Human–Computer Interaction

ISSN: 0737-0024 (Print) 1532-7051 (Online) Journal homepage: https://www.tandfonline.com/loi/hhci20

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To cite this article: Maria Menendez-Blanco & Pernille Bjørn (2019) Makerspaces on Social Media: Shaping Access to Open Design, Human–Computer Interaction, 34:5-6, 470-505, DOI: 10.1080/07370024.2019.1566000

To link to this article: https://doi.org/10.1080/07370024.2019.1566000

HUMAN–COMPUTER INTERACTION, 2019, Volume 34, pp. 470–505

ISSN: 0737-0024 print / 1532-7051 online
DOI: https://doi.org/10.1080/07370024.2019.1566000

Makerspaces on Social Media: Shaping Access to Open Design

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Open Design is an emerging area of research that seeks to connect and extend the culture of making, social innovation, open-source software, and open-source hardware. A cornerstone for Open Design is to broaden participation in technology innovation by allowing people to use and contribute to publicly shared resources. Makerspaces are important access points to share and contribute to these resources. However, prior to entering the physical door of a makerspace, makerspaces' social media presence serve as the 'front door' for Open Design activities. In this paper, we examine different 'front doors' of Open Design, asking: *What are the characteristics that produce makerspaces' social media presences, and how do these representations shape potential access to Open Design activities?* We manually collected and qualitatively analyzed 500 public posts on the Facebook sites of five makerspaces in Copenhagen, Denmark. By choosing the same geographical area, we were able to explore the characteristics of makerspaces' social media presences for the same potential population of Open Design participants. Our analysis identifies three main characteristics of makerspaces' social media presence, which together shape access to Open Design activities, namely reach, transparency, and discourse. The display of these characteristics produce openness and availability in unique ways, and is constitutive for how Open Design activities are produced online. In this paper, we do not argue for

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or against specific social media representations. Instead, we argue that the specificities and differences between makerspaces' social media presences in the same geographical region have the strength of producing different identities across spaces, allowing for a broader definition and potential participation in Open Design.

1. INTRODUCTION

Governments, companies, and societies express increased interest in democratic forms of participation in innovation (Chesbrough, 2006; Manzini, 2015; Mulgan, Tucker, Ali, & Sanders, 2007). Within the European Union, this interest is associated with the 2008 financial crisis, which unveiled a fault in the assumption that investments in knowledge alone would equate to growth and jobs (European Union Financial Programming and Budget, 2008); when, in fact, *access* to knowledge turned out to be a significant challenge. Having opportunities to join the global economy and produce technology is not equally accessible for all (Bjørn & Boulus-Rødje, 2018). Political, geographical, and financial differences across technology development matter for whom is included or excluded – as well as who has a voice (Bjørn, Søderberg, & Krishna, 2017; Kristiansen, Valeur-Meller, Dombrowski, & Holten Moller, 2018). Open Design, with its focus on publicly accessible and shared resources, seeks to respond to this challenge. Concretely, Open Design facilitates multiple participants in gaining access to relevant knowledge and artefacts, which allows them to design, develop, and share ideas to larger distributed communities of innovation (Green et al., 2017). While Open Design is a promising approach to foster innovation, there is limited understanding of how access to Open Design is actually enabled.

Workshops such as makerspaces, hackerspaces, FabLabs etc. are potential places which can enable Open Design activities. In this paper, we will use 'makerspaces' as an umbrella term for workshop studios that provide access to tools and materials, such as laser cutters, 3D printers, and micro-controllers, and where the principles of DIY cultures are facilitated by open software and hardware (Lindtner & Li, 2012). Previous work on makerspaces identify language (Lundbjerg, Pflug von der Osten, Kanto, & Bjørn, 2017), gender (Fox, Ulgado, & Rosner, 2015), and skills (Toombs, 2017) as potential barriers for participation, since these elements are found to act as exclusive mechanisms producing participation in certain ways. However, before entering the physical door of a makerspace, there is another front door to Open Design (Davies, 2017) – namely the 'door' producing the digital identity of the makerspace: The makerspace's social media presence.

Current research highlights makerspaces' use of social media as important for enabling participation (Sheridan et al., 2014), supporting community building (Taylor, Hurley, & Connolly, 2016), and sharing information (Smith, Hielscher, Dickel, Soderberg, & van Oost, 2013). We extend this research by focusing on how social media produces access in different ways to makerspaces and ultimately to Open Design. In this paper, we identify characteristics displayed by makerspaces' social media presences and examine how

distinctive representations shape access to Open Design activities differently. Our research approach builds upon prior research which suggests that social media transcend digital environments and influence participation in offline events and physical spaces (Bennett & Segerberg, 2012; Crivellaro, Comber, Bowers, Wright, & Olivier, 2014; Menendez-Blanco, De Angeli, & Teli, 2017; Mosconi et al., 2017). Following this line of work, makerspaces and their social media platforms – such as Facebook sites – act as hybrid participatory spaces for connective action, where digital and physical dimensions coexist.

In this paper, we analyze the social media presences produced by five different makerspaces, all located in close geographical proximity in the same European capital city, namely Copenhagen, Denmark. Our research question is: *What are the characteristics that produce makerspaces' social media presences, and how do these representations shape potential access to Open Design activities?* The empirical data include 500 public posts from the Facebook sites of the five Danish makerspaces. These posts were analyzed in the context of our ongoing empirical engagement. Indeed, since 2014, we have studied and participated in the broader Copenhagen Maker community. We find that the characteristics which produce makerspaces' social media presences were shaped by the ways in which each makerspace displayed *reach* of their activities (e.g. did the activities include global agendas or were they about learning a new technology); *transparency* of social norms and resources (e.g. the extent to which social norms and access to resources for participation were displayed and articulated explicitly); and finally, the use of *discourse* (e.g. the extent to which posts displayed temporal patterns or only finished projects). Together these characteristics shaped access to Open Design activities for certain populations in different ways. These insights are important for Human Computer Interaction (HCI) research, as they help us understand access and exclusion as produced in Open Design. In addition, these insights allow us to think differently about the openness of Open Design activities and artefacts. Moreover, our findings are relevant for makerspaces, as they can assist such spaces in formulating strategies that consider social media as digital 'front doors' to Open Design activities.

The paper first describes related work on Open Design, makerspaces, and social media. Then, it introduces the research context, our method, and data. The results section elaborates on the distinct characteristics that we identified, and then, the discussion elaborates on how different social media representations shape the potential access to Open Design activities. The paper concludes by considering implications of our work and introduces a set of design cards that we have created to foster reflective conversations (Bjørn & Boulus, 2011) guiding social media choices for makerspaces.

2. OPEN DESIGN, MAKERSPACES, AND SOCIAL MEDIA

Open Design grew out of the open-source movement and is becoming an emerging term within the field of HCI (Green, D. P., Fuchsberger, V., Kirk, D., Taylor, N., Chatting, D., Meissner, J. L., Murer, M., Tscheligi, M., Lindtner, S., &

Bjorn, P, 2017). Core values include free sharing of software, open and free innovation, and engagement with projects for the greater good. While sharing software code on the Internet centers around digital exchange of source code, Open Design goes beyond software source code by including the creation of physical objects. Indeed, Open Design projects entail adding atoms to the usually intangible open source projects (Balka, Raasch, & Herstatt, 2009). Open Design can thus be seen as 'open source development of tangible objects' (Raasch, Herstatt, & Balka, 2009). Due to the physical aspects of Open Design, physical locations supporting participants in sharing knowledge and expertise - as well as tools and machines - are instrumental for people to engage in Open Design activities. The focus on open-source software, hardware, and digital fabrication make makerspaces central to Open Design.

Makerspaces and makerspace methodologies are a growing object of inquiry in HCI research (e.g. Bardzell, Bardzell, & Ng, 2017; Fuchsberger et al., 2015; Rosner et al., 2014; Taylor et al., 2016). Existing HCI research documents how makerspaces are locations where practices of design, innovation, and entrepreneurship are being transformed (Hui & Gerber, 2017; Smith et al., 2013). Makerspaces form post-consumer spaces, led by notions of peer-production and the sharing economy (Bardzell et al., 2017) and interlink hobbyist making and industrial production in interesting ways (Fuchsberger et al., 2016). Existing research documents how participation is structured and takes place within makerspaces (Fox et al., 2015), and how makerspaces produce new types of intimacies between people and the objects they create (Davies, 2017). Thus, activities within makerspaces produce new kinds of relationships between technology and people (Taylor et al., 2016). In addition, makers develop new relationships with technologies when they take part in their creation through tinkering technologies to fit specific purposes or domains (Jabbar & Bjørn, forthcoming). Through making, participants depend on their relationships with people and tools. These relationships form an ecosystem of people and tools that is accessible to the individual maker via their participation in a makerspace. The community allows them to reduce their 'google search' since they have a direct access to an impressive technical knowledge produced by the community of practice through diverse makerspace activities (e.g. Lundbjerg et al., 2017; Sheridan et al., 2014).

