment reduced to the bare essentials. Another commons-oriented initiative with regards to the life sciences is the Backyard Brains, which emerged in the US-based All Hands Active makerspace. This start-up company has an array of novel, open source products including the Spikerbox, which uses invertebrates to help learn about how the cells in the brain work to communicate; the Muscle SpikerBox, which records electrical activity produced by cells in human muscles; the Completo, which is a full tabletop, portable electrophysiology rig; or RoachScope which can turn the mobile phone into a microscope.

In all, makerspaces should not be viewed merely as experimentation sites with local manufacturing technologies but as places "where people are experimenting with new ideas about the relationships amongst corporations, designers, and consumers" (Lindtner et al. 2014: 9). The review of makerspaces-related innovation illustrated that they mainly produce user-led, incremental product and process innovations. Some of the aforementioned projects and eco-systems, such as the RepRap- or Arduino-based eco-systems, may represent both the Schumpeterian and social-oriented understanding of innovation. They seem to create win-win situations for both instigators/entrepreneurs and society, and inaugurate commons-oriented business models which arguably go beyond the classical corporate paradigm and its extractive profit-maximizing practices.

Further, innovation in makerspaces has exemplified the potential of the commons and the governance models associated with the practice of "commoning" (Bollier, 2016), as a new form of interpersonal understanding and coordination. There are numerous technological infrastructures that have been developed in makerspaces in response to certain needs of the community, which are openly shared, regardless of whether or not they lead to the commercial introduction of new products or services. Makerspaces thus arguably illustrate the unique human capacity that is unlocked through access to (and co-creation of) knowledge, infrastructure and fundamental means of making.

Such processes promote the diffusion of technology among makerspaces, which in turn could outline future trajectories on innovation. Therefore, since it is the availability of potential innovation as investment opportunities that leads to economic growth (Schumpeter, 1939/1982), makerspaces' contribution might be viewed as valuable. At the same time, by offering real solutions within and beyond the market system makerspaces provide fertile ground for the flourishing of CBPP. They serve as socio-technical niches (Smith et al., 2005) or ''proof-of-concept" for a mature CBPP ecosystem, able to reproduce itself and support its contributors, including a variety of people, from hackers, tech-enthusiasts and tinkerers, to researchers, engineers and entrepreneurs, that are engaged in commons-oriented projects.

This innovation potential of makerspaces, whose environments are very diverse in norms and forms, is opening up to society in plural and contested ways, which, however, ought to be critically examined and understood (Smith et al., 2013).

4. Conclusions

This article investigated the community-building, learning and innovation potential of makerspaces with the aim to explore their role as vehicles for citizen-driven transformation. There are several opportunities emerging in the areas of reference, as well as barriers that need to be overcome. The table below summarizes our findings (see Table 1).

Table 1
The potential of makerspaces in a nutshell.

	Opportunities	Barriers
Community-building	• Local hubs for socializing and collaborating • ''Open door policy" • Connecting citizens locally and worldwide (network of makerspaces) • Proliferation of makerspaces in the last decade	• Reliance on informal and paid roles to operate • Lack of racial and gender diversity • Makers primarily engaged and committed into one local makerspace • Situation of makerspaces (mostly present in the North-West world)
Learning	• Making electrifies literacies and creative capacities • Access to open learning environments Production of knowledge artifacts as a personal experience • Focus on the social nature of the learning process	• High threshold for participation (the majority of makers are well-educated and tech-savvy) • Shortage of qualified educators
Innovation	• Citizen-led innovation • Diversity of skills • Synergies and cross-pollination of ideas • Enabling participatory explorations by prototyping	• Trajectory could go closed-source

Are makerspaces a manifestation of the ''new spirit of capitalism" that has successfully incorporated and adapted several of its various critical cultures (Söderberg and Delfanti, 2015)? Or could we consider makerspaces as sites with non-negligible post-capitalist dynamics? Both possibilities still exist.

