The gender-based digital divide in maker culture: features, challenges and possible solutions

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ABSTRACT

Despite advances made in the last five decades, women remain underrepresented in science, technology, engineering and mathematics (STEM) degrees and occupations. This gender gap is also evident in the number of women in modern communities of technophiles called Maker culture and the common Maker co-working spaces such as fablabs. Since fablabs are considered as inclusive and collaborative workspaces, we aim to research the current level of women's inclusion in the Maker culture, the possible root causes of women's underrepresentation, and we examine the means to tackle this issue at a micro-level. Our findings from an ethnographic study that started in a fablab community located in the south of France and expanded through semi-structured interviews with members of the Maker culture offer interesting insights on the question of gender inequalities.

KEYWORDS: Gender, Equality, Women, STEM, Maker, Fablab

JEL CODES: O3, L3, J16, I24, Q55

At the threshold of the twenty-first century, with the strong impetus derived from advancements in digital technologies, our societies and economies entered what is referred to as the Fourth Industrial Revolution (Schwab, 2016). This revolution is marked by digitalization and servitization processes that are blurring the line between the physical and digital worlds, disrupting various

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industries and economies, and leading to new opportunities in innovation and entrepreneurship (Dubey *et al.*, 2017; Jabbour *et al.*, 2018; Opazo-Basaez *et al.*, 2017; Sánchez-Montesinos *et al.*, 2018). To fully harness the potential of this ongoing revolution, STEM (Science, Technology, Engineering and Mathematics) fields are marked out as key strands for research and industry, enhancers of a state's competitiveness and productivity through scientific and technological innovation or the introduction of new technologies (CE, 2008; Langdon *et al.*, 2011; Mavriplis *et al.*, 2010).

In such a situation, diversification of the workforce in STEM is expected, with the inclusion of minorities to maximize innovation outputs, creativity and competitiveness and, thus, generate creative and innovative solutions that are likely to be accepted by a larger base of users (Galia, Zenou, 2013; Hill *et al.*, 2010; Torchia *et al.*, 2011). Women's inclusion in teams has been shown to positively influence innovation outcomes since gender differences have a positive effect on innovation behavior and may lead to more effective and creative solutions (Pons *et al.*, 2016; Ruiz-Jiménez, Fuentes-Fuentes, 2016). This may be a particularly important subject in the context of coworking spaces to facilitate a climate of open working, develop closer interpersonal relations, or offer more varied perspectives and ideas on specific problems (Milliken, Martins, 1996; Nielsen, Huse, 2010).

Gender equality and the empowerment of women are topics that originated in the societal turmoil of the second part of the twentieth century (Schiebinger, 2000). Even though women managed to regain their social status in developed societies, new challenges for gender equality are seen in access to digital technologies (Cooper, 2006). Women in STEM seem to be disadvantaged when it comes to career choices and access to new digital technologies, so it seems extremely relevant to study the challenges for gender equality in such a particular context (UN Women, 2018; UNESCO, 2018).

Our study is based on the exploration of the digital divide in contemporary phenomena linked to the new industrial revolution and digital technologies—Maker culture (Anderson, 2012; Fabbri, Charue-Duboc, 2016; Fabbri *et al.*, 2016). Maker culture is a global movement based on the philosophy of a group of individuals with the ability to create or '*make*' things using an extensive set of Information and Communication Technologies (ICTs) and Exploration and Fabrication Technologies (EFTs) (Blikstein *et al.*, 2017). The umbrella term of Maker culture comprises different initiatives of coworking spaces such as fablabs, makerspaces, hackerspaces, and innovation laboratories (Capdevila, 2015; Fabbri *et al.*, 2016; Maric *et al.*, 2016). Fablabs have experienced an expansive growth in recent years in France, partly due to the fact that the French government supports and develops networks

of co-working spaces through deliberate policies and public funds (French Ministry of Culture and Communication, 2016).

However, even though Maker culture and related initiatives should provide equal gender inclusion, there are few studies that deal with gender issues in Maker communities (Bean *et al.*, 2015; Faulkner, 2014; Papavlasopoulou *et al.*, 2016). Therefore, in response to the lack of existing literature, the objective of the present study is to provide answers on the causes of women's underrepresentation in the Maker community within our geographical proximity and demonstrate how fablabs can be effectively used to alleviate gender discrepancies.