Communities of practice, as introduced by Wenger (1998), refer to groups of people who share an identity. This shared identity shapes learning and participation, allowing people to explore shared interests about certain topics through practice, while 'deepen[ing] their knowledge and expertise in this area by interacting on an ongoing basis' (Wenger, McDermott, & Snyder, 2002, p. 4). In-depth studies of communities of practices within different professions of crafts have pointed to the important role of experiencing opportunities for participation when moving from a space of legitimate peripheral participation into being full members (Lave & Wenger, 1991). Legitimate peripheral participation is the process by which a learner participates in the productive activities of an expert, but only to a limited degree and with limited responsibility for the ultimate product (Lave & Wenger, 1991). A key feature to support participation is to

provide opportunities for accessing these productive activities. Considering makerspaces as locations where communities of practices are formed proposes an important research challenge, namely to explore the different opportunities for accessing activities that take place in makespaces as they are shaped by the identity of the community.

An increasing amount of research is being conducted to investigate how people join makerspaces. Among these are Hudson, Alcock, and Chilana (2016), who pointed to limitations and challenges experienced by 'casual makers' when using 3D-printing facilities (Peek, Coleman, Moyer, & Gershenfeld, 2017). In addition, it has been suggested that there is a distinction between the types of makers' identities. More concretely, existing research differentiates between 'casual' makers, who occasionally participate in DIY activities; and 'established' makers, who regularly participate in making activities, and create their own processes and situations to enact these activities (Toombs, 2017). Participation in making entails engaging in different kinds of productive activities, which include the labor of care required to maintain the physical space (Lundberg et al., 2017). Recent research highlights the importance of such care and maintenance activities, since they ultimately influence who is included or excluded (Sun et al., 2015; Toombs, Bardzell, & Bardzell, 2015). Indeed, barriers for participation in makerspaces have less to do with practical skills than with the ability to fit in (Toombs et al., 2015). Therefore, fitting in is not only about willingness to join, but it also depends on the external representation of the makerspace, which often is displayed through social media. Thus, to extend current research, we explore the characteristics that produce makerspaces' presences on social media and how these representations shape access to the knowledge and tools required to participate in Open Design.

A makerspace can be seen as a 'visible, observable representation of what happens when a group of people decide to formalize material peer production in terms of a designated space and provide a certain infrastructure for "making"' (Kohtala & Bosqué, 2014, p. 7). With the increasing presence of makerspaces on social media, these representations are not only visible and observable for those who participate in the physical makerspace, but also for those who join *only* on their social media. Indeed, existing research suggests that first encounters with a makerspace take place through social media (Davies, 2017; Taylor et al., 2016). The existing corpus of research investigating social media and makerspaces focuses on the role of social media from *within* the makerspace. This previous work highlights what social media does for those who are already within and belong to the makerspace. For example, based on a series of ethnographic studies, Khanapour, DesPortes, Cochran, and DiSalvo (2017) found that makers use online media, such as Instructables.com[1] and videos in YouTube, as a source of inspiration for their own projects. Also, Goodman and Rosner (2011) found that social media contributed to the coordination of the activities of two groups of knitters and gardeners, shaping their material relationship to the objects they created. In addition, Davies (2017) found that people participating in hackerspaces described Facebook as an

[1] www.instructables.com.

output device, meaning a space to publish and recruit new members, rather than a place for community performance. While all the above research is important for understanding the role of social media for makerspaces, our interest takes a different analytical perspective. More specifically, our research investigates makerspaces' social media presence from *outside* the physical makerspace.

In recent years, a small but steadily increasing corpus of research in HCI and CSCW has investigated ways in which social media platforms influence participation in offline activities. This research is grounded on digital media studies that explore how social media platforms, such as Facebook, influence and transform opportunities for connections across multiple people at the intersection of the offline and online worlds (Bennett & Segerberg, 2012). For example, recent research investigates how social platforms influence participation in issues of public interest. An example is the work by Crivellaro et al. (2014), who investigated how the interactions on a Facebook site influenced how people organized themselves around an issue of concern. Concretely, they studied how a Facebook site facilitated the emergence of a public with a political agenda around an issue of urban planning, and how the affordances of this site changed the ways people organized themselves around the issue. Furthermore, Menendez-Blanco et al. (2017) investigated how online and offline interventions engaged people to join a social movement to transform the social construction of dyslexia in a region of Italy. They discovered that intertwining digital platforms, physical artefacts, and offline events allowed for people with different perspectives on dyslexia to come together and create alternative narratives. Also, Mosconi et al. (2017) studied the cooperative interactions among members of a Social Street community. They found that hybrid forms of community, based on offline and online interactions on social media, shaped the community in ways that were not possible using purely face-to-face interactions. These findings suggest that, if we are to understand how social media shape the ways in which people access Open Design activities, we need to identify the characteristics that produce makerspaces' representations on social media.

3. METHOD

To identify the characteristics by which we can categorize makerspaces' social media presences, we followed a multi-sited research approach (Bjørn & Boulus-Rødje, 2015). Specifically, we collected empirical data from five different makerspaces, located in Copenhagen, Denmark. In addition, we connected the insights from these data to the larger insights we have collected in the maker community across Copenhagen. What makes Copenhagen an interesting geographical location to explore access to makerspaces is that the city is the home for more than 15 makerspaces. These makerspaces are located within a rather small geographical area of 88 sq. km, and they vary greatly. For this paper, we chose to focus on five of these makerspaces. They were chosen because they all have very different

characteristics, purposes, and traditions – and they were all core members of the community 'Copenhagen Makers'. Copenhagen Makers is an umbrella organization that cuts across all the makerspaces and brings people together for events and activities. The larger community is also responsible for joint events, such as the Copenhagen Maker faire and the 'Maker Area' at the yearly Roskilde music festival, which is the largest music festival in Northern Europe, dating back to 1971. In 2018, the Roskilde festival took place over eight days with 130,000 visitors and 170 music acts.

3.1. Research Context

We have researched the maker community in Copenhagen through different types of activities since 2014. Concretely, we have conducted ethnographic observations in different makerspaces. In some cases, we have participated in events and activities; while in others, we have participated through observations of the everyday interaction in the space. In addition, we joined different types of activities, such as creating personal projects in the makerspace (ceramic objects, laser-cutted lamps), participated in organized workshops (discussing policies and strategies for the space), attended several activities during public events (workshops on reusable-material beer openers, energy saving flashlights, solar-panel USB chargers), joined public events (Copenhagen Maker faire, Maker Area at Roskilde festival), and eventually becoming full members and taking part in organizing the second Copenhagen Maker faire in 2017 as one of the 38 invited makers. For this occasion, we designed and constructed a playful interactive installation as a critical design artefact that sought to articulate normative issues hindering inclusion in Computer Science (Menendez-Blanco et al., 2018).

Throughout this research journey, we have conducted informal interviews with many different participants in the Copenhagen Maker community, as well as with participants during events (e.g. we conducted 70 micro-interviews with participants at the Copenhagen Maker Faire in 2017). Between February and March 2016, we conducted four interviews with core people, who had been engaged in the early development of the Copenhagen Maker community. They had been part of starting four out of the five makerspaces, which are the focus of this paper. These interviews sought to investigate the activities and events and the maker community in Copenhagen. In addition, they served as the foundation for creating a makerspace at our own university. In total, we participated in more than 20 events and activities at the five makerspaces within a period expanding over four years.

In March 2016, we began to consider how participation in the maker community in Copenhagen was influenced by the ways in which different makerspaces were represented on social media. Based upon our insights from all the different activities we have been involved in, we noticed that each makerspace had a different 'flavor'. This flavor seemed to be known by members of the Copenhagen Maker community and we wanted to investigate whether this was also displayed on the social media presence of each makerspace. Furthermore, we wanted to explore whether social media presences were part of shaping access to the spaces. Our curiosity motivated us to systematically

collect data on five makerspaces on Facebook, where all makerspaces had a profile. While there are more than 15 makerspaces in Copenhagen, all with a social media presence, we chose to focus our analysis on five of them, because the selected makerspaces were the most influential in the maker community. We knew this because of our prior knowledge gained from the various activities we had been involved in. Furthermore, we knew that the selected makerspaces had very diverse types of participation, organizational structure, and activities. In this way, we were able to compare the differences across five social media sites as a strategy to identify the core characteristics of makerspaces' social media presences.

Proprietary social media platforms, such as Facebook, might create tensions with the values and identities in the culture of making (Toombs et al., 2015). In turn, this might influence the extent to which makerspaces use social media platforms, how, and whether they use them. To explore the extent to which European makerspaces are present on social media, we investigated their presence on Facebook. We started by looking at the spaces that are formally registered on FabLab.io. This site is the 'current official list of Fab Labs that share same principles, tools, and philosophy around the future of technology and its role in society'.[2] In spite of the name, the list does not only contain FabLabs, but also spaces that refer to themselves as makerspaces and hackerspaces. We manually collected data of 400 spaces distributed across 15 European countries in relation to their Facebook presence. More especifically, for each space, we collected information regarding the number of 'likes', the date of the last publication and – when available – the estimated time taken to respond to a message ('typically responds within minutes' or 'typically responds within a day'). This estimated time is an indicator provided by Facebook, which is based on the time that page administrators take for replying to previous messages. We collected the date of the last publication and the estimation of response time to give an indication of presence, because we were not only interested in whether they were present on Facebook, but also if they used their social media.