If we subscribe to the idea that at least some makerspaces can be seen as CBPP in practice, then, makerspaces may belong to a new form of capitalism but, at the same time, also highlight ways in which this new form might be transcended. If the dominant discourse of the ''smart city" project is aligned with a neoliberal, corporate vision for urban development (Greenfield, 2013), then the ''makerspace" could simultaneously be a source of legitimacy for the project and also serve as an institution for citizen-driven transformation.

An alternative vision for the smart city may be possible through a commons-oriented approach, geared towards the democratization of means of production. The basic tenet of this approach encourages citizens to participate in creating solutions collectively instead of merely adopting proprietary technology. In addition to virtual connections observed in several sharing economy initiatives, makerspaces can be the physical nodes of a collaborative culture. Further, they can serve as a new ''design template" (Boxenbaum et al., 2011), where knowledge/design is developed and shared as a global digital commons while the actual customized manufacturing takes place locally, thus initiating a decisive break from the current production model.

Within this context, makerspaces may be seen as spaces where people can engage in technology development for a more democratic and sustainable urban life, which is not subsumed to the dictates of economic growth.

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References

Ackermann, E., 2001. Piaget's constructivism, Papert's constructionism: what's the difference. Future Learn. Group Pub. 5 (3), 438.

AKER. (2016). Store. Retrieved from: https://aker.me/#section-store
Albino, V., Berardi, U., Dangelico, R.M., 2015. Smart cities: definitions, dimensions, performance, and initiatives. J. Urban Technol. 22 (1), 3–21.
Baichtal, J. (2011). Mitch Altman talks about the hackerspace movement. MAKE Magazine. Retrieved from: http://makezine.com/2011/08/19/mitch-altman-talks-about-thehackerspace-movement/.
Baichtal, J. (2013). Open access secures hackerspaces. MAKE Magazine. Retrieved from: http://makezine.com/2013/09/25/open-access-secures-hackerspaces/.
Ballinger, M., Talbot, L., Verrinder, G., 2009. More than a place to do woodwork: a case study of a community-based men's shed. J. Men's Health 6 (1), 20–27.
Bauwens, M. (2005). The political economy of peer production. CTheory Journal. Retrieved from: http://www.ctheory.net/articles.aspx?id=499.
Bauwens, M., Kostakis, V., 2016. Why platform co-ops should be open Co-ops. In: Scholz, T., Schneider, N. (Eds.), Ours to Hack and to Own: The Rise of Platform Cooperativism, a New Vision for the Future of Work and a Fairer Internet. OR Books, New York, NY, pp. 163–166.
Benkler, Y., 2006. The Wealth of Networks: How Social Production Transforms Markets and Freedom. Yale University Press, New Haven, CT.
Benkler, Y. (2014). Ch@nge: Distributed innovation and creativity, peer production, and commons in networked economy. BBVA Open Mind. Retrieved from: https://www.bbvaopenmind.com/en/article/distributed-innovation-and-creativity-peerproduction-and-commons-in-networked-economy/.
Blikstein, P. (2013). Digital fabrication and 'making' in education: The democratization of invention. FabLabs: Of Machines, Makers and Inventors, 1–21.
Blikstein, P., Martinez, S.L., Pang, H.A., 2015. Meaningful Making: Projects and Inspirations for Fablabs and Makerspaces. Constructing Modern Knowledge Press, Torrance, CA.