Our paper is structured as follows: Section 2 provides the theoretical background on Maker culture, gender imbalance in STEM and explains in detail the research gap in our study. Section 3 describes our research design and introduces the methodology. Section 4 presents the findings of our study, covering the root causes that are hampering women's inclusion in Maker culture, the attitude of female Makers, and presents some of the initiatives of the local fablab community to tackle the gender issue. Section 5 discusses the results and limitations of our study and highlights future perspectives. It also discusses several global initiatives and projects that help to understand the trends on gender issues in the Maker community. Section 6 concludes our paper.

Theoretical background

Maker Culture and the Fablabs

Maker culture is a contemporary social phenomenon directly connected to digital fabrication technologies. The term *makers* refers to the innovators, artists, engineers and tinkerers in this technology-driven movement (Bean *et al.*, 2015; Hein, 2012). Maker culture is based on the philosophy in which individuals or groups of individuals create artefacts that are recreated and assembled using software and/or different technologies (Anderson, 2012). A similar philosophy can be encountered in the early developments of home computing (Kietzmann *et al.*, 2015).

Maker culture aims to empower people of all ages to create, innovate, tinker and transform their ideas and solutions into reality. This initiative turned into a global movement with numerous co-working spaces such as makerspaces, hackerspaces and fablabs around the world (Anderson, 2012; De Vaujany, 2016; Lô, 2017). These tend to be non-profit organizations that operate primarily on the basis of a membership fee. Members thus gain access to integrative and collaborative environments where they can meet, create, and

learn subjects related to computing, digital arts, technology, science, machining and other relevant areas (Capdevila, 2015; Fabbri, Charue-Duboc, 2016; Fabbri *et al.*, 2016; Lewis, 2015). Moreover, such spaces are equipped with all the necessary tools to realize projects and obtain up-to-date technology skills that would otherwise be difficult to obtain (Blikstein *et al.*, 2017).

Fablabs, as one of the initiatives within Maker culture, are gaining momentum in Europe with a rising degree of acceptance in France. Associated through the Fab Foundation[2], a global network of fablabs, this movement spans more than 80 countries and 1,000 labs worldwide. France is the leading country in Europe with a network of more than 150 labs[3]. Fablabs can be best understood as a small-scale workshop with an array of computer-controlled tools related to ICTs and EFTs (Blikstein *et al.*, 2017; Gershenfeld, 2005, 2012). EFTs constitute a range of toolkits and machines for the pursuit of learning through making and construction, which could be particularly relevant for STEM educational purposes (Blikstein, 2013; Blikstein *et al.*, 2017). Therefore, the co-working spaces can serve not only to democratize technologies previously reserved for heavy industries, but also to foster a transformation of classic school systems and provide pathways to achieve social and environmental sustainability goals (Birtchnell *et al.*, 2017; Maric *et al.*, 2016).

Gender Discrepancy in STEM

The significance of STEM fields for the national economy in terms of innovation and entrepreneurship is widely regarded as critical, even if some variations exist on the disciplines that are encompassed by the term STEM (Langdon *et al.*, 2011; MIT, 1999). Despite the tremendous progress made on gender equality in education and the workforce during the second part of the twentieth century, it seems that progress is uneven in the world of technology and engineering disciplines and results in an overwhelmingly male-dominated environment (Diekman *et al.*, 2015; Hill *et al.*, 2010; Schiebinger, 2000, 2008).

One of the most obvious reasons could be related to general gender stereotyping. Women's STEM career choices are hampered by gender stereotyping from an early age, leading them to seek career paths in fields which tend to have a social contribution (Ruiz-Jiménez & Fuentes-Fuentes, 2016). Conventional male and female roles and socio-cultural influences pair men, rather than women, with STEM fields (Carr *et al.*, 2003; Hewlett, 2007;

2. http://fabfoundation.org/
3. https://www.fablabs.io/labs

Patterson *et al.*, 2012). These socio-cultural influences originate in early childhood, where girls develop beliefs about appropriate occupations to pursue based on gender and consequently lack self-esteem in STEM subjects (Hartung *et al.*, 2005; Pajares, 2005).

However, previous studies proved that there is no biological reasoning for gender stereotyping and that the socio-cultural influences were introduced to subordinate women throughout history (Ceci *et al.*, 2009; Schiebinger, 2000, 2008; Schiebinger, Schraudner, 2011). Modern trends in digital technologies and co-working spaces present a challenging environment to investigate gender equality through the development of a research framework adapted to these particular sectors.