The results showed that most makerspaces (79%) had a social media site. Many of those makerspaces that were not on social media were located in vocational schools, universities, and cultural centers, which had a social media presence of its own, where activities and products created at the makerspace where publicized. Facebook allows creating different kinds of social media presences (e.g. public group, private group, community, page). Our data show that most of the makerspaces that were present on Facebook, were represented as a public page (98%). The number of likes on the pages ranged between three and 10,158. A relatively high percentage of the makerspaces (33%) had more than 1,000 people following their Facebook pages. These data are especially relevant for the purpose of this paper. More concretely, considering that makerspaces are usually not very large, this high number of followers suggests that people who do not usually participate in the physical space, still follow the makerspace on Facebook. With regards to the use of the makerspaces' social media profiles, we discovered that most of them (64%) had

[2] https://www.fablabs.io/about.

published a post in the last month and many had published a post during the last week (36%). This relative frequent participation suggested that Facebook pages were not simply static pages, but had actual activities and interactions happening, although we can only speculate about what they were used for. In addition, for those Facebook pages for which we could access their 'estimated period to respond to a message' (in total, 43% provided this opportunity), most of them replied to messages within a day (14%), followed by within an hour (10%), within minutes (9%), within a few hours (8%) and instantly (2%). These results suggest that, in spite of the fact that there might be tensions between the culture of making and proprietary social media platforms, a significant number of makerspaces in Europe are using Facebook.

3.2. Data Sources

The main data source of this paper are 500 public posts manually collected on the Facebook sites of five makerspaces in Copenhagen, Denmark. Four of the sites were Facebook pages and one was a public Facebook group. For each social media site, we manually collected the first 50 posts after each of the sites were created, the last 50 posts in 2017, and the number of participants (i.e. the number of 'likes' on the Facebook pages and the number of members in the Facebook group). Figure 1 provides an overview of the analyzed sites, the date they were created, the number of participants, and a temporal illustration of the distribution of their first 50 posts. These data illustrate differences in terms of the extent to which each of the selected makerspaces was active on social media. For example, the first 50 posts in Makerspace A spanned over a period of two years, suggesting that it was not very active on social media; however, Makerspace E created the same number of posts in less than a month. In addition, Table 1 shows that the extent to which the makerspaces were active varied over time. For example, the difference in the number of days

FIGURE 1. Overview of the analyzed social media sites.

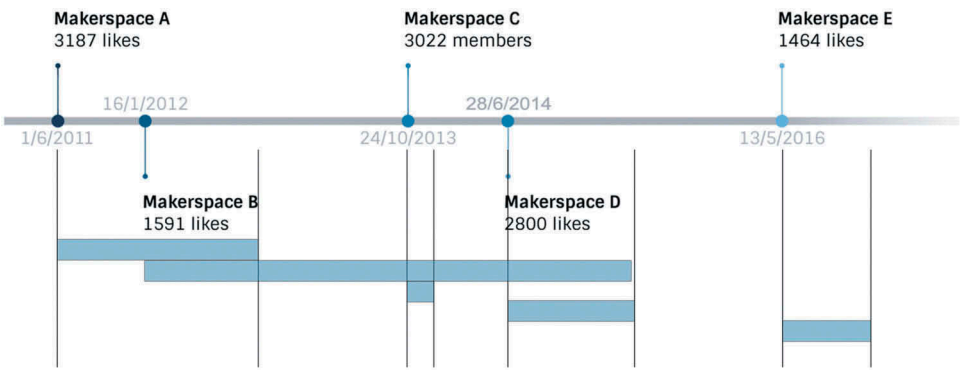

TABLE 1. Selected Makerspaces' Activity on Social Media

Makerspace	People in page/ group	First 50 Posts timeframe in days (% of user posts)	Last 50 posts timeframe in days (% of user posts)
A	3,253	794 days (44%)	334 days (57%)
B	1,579	253 days (32%)	616 days (80%)
C	3,261	68 days (100%)	33 days (100%)
D	3,511	265 days (30%)	93 days (25%)
E	1,687	145 days (30%)	112 days (22%)

required to write 50 posts suggests that Makerspace D became much more active as the site evolved. The data are not meant to provide an exhaustive comparison between two different points in time. Instead, they point to some of the differences among (and within) makerspaces' social media presence, which provide information on their use of the platform.

For each post, we collected the date, language (Danish, English or none, in the case of non-textual media) and, when available, replies. In addition, we wrote down observations that contained relevant information that was not captured by the text. These observations included notes on the content of videos, pictures, links shared on the sites, and on the authors of the posts (e.g., when someone who was a core member of one makerspace posted in another makerspace). Regarding the Facebook pages, we annotated whether the post was created by the Facebook page profiler or by a user. Table 1 shows the percentage of collected posts that were written by users. For example, in Makerspace A, 44% of the first 50 posts were written by users. In Makerspace C, all the posts were written by users because it was a public group.

3.3. Data Analysis

The data of the collected public posts from Facebook were analyzed using ATLAS.ti. It is important to note that our interpretation and analysis of the data were rooted in the knowledge we have gained over the last four years participating in the maker community in Copenhagen. Thus, our ethnographic notes and interviews helped us interpret the data collected on social media and identify the characteristics that shaped the participation. We followed a process of iterative thematic analysis (Glaser, Strauss, & Strutzel, 1968). Thematic analysis is a method for identifying, analyzing, and reporting themes in data and it has previously been used in studies on -> of digital media (Anstead & O'Loughlin, 2015; Herring, 2009; Nosko, Wood, & Molema, 2010).

Initially, the first 250 public posts from each Facebook site were imported into ATLAS.ti and analyzed using thematic analysis. Concretely, following a bottom-up approach, we labelled quotes first with low-level codes, which were as descriptive as possible and close to the actual content of the posts. Then we created high-level categories in which we grouped the coded segments. Finally, we identified higher-level

categorizations in the form of themes. Using this method, the analysis resulted in 289 codes, grouped into 28 categories, such as 'opportunities for participation by learning', 'relationships with educational institutions (universities/schools)', and 'sharing inspirational material'. These categories were inductively clustered into five themes.

The 250 posts corresponding to the last three months in 2017 were then added to the analysis, watching out for new themes and possible differences over time. The data analysis was done iteratively, which meant that themes that emerged during the second part of our analysis were applied to the complete dataset to validate the details of the empirical categories. After our thematic analysis, we began to look across the cases and themes and, guided by our research question, we began to identify characteristics across makerspaces' social media presences and how these characteristics influenced the potential access to open design activities. We found three main characteristics (reach, transparency, and discourse) which together shape makerspaces' social media presence as elaborated in the following sections.

3.4. Limitations

Our empirical data are focused on Facebook, which only represents one of the many online platforms used by the makerspaces to publicly share their activities, outcomes, and source code. By including other types of digital platforms such as GitHub, Instructables, or Wikis we might extend the analysis of details of the characteristics. Although out of the scope of this paper, we did notice interesting developments among and within makerspaces over time. For example, as the sites became more mature, we observed differences in how the relationships among makerspaces were represented. To be concrete, some makerspaces seemed to become closer to others (by increasingly posting and commenting on each other's posts); whereas others seemed to grow apart. In addition, some makerspaces' social media sites, seemed to become more strategic as they became more mature. For example, the two 'youngest' makerspaces seemed to become more specialized in representing ways in which they supported small scale product development. This also seemed to influence the kinds of interests that the sites attracted (Makerspace B increasingly got questions regarding electronics; whereas Makerspace E seemed to attract more and more people interested in product development). The 500 posts we analyzed correspond to the first and last 50 posts for each makerspace; however, extending the temporal boundaries of the project could provide additional insights on the evolution of the makerspaces. It would be interesting to investigate how social media presence change over time and the impact on access to Open Design activities. Finally, although our analysis included notes on the content of videos and pictures, the main data source of this paper are the textual posts. It would be interesting to carry out an analysis focused on the visual representations of social media presences, and how these might differ across and within makerspaces.

4. RESULTS

In the following section, we will present the results of our analysis in five sub-sections: Reach of productive activities, Transparency of institutional arrangements, Manifestation of opportunities for participation, Boundaries of legitimate expertise, and Written discourse in online participation. Each of them demonstrates different aspects which shape makerspaces' social media presence. Together they produce access to Open Design activities in various ways.

4.1. Reach of Productive Activities

All the social media sites displayed different productive activities that were carried out in the makerspaces. We found out that while all the makerspaces sites displayed their productive activities online, they did it differently. One major difference was the *reach of productive activities*. We define reach as both related to the purpose of activities as well as to the potential participation in the concrete activities. Below, we elaborate on the different types of reach, and how these were articulated differently on social media.

The reach of productive activities was closely related to the described purpose. The purpose of some activities was described having an impact on higher goals, e.g. societal, political, or environmental goals. One example was an activity, which was described as aiming:

> 'to provide a locally accessible, economically efficient platform for the development of ocean-cleaning data collecting robotic drones. The goal [was] to harness human innovation, technological ingenuity, and creative design to preserve the integrity of our natural resources' [Makerspace B].

This post introducing the ocean-cleaning activity as fundamentally about having an impact on technological innovation and sustainability – thus, the activity reached far outside the actual makerspace. The device was described as an 'open source sailing drone'. The above example demonstrates how reaching out through innovation was connected to the agenda on saving the Earth's natural resources, thus reaching outside the makerspace was a set goal.