Blumenfeld, P.C., Soloway, E., Marx, R.W., Krajcik, J.S., Guzdial, M., Palincsar, A., 1991. Motivating project-based learning: sustaining the doing, supporting the learning. Educ. Psychol. 26 (3–4), 369–398.
Bollier, D. (2016). State power and commoning: Transcending a problematic relationship. Commons Strategies Group and Heinrich Böll Foundation. Retrieved from: http://cdn8.commonsstrategies.org/wp-content/uploads/2016/07/State-Power-and-Commoning.pdf.
Borzaga, C., Bodini, R., 2014. What to make of social innovation? Towards a framework for policy development. Social Policy Soc. 13, 411–421.
Boxenbaum, E., Acquier, A., Pinheiro-Croisel, R., Garza de Linde, G. (2011). Processes of institutional innovation: reference tools for eco-cities in France and Denmark. Retrieved from: https://halshs.archives-ouvertes.fr/halshs-00743372/file/PROCESSES_OF_INSTITUTIONAL_INNOVATION-_REFERENCE_TOOLS_FOR_ECO-CITIES_IN_FRANCE_AND_DENMARK_Boxenbaum_Acquier_Pinheiro-Croisel_Garza_Linde.pdf.
Britton, L. (2012). The makings of maker spaces, part 1: Space for creation, not just consumption. The Digital Shift. Retrieved from: http://www.thedigitalshift.com/2012/10/public-services/the-makings-of-maker-spacespart-1-space-for-creation-not-just-consumption/.
Buechley, L., Peppler, K., Eisenberg, M., Kafai, Y., 2013. Textile Messages: Dispatches From the World of E-Textiles and Education. Peter Lang Publishing Incorporated, New York, NY.
Bulu, M., 2014. Upgrading a city via technology. Technol. Forecast. Soc. Chang. 89, 63–67.
Capdevila, I. (2015). How can city labs enhance the citizens' motivation in different types of innovation activities? Social Informatics (pp. 64–71): Springer.
Carvalho, L., 2015. Smart cities from scratch? A socio-technical perspective. Cambridge J. Reg. Economy Soc. 8 (1), 43–60.
Castells, M., 2000. The Rise of the Network Society. Blackwell, Oxford.
Castells, M., 2003. The Power of Identity. Blackwell, Oxford.
Dafermos, G., Söderberg, J., 2009. The hacker movement as a continuation of labour struggle. Capital Class 33, 53–73.
de Jong, J.P., de Bruijn, E., 2013. Innovation lessons from 3-D printing. MIT Sloan Manage. Rev. 54 (2), 43.
Denison, D., 2015. 3Doodler creator shares his experience from makerspace to market. Makezine. Retrieved from: http://makezine.com/2015/06/14/drawn-to-it/.
Drechsler, W., Backhaus, J., Burlamaqui, L., Chang, H.-J., Kalvet, T., Kattel, R., Kregel, J., Reinert, E., 2006. Creative Destruction Management in Central and Eastern Europe: Meeting the Challenges of the Techno-Economic Paradigm Shift. In: Kalvet, T., Kattel, R. (Eds.), Creative destruction management: Meeting the challenges of the techno-economic paradigm shift. Praxis Center for Policy Studies, Tallinn.
Dunbar-Hester, C., 2014. Radical inclusion? Locating accountability in technical DIY. In: Ratto, M., Boler, M. (Eds.), DIY Citizenship: Critical Making and Social Media. The MIT Press, Cambridge, MA.
Erickson, J., 2008. Hacking: The Art of Exploitation. No Starch Press, San Francisco, CA.
Foster, S., Iaione, C., 2016. The city as a commons. Yale Law Policy Rev. 34 (2).
Fuchs, C., Horak, E., 2008. Africa and the digital divide. Telematics Inform. 25, 99–116.
Gandini, A., 2015. The rise of coworking spaces: A literature review. Ephemera Theory Politics Organiz. 15, 193–205.
Glaeser, E., 2011. Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier, and Happier. Penguin, New York, NY.