Reaching outside the makerspace was a common practice when posting on social media across makerspaces. However, reaching outside does not have to be connected to global agendas of climate change, it also took the forms such as creating networks or supporting entrepreneurial activities. Indeed, in some of the makerspaces, it was common to see opportunities for gathering and networking in entrepreneurial events. Posts with explicit connections to companies and start-ups were an invested interest from several of the makerspaces. In the case of entrepreneurial networking, productive activities in Makerspace B sometimes displayed the makerspace as an innovative hub, in which people with common interests in entrepreneurship and innovation could get together:

> 'We are co-hosting this super cool event. Great networking and a great way for [makerspace] to get attention! They are really looking for creative tech projects, so if you are working on something and could use some extra cash to develop it - this is a very easy way! All it takes is a 5 min pitch - no attachment and no requirements about commercial potential' [Makerspace B]

While 'reaching outside' the makerspace was very prominent in most of the makerspaces' social media sites; some makerspaces also publicized activities that focused on 'reaching inside'. Activities for reaching inside the makerspaces were often framed as exploring concrete pieces of software, hardware, or digital fabrication machines. This is illustrated in the post below, in which a makerspace announced a forthcoming productive activity for creating an exploratory project on hydroponics:

> 'We will soon start up a hydroponics project in [Makerspace B]. Controlling moisture levels, light and probably much much more. One of the goals is to produce spices for the food-lab in [Makerspace B], another is to just have fun and see if we have green fingers at all.'[Makerspace B]

Even though 'open design' and 'open source' are not explicitly mentioned in the post, enough information about the project and activities is shared, making it possible for others to replicate and/or re-mix the open design project. The reach of productive activities thus spans a continuum between *reach as the expected impact* and *reach as a practical feature*. These different representations attracted diverse sets of interests and people. For example, activities with global reach on climate change resonate with certain people who share these values, identities, and interests; whereas activities focusing on practical tasks of learning technology resonate with people's curiosity and interests for learning concrete technologies – even without knowing the concrete application domain. Furthermore, reach of productive activities also spans a different continuum – namely between *reaching within the makerspace* and *reaching outside the makerspace*. Let us take a closer look.

In our analysis, we found that reach referred to whom the productive activities were targeted and whether the activities were collaborative or individual. All the posts above refer to productive activities to be carried out in groups. The majority of social media posts announced collaborative activities, and only a few posts were related to individual projects. In this respect, Makerspace C stood out because it contained a higher number of posts related to individual projects. These posts were often written by people who seemed unfamiliar with the makerspace and, in most cases, posed practical questions. For example, people often asked for help on how to operate the machines, which materials could be used, or where materials could be bought, as illustrated in the following post:

> 'Quick question in regards to the laser cutter: ABS plastic isnt listed in the guidelines under usable materials. It it possible to cut it? -Does anyone have

> prev. experience in working with the material. The job itself is small badges (1-3cm in diameter), so if anyone knows of a similar material (with the limitation being a material thickness of max 2mm), which might suit my needs better, feel free to chime in.' [Makerspace C]

Frequently, such questions on individual projects triggered conversations among people on the social media site, who shared their experiences with similar projects and provided expert knowledge on how to operate the machines. Sometimes, people would tag others in their replies, and thus include them by asking for their opinion, or referring to their expertise with previous similar projects. In general, replies were posted quickly and provided high-quality practical information. In Makerspace C, a specific group of users (called 'superusers'), played a paramount role in replying to individual requests. The superusers were volunteers with specialized knowledge on how to use and operate machines, who offered their time to help others. For example, using the laser cutter and the CNC machine required a superuser to be present.

In addition, it was common to see similar questions regarding materials and machines being asked multiple times by different people over time. This highlights an important consideration with respect to using social media for sharing expert knowledge on the basis of individual projects. To be concrete, answering practical questions on the basis of individual projects can be seen as a suboptimal use of the social media site – and thus a waste of people's time, since the page is difficult to navigate and have repetitive information. At the same time, the high number of posts asking practical questions and related replies provided an impression of frequent activity level and engagement. Demonstrating high frequent activities and quick responses to 'the usual questions' produce an impression of supportiveness, suggesting that people are open to offer their help to anyone. Thus, using social media for sharing expert knowledge on the basis of individual user projects presented the makerspace as a living entity, in which there was always something going on. Indeed, it was quite common that the replies to these questions evolved into a series of questions and answers. Sometimes these online conversations resulted in arranging an appointment at the makerspace, so those with more experience could help people with their individual projects. Even though there seemed to be a tendency to use social media for announcing group activities that brought people together, the potential of social media for supporting individual projects was also pertinent.

The reach of productive activities shaped the representation of the makerspaces on social media. Some makerspaces reached outside towards political agendas or networking as was the cases of Makerspace D and E; while other makerspaces reached within the walls of the makerspace, allowing for personalised creative fabrication as was the case of Makerspace C, or to mainly create artefacts for the space in itself as was the case of Makerspace B. The ways in which the reach of productive activities were displayed produced access in different ways. We found that producing access to makerspaces on social media was not only about portraying activities in the physical space but also

about enabling opportunities for sharing knowledge. Sharing knowledge included informing about activities, the space and machines as well as networking. In this way, social media allowed people to ask questions and learn about the activities prior to entering the physical space.

4.2. Transparency of Institutional Arrangements

In our analysis, we found that makerspaces social media sites displayed access to shared resources in different ways. Some makerspaces openly described organizational arrangements in the space, including how available resources were managed, and by whom. Other makerspaces did not provide information on the arrangements or available machines. The choice of displaying institutional arrangements on social media provided an indication as to how the makerspace was structured, thus expressing relevant characteristics of the makerspace.

To be concrete, Makerspaces A and B did not display on their Facebook sites which machines they owned or the conditions for accessing these. Their Facebook sites had little information regarding the machines. Also, in comparison to other makerspaces (such as makerspace D), they seldom posted announcements of the arrival of a new machine, or how they were being used at the makerspace. Indeed, in Makerspaces A and B, the focus of posts was the outcomes of activities rather than the resources involved in the process.

The extent to which rules for accessing machines were available on the social media differed across the makerspaces. For example, makerspaces C, D, and E provided information regarding the available machines and the rules for accessing them. In two of the makerspaces (D and E), being able to access the machines required people to pay a membership fee. This information was sometimes included in the posts. However, in Makerspace C, the access to the resources was free and accessing machines only required to be formally registered as a citizen in Copenhagen. Although using the machines was free of cost, gaining access to some of the machines required the presence of a superuser. Facebook was the most used channel for interacting with the superusers. Indeed, the superusers were available and responsive on the Facebook site, even if this required extra commitment and flexibility from them. For example, it was common to read posts from users asking whether any superuser had time outside pre-defined hours:

> 'The usual question: when is the next laser cutter day - Thursday? Also: If a superuser happens to be there tomorrow after 3pm, and have time to let other users cut some stuff, please let me know. ' [Makerspace C]

The above posts illustrates a situation in which someone wanted to use the machines for their own purposes, which was very common in Makerspace C. In these cases, the makerspace became a place where individuals were able to carry out activities without necessarily engaging with others. For example, Makerspace C organised an 'open laser cut day' at least once a week. At the 'open laser

cut day', superusers introduced and supported people in learning how to use the laser cutter individually. This event was posted on their Facebook site weekly. One of the authors of this paper joined this activity several times. During the event, one of the users described the risk of turning the makerspace into a commodity, where it was all about using machines rather than about sharing and bringing people together.

Indeed, through our analysis, we saw several examples where the makerspaces took the form of commodities. However, even in these situations people would also give something back to the makerspace. As an example, some of the frequent users of makerspaces offered their knowledge in the service of the makerspace as a token of gratitude for using the space and the machines. In another situation, a group of superusers, who often used the laser cutter machine offered free and open workshops for all. In Makerspace C, a user organized workshops on 3D modelling and ceramics to express his gratitude for using the machines for free for more than a year.

The social media site also supported the coordination of shared resources. In Makerspace C, one of the local high-schools came to use the laser cutter for a school-related project. On this occasion, an announcement was made on the site: 'a reminder folks, the lab is booked out every day from 9:00 until 15:00 for a school'. In addition, the social media site was used to coordinate the availability of superusers, by posting a shared public calendar on the makerspace site. This calendar was updated at least once a week and was set as a 'permanent announcement' at the top of the Facebook site. The Facebook functionality of making permanent announcements, which are visually designed to stay fixed at the top of the site, helped the makerspace to coordinate access to their resources and to make this information accessible for everyone. The fact that Makerspace C placed the calendar so it was the first thing that everyone saw as they entered the site produced access to the makerspace through its shared resources - thus the availability and coordination were an important part of the makerspace.

It was common practice across all makerspaces that the participants would post the results of their projects using individual Facebook profiles. These types of posts demonstrated what was possible to do in the makerspace, rather than demonstrating how to do these. In Makerspace C, in which opportunities for using the machines were regularly announced on the social media site, people were encouraged to share their work publicly. Here, participants often did not only share their final results but they also shared the source files of their work, often accompanied with pictures. In addition, it was also common to see posts acknowledging help from superusers in creating their projects:

> 'I'm quite new in the world of ceramics and I had to make a mold. That's why I asked if someone would help with a [lasercut] template. The deal was I shared the result here. I drew and sent goals and pictures to [superuser_name] that helped me laser cut a template […]. Thanks for the time and help to [superuser_name]! ' [Makerspace C]

One core aspect of the institutional arrangements was the extent to which social media supported commercial activities in the makerspaces. Commercial activities took very different forms on social media. The extent to which the makerspaces supported commercial activities seemed to be directly related to the way participants could access shared resources. For example, in Makerspace C, commercial activities were not allowed. Reminders about this were posted often. We found instances of reminders both in 2013 and 2017, suggesting that being aware of the conditions for using the shared resources was something that needed reminders over time. In the quote below, the situation was that a member wanted to use the laser cutter for creating a logo, and a superuser promptly replied to the post that:

> 'Gifts are fine but anything that makes any income/money is not allowed' [Makerspace C].

In contrast, Makerspaces D and E's social media presences displayed a specific focus on product development and innovation. In these makerspaces, funding was provided through membership, so the machines could only be used after paying a membership fee. Furthermore, Makerspace D created an additional Facebook site (in this case, a closed group instead of a page), in which the focus was to engage and exchange ideas by participants interested in making a profit out of their productive activities in the makerspace. Here, Makerspace D was described as a platform for enabling the development and business activities of its users, including supporting fundraising activities, and organizing workshops and events for companies. Neither Makerspaces A nor B made clear statements on their social media sites on whether they supported commercial activities or not.

The social media presences of the makerspaces made visible (or invisible, as in Makerspace A and B) the dynamics for accessing shared resources, which in turn influenced the representations of how open the makerspaces were for people to use the resources. In addition, their institutional arrangements also influenced the extent to which the resources could be used for commercial purposes. Commercial activities were either welcomed – and encouraged – as in makerspaces D and E; or not allowed, as in Makerspace C. Enacting transparency of institutional arrangements is when the conditions for access and use of shared resources are explicitly stated together with expectations regarding what to do with the outcomes, and finally the extent to which commercial activities are (or are not) allowed and supported are clearly displayed.

4.3. Manifestations of Opportunities for Participation

The makerspaces' social media presences manifested different opportunities for participation. These opportunities referred to both participation in the makerspaces' online social media and how these social media sites represented opportunities for offline participation.

Across all makerspaces, social media sites were set as public, suggesting that they welcomed anyone who wanted to participate on Facebook. There were a few exceptions, such as Makerspace D, which had a linked closed group to the public Facebook page, requiring users to submit a request to join. The data suggest that the settings choices on social media sites could influence how accessible a makerspace appeared. For example, choosing between instantiating the Facebook site as a group or a page (these are two of the possibilities available on Facebook) might not be a trivial decision. Our data suggest that this choice had implications on how people could participate. Concretely, the Makerspace C's site was created as a group and therefore everyone could post with their personal profile. Our data indicate that this was the most active social media site in terms of posts, likes, and replies. On the other hand, Makerspaces E and D created a page, meaning that only administrators could write posts on the main page, thus providing an impersonal and official profile rather than a personal one.

People participated in the makerspaces Facebook pages and groups by engaging in activities, such as posting, liking, commenting, or responding to events. These forms of participation can be seen as one of many different forms of engagement with makerspaces, complementing the productive activities that took place in the physical makerspace and potentially influencing how open a makerspace is displayed online. For example, online participation included posts which contained links to videos and tutorials of existing projects. These links often referred to websites such as Instructables.com or YouTube and were described as interesting or inspirational. Because the Facebook pages were public, anyone could post what they found to be relevant and inspiring for the makerspace. Indeed, it was very common to see posts that only contained a link to inspirational material. This is a type of participation enabled by social media, allowing participants to shape the online representation of the makerspace by sharing suggestions of inspiring links and videos.

The choice of language also shaped the representations of makerspaces. Most makerspaces posted both in English and Danish; however, for some, one language was more prevalent than the other. For example, Makerspace C mostly posted in English, although individual users also posted in Danish when asking a question. However, Makerspace D mostly posted in Danish, and only a very small percentage of posts were in English. The post regarding courses and workshops were all in Danish, which suggested that this was also the language to be used at the workshop and might hinder the participation of non-Danish speakers. Makerspace E posted regularly in both Danish and English. Making the effort to translate posts in both languages suggested an explicit interest in engaging both Danish and non-Danish speakers, therefore contributing to representing the makerspace as a welcoming space regardless of language.

Furthermore, makerspaces' social media sites displayed many opportunities for participating in offline activities and projects. For many of the announced activities, participation did not entail any particular skills. Some of the activities were about joining organizational activities, such as becoming part of the makerspace board,

helping to set up a new CNC workshop, or joining maintenance activities. Other activities were about socializing and having a good time together. Along these lines, posts often displayed opportunities for taking care of the physical place, sometimes accompanied by pictures of their rather picturesque locations (one makerspace was located inside a boat, another one in a dwelling basement, and another in a workshop under a bridge). Social media often represented opportunities for participation as convivial and caring, as highlighted in the following post:

> 'Time to prepare for winter: This Saturday, 10. November from 12:00 we will do a bit of cleaning and winter preparations on [makerspace]. Please bring your warm clothes and come give a hand making the old lady ready for the chill:-) - There will be fire and warm coffee in the mess room. ' [Makerspace A]

These activities were sometimes announced in posts and sometimes published in the form of Facebook events. When announced as events, it was easy for anyone to indicate whether they were interested or would like to participate. Similarly, it was easy for everyone to see who else would be there. These activities suggest that opportunities for participating in the makerspace went beyond designing or creating physical products into socializing activities, which is indeed common in makerspaces (e.g. Davies, 2017; Taylor et al., 2016; Toombs et al., 2015). However, what was unique for the purpose of this study was that they were announced as public posts in an open group or page, on which everyone reading the public post was welcome to join. Resultantly, these online posts played a crucial role in presenting the makerspaces as open spaces.

Sometimes, online posts announced learning activities, such as courses and workshops. These workshops ranged from hobbyist to technical projects, such as letter pressing, 3D-modelling software, sewing, or packaging. For example, Makerspace D was particularly active in posting events announcing workshops. During these events, people could participate and learn a concrete skill. In this makerspace, most of the workshops required participants to pay a fee:

> 'To use fablab's machines, go through a mini-course to fablab's machines. Then on Thursday we invite to a mini-course in laser cutting. You must also be a member to use the machines. Read more on our website:-) For those who met up last Thursday, it's easy to meet again. We introduce the small universal laser. ' [Makerspace D]

Although payment can be controversial in makerspaces, especially because sharing and open access are core values of makerspaces (The Fab Charter, 2018), it was common in Makerspaces D and E. Financial contributions can legitimize certain forms of participation, since financial contributions can justify joining activities. In addition, some of these paid courses did not only provide knowledge on how to use the machines but also allowed the participants to use the machines on their own. Therefore, displaying fee-based activities did not only

potentially allow people to learn a concrete skill, but also opened a wider range of opportunities for accessing the makerspace. However, even among the makerspaces that required a fee, there were differences in terms of how salient payments were. In Makerspace D, payment was very prominent: using the machines required paying membership and most of their posts were about workshops, which included how much they would cost as part of the description. Fees varied between 200–300 kr. (20–30 euros). These workshops were very popular and most of them were sold-out. No one questioned why they had to pay for the courses, just one student asked:

> 'Hey, you guys offer a lot of exciting courses - but they are usually too expensive for me as a student. Can you not have reduced prices for students? ' [Makerspace D]

Indeed, Makerspace D was quite an interesting case with respect to online participation. Their social media presence suggested that they succeeded at attracting a great amount of attention in a short time. Indeed, even though they were one of the youngest makerspaces in Copenhagen, they had the highest number of people following their social media page (see Figure 1). Online participation was relatively high, in terms of people liking and commenting. Most of these posts were related to asking for practical information regarding courses and machines. However, a few posts shared knowledge and connected people with shared interests. The data suggests that their strong focus on courses and machines represented the makerspace as a place for providing services rather than for performing community, which could eventually influence the type of participation. For example, when Makerspace A made a call for people to come and help them clean the space, many people responded with likes and comments. Also the Makerspace D posted such a call when they needed to move from one space to another. However, in this case, there were no reactions.

Makerspaces' social media did not only announce opportunities for participation in the makerspaces, but also publicized other activities and events at libraries, festivals, and Maker Faires. Of special interest were those posts that announced activities and events taking place at other makerspaces in Copenhagen. What is interesting here is how the different makerspaces complemented each other by having unique profiles, and how these connections were represented through the sites. Indeed, it was common that participants would be active in several makerspaces' sites although at different levels of engagement. Concretely, some participants, who were very active on one social media site (writing posts and organizing activities), would be peripherally active on other makerspaces sites by commenting on posts from time to time. The social media sites offered opportunities to participate online in several makerspaces simultaneously, with different degrees of involvement, while creating connections across makerspaces and also supporting joint activities. In these cases, social media presence allowed people in Copenhagen to be present and maintain connections across makerspaces.