Greenfield, A., 2013. Against the Smart City. Do Publications, New York, NY.
Hackerspaces.org. (2017). List of all hacker spaces. Hackerspaces.org. Retrieved from: https://wiki.hackerspaces.org/List_of_ALL_Hacker_Spaces.
Halverson, E.R., Sheridan, K., 2014. The maker movement in education. Harvard Educational Review 84 (4).
Hannafin, M.J., Hill, J.R., Land, S.M., Lee, E., 2013. Student-centered, open learning environments: research, theory, and practice. In: Spector, J.M., Merrill, M. D., Elen, J., Bishop, M.J. (Eds.), Handbook of Research on Educational Communications and Technology. Springer, New York, NY, pp. 641–651.
Himanen, P., 2001. The Hacker Ethic and the Spirit of the Information Age. Random House, New York, NY.
Hogge, B., 2011. Barefoot Into Cyberspace: Adventures in Search of Techno-Utopia. Barefoot Publishing, Essex.
Hollands, R.G., 2015. Critical interventions into the corporate smart city. Cambridge J. Reg. Economy Soc. 8 (1), 61–77.
Honey, M., Kanter, D.E., 2013. Design, Make, Play: Growing the Next Generation of STEM Innovators. Routledge.
Hunsinger, J. (2011). The social workshop as PLE: lessons from hacklabs. Retrieved from: http://www.academia.edu/1086161/The_Social_Workshop_as_PLE_Lessons_from_Hacklabs
Hunsinger, J., Schrock, A., 2016. The democratization of hacking and making. New Media Soc. 18, 535–538.
Hurst, S. (2015). 3Doodler 2.0 becomes Kickstarter's most successful hardware sequel as it surpasses $1 million in 10 days. Crowdfund Insider. Retrieved from: http://www.crowdfundinsider.com/2015/01/61176-3doodler-2-0-surpasses-1-million-10-days-kickstarter/.
Jeffres, L.W., Bracken, C.C., Jian, G., Casey, M.F., 2009. The impact of third places on community quality of life. Appl. Res. Qual. Life 4 (4), 333–345.
Kilobaser.com. (2016). Kilobaser: Rapid DNA prototyper. Briefcase Biotec. Retrieved from: http://www.kilobaser.com/.
Kitchin, R., 2014. The real-time city? Big data and smart urbanism. GeoJournal 79 (1), 1–14.
Koh, K., Abbas, J., 2015. Competencies for information professionals in learning labs and makerspaces. J. Educ. Lib. Inf. Sci. 56 (2), 114–129.
Kohtala, C., Hyysalo, S., 2015. Anticipated environmental sustainability of personal fabrication. J. Cleaner Prod. 99, 333–344.
Kostakis, V., Niaros, V., Giotitsas, C., 2015a. Production and governance in hackerspaces: A manifestation of commons-based peer production in the physical realm? Int. J. Cul. Stud. 18 (5), 555–573.
Kostakis, V., Niaros, V., Dafermos, G., Bauwens, M., 2015b. Design global, manufacture local: Exploring the contours of an emerging productive model. Futures 73, 126–135.
Kostakis, V., Niaros, V., Giotitsas, C., 2015c. Open source 3D printing as a means of learning: An educational experiment in two high schools in Greece. Telematics Inform 32 (1), 118–128.
Kostakis, V., Bauwens, M., Niaros, V., 2015d. Urban Reconfiguration after the Emergence of Peer-to-Peer Infrastructures: Four Future Scenarios with an Impact on Smart Cities. In: Araya, D. (Ed.), Smart Cities as Democratic Ecologies. Palgrave Macmillan, New York, NY, pp. 116–124.
Lawson, K., 2004. Libraries in the USA as traditional and virtual "third places". New Library World 105 (3/4), 125–130.
Levy, S., 2001. Hackers: Heroes of the Computer Revolution, vol. 4. Penguin Books, New York, NY.
Lindtner, S., Hertz, G. D., & Dourish, P. (2014). Emerging sites of HCI innovation: Hackerspaces, hardware startups & incubators. Paper presented at the Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.