Makerspaces' social media representations were influenced by their choices regarding Facebook settings (illustrated by the decision of Makerspace C to create a group) and choice of language (as in Makerspace E, which posted most of its announcements in Danish and English). In addition, social media was instrumental in publicizing different ways in which people could access a makerspace. Accessing was not only about joining workshops, using machines, and creating objects; instead, accessing a makerspace was also about creating social relationships by socializing and caring, which might not be something obvious for people who had never been in a makerspace. What was unique about social media was that it produced legitimate participation for people who were 'external' to the space, potentially allowing access for people who were not already joining open design activities. Finally, the social media presences represented opportunities to engage across makerspaces, complementing individual and collaborative activities, while supporting different makerspaces within Copenhagen.

4.4. Boundaries of Legitimate Participation

The social media presence produced certain *boundaries of legitimate participation*. This related to the ways in which social media represented activities where people were welcome to join, or what skills were seen as important in the makerspace. Unlike other communities of practice, the skills that were central to legitimate participation in makerspaces were in continuous negotiation, rather than being a pre-defined set of skills.

In communities of practice, legitimate participation is influenced by the skills required to be an expert in the practice at stake. However, our study of social media presence indicated that the practices relevant to makerspaces were multiple and varied among different makerspaces with respect to their reach, institutional arrangements, and productive activities. Also, the range and type of skills to join events and activities published on Facebook took different forms. While some activities were for amateurs, other activities required expert knowledge in different domains. For example, one of the makerspaces published an open call for participation to join in creating a sauna, welcoming people with expertise in architecture or wood-cutting. However, it was not limited to these as any kind of relevant expertise was welcomed, as illustrated in the following post:

> 'We want to invite everyone to the first workshop and work weekend in the Sauna Dome project!! […] We have conjured up some schematics for the raft structure which we are going to share on this event and in paper on site. So as to the plan of building this wonderful structure. We are going to build seven identical triangular modules for the raft and hopefully piece them together on sunday. During the weekend there are also going to be some more or less structured discussions about how the raft is going to float! So bring your cool ideas and we will bring ours!' [Makerspace A]

Similarly, another makerspace initiated a project to create a Segway – a self-balancing motorized vehicle that can carry one person. In this project, it was not clear which skills were required, and thus the call for participation was published openly:

> 'Some time ago we started a custom Segway project in [makerspace]. The hardware has been constructed and all the electronics and battery etc has been bought. A small model has been created, which the balancing software were being developed for. The software development has stalled and we need some people to finish the project. If you know how to code and would like to help finish this TOTALLY AWESOME project, come by the space:-)' [Makerspace B]

Some posts published opportunities for participating in activities, requiring particular skills or knowledge. Some of these activities were about learning, brainstorming, or constructing, while others were defined in terms of workshops or other types of established activities. For example, the posts about informal 'get-togethers' and brainstorming activities on ideas for social entrepreneurship were different to the post about the sauna.

Interestingly, social media sites were also a place where people spontaneously proposed their expertise for the service of the makerspaces. This was the case of one person, who proactively helped setting up a fabric weaver at the makerspace; and another, who had expertise with working with wood and wanted to contribute to the makerspace, as illustrated in the following post:

> 'I dont have a lot of knowledge about your machines yet I've mostly been working wood by hand tools. but i really like the place and I'd like to help along to maintain and maybe improve fablab' [Makerspace C]

These posts represented the makerspaces as flexible entities in which people could propose their expertise, especially if it was related to handcrafting. In this way, social media helped to continuously broaden and negotiate what could mean legitimate participation. For example, in one of the makerspaces, they came up with the idea of 'skill swap meetings', during which people could exchange skills and learn from each other. This is shown in the following post, a reply to the post above:

> 'A lot of us could really benefit from a cosy coffee workshop on how to sharpen drills and chisels. Also basic wood joining techniques would be beneficial to many users needs. The machines are easy - we can show you how to do that. Fablab Skills Swap Meetings?' [Makerspace C]

Still, social media representations also contributed to separating peripheral and core participants. This was often represented in the written discourse, for example, the use of pronouns. Makerspaces used pronouns differently; some of them referred to 'we' when posting updates, announcements, and reports. The problem was that it was difficult to understand who 'we' actually were. Thus, these posts created

different categories between those that had been in the physical space and those that had not, i.e. those who knew who 'we' were and those who did not. In addition, some posts seemed specially suitable for experts to join sophisticated projects. In these cases, many technical details would be part of an open call for participation and included links to external resources such as wikis and GitHub repositories, thus relying on multiple digital resources to represent and open up the complexity of the project. These sophisticated projects were often portrayed using technical jargon, which might be difficult to understand for novices.

Social media presence produces the boundaries of legitimate participation differently across the makerspaces. Social media can lower the participation barrier of a makerspace by simply sharing links and videos for inspiration. Defining participation in broad terms without requirements for specific skills or prior knowledge can increase the possibilities for access to the makerspaces. Social media opened up opportunities for legitimate peripheral participation by inviting in certain expertise and knowledge, complementing those of existing participants, while offering opportunities to learn new skills. Thus, legitimate participation in makerspaces cannot simply be understood in terms of novice-expert. Instead, legitimate participation spans across two sets of continuums, in which legitimate participation is understood in different dimensions: Novice-expert and newcomer-full participant. Newcomer-experts (craft experts), novice-full participants (laser cutter superusers learning new things), newcomer-novice (people sharing links and videos), and expert-full member (core members), all produce legitimately participation. The social media presence of the makerspaces welcomed these divergent types of legitimate participation.

4.5. Written Discourse in Online Participation

The written discourse on social media produced opportunitities for participation in different ways, and one important feature was the temporal representations of events and activities. Temporal representations concerned the timeliness of posts and the ways in which these were articulated in the past, present, and future tense. The majority of posts across all sites mentioned the status of one particular project at a single point in time. These posts reported the outcome of group activities or showed the outcome of personal projects, usually accompanied by pictures or videos. This was illustrated by the following post, written by someone who had used the 3D printer at the makerspace:

> 'Thanks to [makerspace_name] for letting me print these pieces which are on exbition for stop slaveri at the workers museum of denmark! and thanks to those who came to support my opening night!' [Makerspace C]

Social media sites often showed the current status of a project at a given time, without any follow-up posts. There were several examples of posts on projects and activities that had ended but had not been announced prior to the event taking

place. For all these project-related posts, there was not much interaction on the social media sites apart from the occasional 'like'.

However, we also identified a different type of temporal pattern related to projects. Even though they were less common, they often spurred much more interaction on the site. These posts reported projects as temporal entities across multiple posts, thus creating a continuity among different posts. This was the case for individual projects and activities initiated by the makerspace. For example, in makerspace C it was very common to read posts from people asking how to operate a machine or where to buy materials. It was also quite common to read posts of those people showing the final result, as exemplified in the following post:

> 'So, a while back I asked you guys if you had ideas for a mold for an award. Here is the result made this way: mold for top lasercut in acrylic. Plaster version made in this mold. Sanded and used for rubber mold for concrete. Bottom stand mold made in engraved acrylic box with incorporated holder for the top. The engraved letters turned out really nice.' [Makerspace C]

Continuity was also enacted in projects initiated by people who participated in the makerspace. Makerspace C was particularly good at enacting continuity on their social media site. For example, at the beginning of the week, Makerspace C would often post an announcement with all the activities and events for the week:

> 'Hello all ! new week, new events. This week Monday - Open laser with [superuser]; Tuesday - Open laser with [superuser; Wednesday - Open laser with [superuser]; Thursday - Open laser and FabRIK event- Learn to laser cut fabrics; Friday - Openideo meeting - what next for our chapter. Saturday 3DS max class A pretty busy week and im back from vacation for those who need help and guidance on things. See you in the lab!' [Makerspace C]

During the week, Makerspace C often added updates on each of the daily activities; this enabled continuity within those activities. An example was that of a member in Makerspace C, who posted updates on a project cultivating a special kind of fungus, which was able to decompose plastic. These early posts illustrated the results of experimenting with the fungus and showed how it started to sprout. In subsequent posts, the member invited people to join a series of hands-on workshops. At these workshops, people with no prior knowledge could learn about the fungus, its applications, and how to grow it. The subsequent posts illustrated what happened at the workshop, including pictures. After the workshop, some posts included pictures showing working with bioplastics at the makerspace. Then, someone replied to one of these posts saying that they wanted to drop-by and experiment outside of the workshops:

> 'This is really cool to see! Will you be experimenting in the lab next week? I want to try and come by more on non-workshop moments! I would love to

> see what you are doing now! Maybe combine it with getting some sewing work done!' [Makerspace C]

Interestingly, enacting continuity across multiple posts prompted interaction on the site. In addition, the narrative aspects of the posts facilitated people to join the discussion on the project through comments and encouragement. Furthermore, enacting continuity also created opportunities for participants to ask about the required expertise and potentially join the activities (or at least see the projects at the makerspace). In addition, some of these posts were accompanied by visual and audio media, such as pictures and videos. Pictures and videos portrayed the space, objects, activities, and people, and therefore contributed to making sense of the physical makerspace, what happened there, and who was involved.

These posts facilitated different types of participation: people who participated in the physical makerspace and those who followed the activities online. By making it available, as well as being able to see what had already happened in the past (outcome), what will happen in the future (process) was also visible to represent activities as an on-going experiment. This could influence potential access because people were prompted to drop by and 'hang out'. Also, by displaying projects at different stages (including text descriptions and images), tagging people who participated in each stage, and describing the context in which it happened (individual experimentation, workshop), social media could be seen as a place for project storytelling. Showing projects within a long-term temporal structure can help represent the makerspace as having expertise on a concrete subject. Indeed, one student replied to one of the posts on bioplastics and asked:

> 'I noticed that you are doing an event about algae bioplastic - in the description it says that algae bioplastic takes some time to degrade, but not as long as regular plastic - do you know anything about how long? I'm doing a project on bioplastic in school, and it would help a lot' [Makerspace C]

As could be expected, most of the makerspaces used social media to announce upcoming activities and to report recently finished individual projects. On top of this, some makerspaces would also report on ongoing projects and activities. For example, Makerspace C was prolific in posting updates on activities happening in the physical space while they were happening. This included posting pictures of ongoing activities, using the site to let people know that they were at the makerspace:

> 'Anyone coming around the lab today. There's room enough for cnc-ing and laser cutting. I'm all alone here.' [Makerspace C]

In addition, the choice of using a public social media channel or private channels to broadcast what was happening at the space influenced who had access

to information. Indeed, in one of the Makerspaces Facebook sites, it was common to see posts in which people would declare that they were considering dropping by at a certain time – but wanted to know if anyone was there. It was common to read these kinds of requests posted by people who had never been in the physical space, as illustrated in the following post:

> 'Good morning! I'm a newbie and would like to stop by tomorrow around 10:30 to check things out and find out how the FabLab works. I'd like to bring my cycle group- a bunch of parents whom are also interested- and have built a route to include your building. Would this be okay or would I be starting off on the wrong foot?' [Makerspace C]

What was interesting about this post was that it served as a request to know more about the social rules for participation. As the above quote demonstrates, the question about dropping by explaining all kind of details as a question about social norms for participation, when the new member asks: 'Would this be okay, or would I be starting off on the wrong foot?' This suggests that asking about how something might be in the future was important for people to know so they could decide whether it would be appropriate to join. Interestingly, these kinds of requests about social norms happened more often in some of the makerspaces' social media sites than in others.

The temporal pattern on the social media sites was also related to whether posts were written in the past, present, or future tense. While some makerspaces had a mixture of posts written in different tenses, we did see a pattern in how some makerspaces had mainly written posts in the past tense. In terms of potential access, social media sites with most posts written in the future and present tenses, tended to have more interactive visitors.

The written discourse can also influence makerspaces' representations on social media. More specifically, discourse choices can contribute to shift the focus on Open Design as a term that refers to a finished artefact (i.e. open design as a substantive) to a term that refers to a process (i.e. to open design as a verb). When discourse choices refers to Open Design as a process, purpose, impact, and knowledge sharing become constitutive elements of this process. In addition, written discourse puts forward a perspective in which Open Design is not only about making the source code and files available but also about enabling people to find and make sense of this information.

5. DISCUSSION

Analyzing the five Copenhagen-based makerspaces' Facebook sites, we found that social media sites were not only a communication device to recruit newcomers (Davies, 2017). Nor were they only a coordination tool (Goodman & Rosner, 2011). Instead, our findings suggest that social media presences are a constitutive element

of the uniqueness of the makerspaces. When entering the front door of social media to specific makerspaces, their representations display opportunities for participation, shaping the boundaries for what makes legitimate participation in each makerspace. We identified three characteristics which produce makerspaces' social media presences, namely *reach, transparency*, and *discourse*. Below we explore each of the characteristics in details.

5.1. Reach

All the makerspaces displayed the kinds of activities they were involved with in different ways, and we discovered how 'reach' of these activities was an important characteristic for the social media presence. 'Reach' refers to the ways in which activities were designed to address larger global agendas, or focused on learning about new technologies without a predefined application. Reach also refers to the extent to which the activities were meant to transcend the physical wall of the makerspace or not. More concretely, some productive activities went beyond the physical walls of the makerspace, as was the case with Makerspace E; while others provided idiosyncratic activities to develop the concrete physical space, as was the case with Makerspace B. As a result, the demonstration of *reach* on the makerspaces' social media sites displayed insights that presented their 'identity' (Lave & Wenger, 1991). Consequently, social media presences opened up opportunities for people to get a glimpse of the possibilities that each makerspace offered. In this way, social media could support people to find out which type of makerspace would provide relevant engagements based upon their preferences. Furthermore, the ways in which the social media sites represented productive activities also produced different 'ways of belonging' (Lave & Wenger, 1991). By displaying *reach*, the makerspaces produce the nuances of legitimate peripheral participation as enacted in the specific spaces, thus displaying the 'front door' of each makerspace differently. Thus, *Reach* displayed on social media shape the external image related to, e.g., political agendas or learning. For activities with global agendas, diverse types of expertise and knowledge were required, and thus the activities reached beyond technical and engineering knowledge. In these cases, social media displayed how political knowledge, communication skills, and performance competences were also relevant types of knowledge and expertise. In contrast, when activities were about constructing and learning about technologies, the competences and skills required emphasized the computational and engineering competences, thus producing legitimate participation more narrowly. Across all spaces, the posts displaying the makerspaces' productive activities produced different forms of access and participation.

5.2. Transparency

By making makerspaces' institutional arrangements visible on social media, such as clearly displaying the conditions for accessing shared resources, demonstrated transparency in different ways. We found that the extent to which

transparency was displayed formed an important characteristic of the social media presence. The way transparency was displayed promoted the individual makerspace either as a space allowing for questions that addressed the sociocultural organization of the makerspace, like Makerspace C; or as a space in which only core members could post and drive projects, as with Makerspace B. Recognizing the specifics of the sociocultural organization includes being able to recognize under which conditions people are allowed to access the physical space and the relationship between newcomers and 'old-timers' (Lave & Wenger, 1991). Makerspaces with high transparency received a larger number of questions and requests about ways to engage, and thus appeared more open than makerspaces where no information about tools and machines were posted. Prior work has identified how the continued organizational negotiations is part of what makes the collaborative practices in a makerspace (Lundberg et al 2017). By explicitly displaying organizational structures and engaging with questions upon sociocultural norms in the space, the transparency promotes access and discussions for 'not-core-members' to join these discussions. Our data show that providing information about shared resources and having formally appointed superusers as mediators increased interaction and engagement between the social media site and digital fabrication machines, between the outside and inside of the makerspace. Indeed, the presence and engagement on the social media sites by superusers were critical for creating connections between the physical locations, events, and increasing online participation over time. This was very clear in the case of Makerspace D, in which there was a focus on courses. Here most of the interaction was related to courses with the purpose to learn new skills, and thus a dedicated characteristic of Makerspace D was to foster increased participation in Open Design activities through technical knowledge.

5.3 Discourse

The written discourse on social media shaped the representation of productive activities. The way people wrote about the activities shaped the nature of the actual activities. Their written discourses produced language constructs and storytelling (Lave & Wenger, 1991), which produced and displayed the identities of the makerspaces. Especially, specific aspects of language discourse shaped the representation of the makerspaces related to time. For example, when Makerspace C demonstrated temporal continuity in the way that posts connected related activities over time. This contributed to displaying the makerspace as a place characterized by related activities and events promoted to multiple people. The temporal continuity of the posts encouraged people from the outside to join conversations, thus adding to the narrative displayed on the social media site, while shaping the identity of the makerspace. We also saw examples in which the social media sites did not display temporal continuity – e.g. Makerspace B. However, the lack of temporal continuity limits the opportunities for people from the outside to interpret how and when to engage. If you are not in the physical space, it is difficult to know when to join if not many activities are displayed on the social media ahead of time. We also saw

makerspaces in which they addressed this problem by posting about the process (materials, options, choices, decisions taken, and problems) instead of the end product, e.g. Makerspace C.

Reach, transparency, and discourse are all important characteristics of makerspaces' social media presences. These characteristics distinguish makerspaces' identities from each other, allowing people to identify which kind of space is appropriate for them. The different ways in which makerspaces are represented on social media are critical for forming opportunities for outsiders to gain access through the social media front door. In combination reach, transparency, and discourse manifest legitimate peripheral participation and thus produce opportunities for outsiders to join Open Design activities.

Our data demonstrate that the ways in which reach, transparency, and discourse were produced influenced makerspaces' social media representations, shaping potential access to join Open Design activities. By publishing posts on socializing and 'mingling' activities, convivial activities, and tedious yet caring activities, opportunities opened up for accessing the makerspaces. It is interesting to note that social media can shape these manifestations of opportunities in unique ways. For example, by enabling digital representations of offline events to which people can respond as 'being interested' or 'participating'. Similarly, payment can also influence opportunities for participation. More concretely, even though payment could be seen as a barrier, we also saw payment as an enabler for producing legitimate participation within Makerspace D. Because of this, social media presence broadens what it means to participate in the makerspaces, by acting as an additional venue for continual negotiation of the boundaries of legitimate participation.