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Litts, B. (2015). Making learning: makerspaces as learning environments (Doctoral dissertation). Retrieved from: http://www.informalscience.org/sites/default/files/Litts_2015_Dissertation_Published.pdf.
Make/Intel. (2012). Maker market study and media report. Retrieved from http://cdn.makezine.com/make/sales/Maker-Market-Study.pdf.
March, H., 2016. The smart city and other ICT-led techno-imaginaries: Any room for dialogue with degrowth? J. Cleaner Prod. xx, 1–10.
Maxigas, 2012. Hacklabs and hackerspaces. J. Peer Prod.
MediaLab-Prado. (2016). About. Retrieved from: http://medialab-prado.es/article/que_es.
Mikhak, B., Lyon, C., Gorton, T., Gershenfeld, N., McEnnis, C., Taylor, J., 2002. Fab Lab: an alternative model of ICT for development. ThinkCycle. Retrieved from: http://citeseerx.ist.psu.edu/viewdoc/download.
Mikkonen, T., Vadén, T., Vainio, N., 2007. The Protestant ethic strikes back: open source developers and the ethic of capitalism. First Monday. Retrieved from: http://www.ojphi.org/ojs/index.php/fm/article/view/1623.
Moilanen, J., 2012. Emerging hackerspaces-peer-production generation. In: Hammouda, I., Lundell, B., Mikkonen, T., Scacchi, W. (Eds.), Open Source Systems: Long-Term Sustainability. Springer, pp. 94–111.
Moilanen, J., Vadén, T., 2013. 3D printing community and emerging practices of peer production. First Monday 18 (8).
Niaros, V., 2016. Introducing a taxonomy of the "smart city": Towards a commons-oriented approach? tripleC: J. Global Sustain. Inf. Soc. 14 (1), 51–61.
Oldenburg, R., 1999. The Great Good Place: CAFES, Coffee Shops, Bookstores, Bars, Hair Salons, and Other Hangouts at the Heart of a Community. Da Capo Press.
Oldenburg, R., 2001. Celebrating the Third Place: Inspiring Stories About the" Great Good Places" At the Heart of Our Communities. Da Capo Press.
Papert, S., 1980a. Mindstorms. Children, Computers and Powerful Ideas. Basic books, New York, NY.
Papert, S., 1980b. Teaching children thinking. In: Taylor, R.P. (Ed.), The Computer in the School: Tutor, Tutee, Tool. Teachers College Press, New York, NY.
Papert, S., 1993. The Children's Machine: Rethinking School in the Age of the Computer. Basic books, New York, NY.
Papert, S., 1997. Why school reform is impossible. J. Learn. Sci. 6 (4), 417–427.
Papert, S., Harel, I., 1991. Constructionism. Ablex Publishing, Norwood, N.J..
Parker, D. (2005). The different shades of hacker. Retrieved from: http://www.windowsecurity.com/articles/different-shades-hackers.html
Pettis, B., 2011. Made in my backyard. In: van Abel, B., Evers, L., Klaassen, R., Troxler, P. (Eds.), Open Design Now. BIS Publishers, Amsterdam, pp. 76–83.
Phills, J.A., Deiglmeier, K., Miller, D.T., 2008. Rediscovering social innovation. Stanford Social Innovation Rev. 6 (4), 34–43.
Pinkse, J., Groot, K., 2015. In: Sustainable entrepreneurship and corporate political activity: overcoming market barriers in the clean energy sector. Entrepreneurship Theory Pract. 39 (3), 633–654.
Publiclab.org. (2017). About Public Lab. Retrieved from: https://publiclab.org/about.
Putnam, R.D., 2000. Bowling Alone: The Collapse and Revival of American Community. Simon and Schuster, New York, NY.
Ratto, M., 2011. Critical making: conceptual and material studies in technology and social life. Inf. Soc. 27 (4), 252–260.
Ratto, M., Boler, M., 2014. DIY Citizenship: Critical Making and Social Media. MIT Press, Cambridge, MA.
Reinert, E. S. (2011). Zeitgeist in Transition: An Update to How Rich Countries Got Rich and Why Poor Countries Stay Poor. TUT Ragnar Nurkse School of Innovation and Governance, 37
Rifkin, J., 2014. The Zero Marginal Cost Society: The Internet of Things, the Collaborative Commons, and the Eclipse of Capitalism. Palgrave Macmillan, New York, NY.
Romano, Z., 2014. Support open source beehives and help promoting international bee recovery. Arduino. Retrieved from: https://blog.arduino.cc/2014/03/19/support-opensource-beehives/..