Technical language and expertise are important enablers for access and participation (Lundbjerg et al., 2017; Toombs, 2017). However, our data show that what 'counts' as important knowledge and expertise is different across spaces and change over time. This was illustrated in Makerspace C, in which specific craft-knowledge relevant for a certain project was valued equally as important as technical and engineering expertise. Such inclusions might be influenced by the fact that the makerspace's social media site was not bounded by a concrete craft, as opposed to communities of practice around activities such as knitting and gardening (Goodman & Rosner, 2011). Instead, makerspaces' sites were constituted by an amalgam of practices, in which additional expertise was welcomed and sometimes encouraged. Moreover, when social media presence is a constitutive element of makerspaces, participating in makerspaces' social media sites also counts as participation in the makerspace. Indeed, this kind of participation was evident in all makerspaces, where people participated in the social media sites by sharing interesting links and videos for inspiration.

While open-source software and hardware development typically entails creating a finished and packed project to be shared with others, Open Design activities usually entail a potentially high level of explorative – and even playful – activities. These activities might include hacking, tinkering, or tearing things apart for the sake of exploring. The majority of activities in makerspaces are not driven by finished

products (as is the case with Instructables.com), but they are rather driven by interests in the process of exploration. This was evident in the post regarding the hydroponics project, in which the described that the purpose was to experiment and have fun. This suggests that makerspaces social media sites are characterized by different types of reach, transparency, and discourse, which potentially form a fruitful strategy to foster increased access and participation in Open Design. In addition, this also helps refine what it means to do Open Design. More concretely, Open Design in makerspaces has elusive boundaries, meaning that it is continuously negotiated by people who participate in the culture of making, among others. In addition, Open Design in makerspaces rarely functions as a linear process in which people go through design, development, production, and distribution stages (Green, D. P., Fuchsberger, V., Kirk, D., Taylor, N., Chatting, D., Meissner, J. L., Murer, M., Tscheligi, M., Lindtner, S., & Bjorn, P., 2017). Instead, Open Design productions seem to happen in much more spontaneous and ramified ways (some projects are left out and others are resumed after one year).

Finally, we found that the connection between social media and makerspaces transforms opportunities for establishing the participation of multiple people at the intersection of the offline and online worlds (Bennett & Segerberg, 2012; Crivellaro et al., 2014; Menendez-Blanco et al., 2017; Mosconi et al., 2017). Concretely, social media affordances, such as tagging, liking, and creating events open up opportunities for alternative participation that are not available in the physical makerspace. Interestingly, makerspaces' use of social media share similarities and differences with other online communities. On the one hand, makerspaces' social media sites facilitate the coordination of relevant activities, in a similar way to online communities (Goodman & Rosner, 2011). This can be illustrated by the shared calendar fixed at the top of the Facebook site as in Makerspace C. On the other hand, makerspaces' social media sites are much less structured than other online communities (Instructables.com or GitHub) and still produce the identity of specific makerspaces. Social media sites' chronological structure of posts (they are structured in terms of dividing people and posts and organized according to temporal parameters) has disadvantages and advantages in the portrayal of a welcoming makerspace. Compared to online communities, the advantages are that the lack of classification schemes in organizing information means that the structure does not constrain the users, who find that existing categories do not fit how they would describe their own activities (Khanapour et al., 2017). The disadvantages of the chronological structure relate to the problem of navigating resources over time, as illustrated by the superusers who answered similar questions multiple times. However, having to continuously answer similar questions also ensures frequent interaction on the social media site, which represents the makerspace as a living entity that quickly responds to people on individual basis. This suggests that a welcoming makerspace might also promote movement, keeping activities, knowledge, and projects alive, and facilitating a continuous public sharing of knowledge.

6. IMPLICATIONS

Above we discuss the theoretical implications of the three characteristics for makerspaces' social media presence: Reach, transparency, and discourse. This section elaborates on these implications in operational terms. While we identified the characteristics based upon existing interaction on social media, these characteristics can also serve as an operational tool that guides decisions on what and how to present makerspaces on social media. Makerspaces take many different forms and serve different purposes and institutions. Makerspaces can be based within universities, grown from grassroots communities, created as cooperate garages in industrial settings, or as emerge as part of social clubs (Lindtner & Li, 2012; Lundbjerg et al., 2017; Toombs, 2017). Furthermore, each space is created with specific types of interests, which shape the kind of activities and events taken place at the space. Therefore, social media presence is important for makerspaces to display their identity and support on-the-ground activities – and as we have shown this is done in different ways. Whether a makerspace's social media presence is organized through Facebook or different online platforms, it is relevant to consider how to align the social media presence with the aims and directions of the makerspace. If makerspaces wish to do so, our conceptualization of reach, transparency, and discourse can be used as an analytical lens through which participants, organizers, or managers of makerspaces can approach their social media presence systematically.

To this purpose, we have created an initial set of questions that can serve as a guidance for makerspaces that are interested in reflecting on their social media representations. In this way, makerspaces can potentially work towards more inclusive models for participation in open design. Table 2 below contains a sample of these questions; a larger set of questions written on cards that can be printed is provided as supplemental material to the paper in the digital library. These questions are not meant to provide the ultimate guide on how to design a makerspace social media site; instead, they provide guidance on issues related to reach, transparency, and discourse that can help reflect on how social media sites are designed and updated. These questions can be used to reflect on the proposed characteristics with respect to an individual makerspace, which include decisions on

TABLE 2. Sample Questions for Designing Makerspaces' Social Media Sites

Reach	Does the makerspace focus on global agendas (e.g. sustainability, education)? Is the makerspace focused on learning about new technologies without a foreseeable application (e.g. Arduino, environmental sensors)?
Transparency	What are the institutional arrangements in your makerspace (e.g. how can people use the machines)? Does the makerspace provide information about the space, and the requirements to join? How open is the makerspace to newcomers, and how does the makerspace make that openness visible?
Discourse	How important is to display a reliable and timely representation of what happens at makerspace? How does the social media site represent the continuity of an activity over time?

the makerspace's social media presence. In addition, the supplemental material includes empty cards that can serve as inspiration for additional questions or characteristics. For example, 'Visual content' could be added as an additional characteristic. Although out of the scope of this paper, our data suggest that pictures can also be relevant in representing the makerspace, potentially influencing how openness is displayed (e.g. Who is represented on the pictures? What activities are represented in those pictures? How are these portrayed?).

7. CONCLUSION

Open Design is based on providing access to knowledge, technologies, and artefacts by utilizing open-source software and hardware as a method of allowing participation in design activities. Multiple collaborative platforms such as Instructables.com or YouTube provide venues for publishing Open Design projects, as well as instructions for how to go about building and constructing these finished projects. However, as prior research demonstrates, following such manuals is not a simple task (Wakkary et al., 2015). Simply placing instructions online does not increase access to the knowledge, technologies, and artefacts required for participating in Open Design (ibid). Furthermore, there is a large gap between 'replicating an existing project' and 'fully engaging with Open Design activities', referring to the ability to alter existing projects, and re-mixing materials and technologies in novel ways (Buechley, Eisenberg, Catchen, & Crockett, 2008). It is a real challenge to find ways to encourage and support people to participate in Open Design.

Makerspaces have the potential to get people involved with Open Design activities. Thus, a potential strategy for increasing participation in Open Design is to facilitate access to makerspaces. However, as prior research elaborates, gaining access to makerspaces is not simply about entering the door – there are multiple exclusive mechanisms, such as language (Lundbjerg et al., 2017) and gender (Fox et al., 2015), which complicates potential participation. We have explored a different type of 'door' to the makerspace: Namely, the makerspaces' digital presence on social media. Social media are relevant for the internal coordination and interaction *within* makerspaces (Davies, 2017; Goodman & Rosner, 2011; Khanapour et al., 2017), while produces the 'front door' which we need to explore from *outside* of the makerspace.

In this paper we demonstrate how makerspaces' social media presence shapes potential access to Open Design activities. Social media representations are diverse and characterized by the ways in which they display reach, transparency, and discourse. Unique social media representations demonstrate the nature of legitimized participation in specific makerspaces, shaping potential access to Open Design activities. If we are to encourage increased participation in Open Design activities, it is important to consider that 'one-size does not fit all'. By exploring different makerspaces within close proximity, we found that multiple joint activities and relationships existed across the spaces. These relationships were also demonstrated through individuals being part of several makerspaces or by joining the same events, such as the Copenhagen Makers

Faire. By having distinct social media profiles, the Copenhagen community can reach beyond one single type of 'maker' and instead embrace the diversity and different interests across makers located in Copenhagen. Each unique profile attracts specific types of interests, and the knowledge about activities across spaces produces a strength in the larger community. It is necessary to find ways to increase participation in Open Design and represent makerspaces as places for democratic forms of participation in innovation. Our work highlights various social media characteristics that foster different forms of participation and potential access to Open Design activities. We hope that others will join us in the continous effort of inclusive participation for Open Design – by future research as well as by joining us in developing the set of questions (and ss) relevant for makerspaces' social media presence in the future.

NOTES

Acknowledgments. We would like to thank the people at the different makerspaces with whom we have interacted with over the last years of our research. They have been amazing in lending us their time and availability. We would also like to acknowledge the insightful feedback and discussions with Stina Mathiassen, Karim Jabbar and Nelson Tenorio, who helped shaping earlier versions of this manuscript.

Funding. Thanks to the Department of Computer Science (DIKU) of the University of Copenhagen for funding important activities reported in this paper, as well as to the Fulbright association for funding the research project: *Makerspace Methodologies: Diversity in Computer Science through Craft, Design & Technology.*

Supplementary Data. Supplemental data for this article can be accessed here.

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