Sander, T.H., 2002. Social capital and new urbanism: Leading a civic horse to water? Natl. Civic Rev. 91 (3), 213–234.
Sassen, S., 2012. Urbanising technology. In: Urban Age Electric City Conference. LSE Cities, London School of Economics, pp. 12–14.
Saunders, T., & Kingsley, J. (2016). Made in China: makerspaces and the search for mass innovation. Nesta. Retrieved from: http://www.nesta.org.uk/sites/default/files/made_in_china-_makerspaces_report.pdf.
Schrock, A.R., 2014. Education in disguise: culture of a hacker and maker space. InterAct. UCLA J. Educ. Inf. Stud. 10 (1).
Schumpeter, J.A., 1912. The Theory of Economic Development. Transaction publishers, New York, NY.
Schumpeter, J.A., 1939. Business Cycles. Porcupine Press, Philadelphia, PA.
Schuurman, D., De Moor, K., De Marez, L., Evens, T., 2011. A Living Lab research approach for mobile TV. Telematics Inform. 28, 271–282.
Seravalli, A. (2012). Building Fabriken: Design for socially shaped innovation. Paper Presented at the DRS 2012 Conference Proceedings.
Sheridan, K., Halverson, E.R., Litts, B., Brahms, L., Jacobs-Priebe, L., Owens, T., 2014. Learning in the making: a comparative case study of three makerspaces. Harvard Educational Rev. 84 (4), 505–531.
Sleigh, A., Stewart, H., Stokes, K., 2015. Open dataset of UK makerspaces: A user's guide. Nesta. Retrieved from: http://www.nesta.org.uk/sites/default/files/open_dataset_of_uk_makerspaces_users_guide.pdf.
Smith, A., Stirling, A., Berkhout, F., 2005. The governance of sustainable socio-technical transitions. Res. Policy 34 (10), 1491–1510.
Smith, A., Hielscher, S., Dickel, S., Soderberg, J., & van Oost, E. (2013). Grassroots digital fabrication and makerspaces: reconfiguring, relocating and recalibrating innovation? SPRU Working Paper Series. Retrieved from: http://sro.sussex.ac.uk/49317/.
Smith, A., Hielscher, S., & Fressoli, M. (2015). Transformative social innovation narrative: Hackerspaces. Project Report. TRANSIT: EU
Smith, A., Fressoli, M., Abrol, D., Arond, E., Ely, A., 2017. Grassroots Innovation Movements. Routledge, London.
Söderberg, J., 2007. Hacking Capitalism: The Free and Open Source Software Movement. Routledge, New York, NY.
Söderberg, J., Delfanti, A., 2015. Hacking hacked! The life cycles of digital innovation. Sci. Technol. Human Values 40 (5), 793–798.
Soukup, C., 2006. Computer-mediated communication as a virtual third place: building Oldenburg's great good places on the World Wide Web. New Media Soc. 8 (3), 421–440.
Suoranta, J., Vadén, T., 2010. Wikiworld. Pluto Press, London.
Toupin, S., 2014. In: Feminist hackerspaces: the synthesis of feminist and hacker cultures. J. Peer Prod.
Townsend, A.M., 2013. Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia. W. W. Norton & Company, New York, NY.
United Nations (2014). World urbanization prospects: the 2014 revision. Retrieved from: http://esa.un.org/unpd/wup/highlights/wup2014-highlights.pdf
van Geelen, S. (2015). Joris van Tubergen. Ultimaker. Retrieved from: https://ultimaker.com/en/blog/47-joris-van-tubergen
von Hippel, E., 2017. Free Innovation. MIT Press, Cambridge MA.
Walravens, N., 2015. Mobile city applications for Brussels citizens: smart city trends, challenges and a reality check. Telematics Inform. 32, 282–299.
Wark, M., 2004. A Hacker Manifesto. Harvard University Press, Cambridge, MA.
Wark, M., 2013. Considerations on a hacker manifesto. In: Scholz, T. (Ed.), Digital Labor: The Internet as Playground and Factory. Routledge, New York, NY.
Wertsch, J.V., Tulviste, P., 1992. LS Vygotsky and contemporary developmental psychology. Dev. Psychol. 28 (4), 548–557.
Ylipulli, J., Suopajärvi, T., Ojala, T., Kostakos, V., Kukka, H., 2013. Municipal wifi and interactive displays: appropriation of new technologies in public urban spaces. Technol. Forecast. Soc. Chang. 89, 145–160.
Zaleski, A., 2015. MakerBot lays off 20% of its staff—again. Fortune. Retrieved from: http://fortune.com/2015/10/08/makerbot-lays-off-20-percent-of-staff-again/..

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