Research Gap and Study Framework

Maker culture implies new paradigms in forms of collaborative working spaces that often foster and nurture conviviality and a sharing mentality. Even though gender neutrality is introduced through the Fab Charter[4], a document all fablabs endorse, we noted persistent gender inequalities in the local Maker community in Montpellier.

A literature review on the topic showed an evident lack of studies on Maker culture and gender-related issues (Papavlasopoulou *et al.*, 2016). The reasons could be attributed to the novelty of Maker culture in contemporary academic discourse. However, few studies address the issue in more detail and provide valuable insights. For instance, Lewis (2015) investigated the reasons surrounding the gender imbalance in UK-based makerspaces and hackspaces. Significantly, this study highlighted several distinctive barriers for women's inclusion in co-working spaces and noted that the reasons for gender imbalance in Maker communities can be traced to the gender imbalance found within STEM fields.

Hence, Bean *et al.*'s (2015) study showcased the motivations, perceptions, needs and goals of a group of female Makers coming from a US-based makerspace and indicated that there are no evident gender barriers for female inclusion in makerspace activities. Faulkner (2014) and Faulkner and McClard (2014) highlighted that female Makers generally struggle to find time to join co-working spaces due to family and domestic obligations.

The significance of these studies is that they help us to better position the question of women's underrepresentation within Maker culture and develop our framework to investigate possible causes of gender imbalance and digital divide in Maker culture (Cooper, 2006).

4. http://fab.cba.mit.edu/about/charter/

Research methodology

Research Context

Our study started with the observations of the local fablab Maker community in Montpellier. The observations were later expanded through interviews with representative fablab members and other Makers in France. The choice of the local fablab in Montpellier is due to its geographical proximity and the dynamic Maker community that is active at a regional, national and international level—for example, the engagement in the *French Fablabs Network* (*Réseau Français des FabLabs*[5]).

The fablab was founded in 2013 and is adjacent to the local business incubator. The community is diverse, with a range of individuals from different profiles, educational levels, age and interests. The fablab's facility is divided into four principal sections—a mechanical, electronics and rapid prototyping section, and a common workshop/presentation area. The sections are equipped with a range of ICTs and EFTs—such as milling machines, computer numeric control machines, and a computer-controlled laser cutter in the mechanical section; personal computers, several 3D printers and a 3D scanner in the rapid prototyping section; and a range of various other tools and equipment in the electronics section.

It is important to highlight that the topic of this paper, women's underrepresentation and the digital divide based on gender in Maker culture, was encountered during much more extensive research investigating digital fabrication technologies (Rayna, Striukova, 2016).

Research Design and Data Collection

Our ethnographic study was realized through observations, interviews and analysis of email communication. Ethnographic research comes from the discipline of social and cultural anthropology where an ethnographer is required to spend a significant amount of time in the field (Hammersley, 2006; Myers, 1997). In our case, direct and indirect participant observations were paired with semi-structured interviews and the community's online email communication.

Annual membership (September 2015 to September 2016) allowed us access to the facility and easier involvement and integration in the local Maker community. The observation data were enriched by semi-structured interviews conducted with a selective list of research participants active in Maker culture (Miles, Huberman, 1994; Wacheux, 1996). Their profile statuses vary from

5. http://www.fablab.fr/

simple fablab members, members of the fablab administration board, or Makers external to the fablab community. Contacts with Makers outside the fablab were based on *word-of-mouth* recommendations.

In total, 13 interviews were conducted—six interviews with Makers from the fablab in Montpellier and seven interviews with Makers outside Montpellier. Even though we tried to integrate diverse perspectives coming equally from both genders, our study obtained inputs from only four female research participants. The interviews were recorded and transcribed (more information about the sample group can be seen in Table 1). The interview length was between 16 and 47 minutes (with an average of 29 minutes), resulting in 78 pages of transcribed data[6].

Annual membership allowed us to participate in fablab activities as full members of the local Maker community. This resulted in more than 70 hours of registered observations through workshops and projects available at the fablab and more than 100 hours when adding indirect observations such as the development of personal projects within the fablab facility, follow-ups on fablab administration-board activities, projects and presentations at various external events, or festivities.

Observations and interviews were clustered with the additional findings via email communication analysis. Email communications were collected during the same period of our research and led to 204 emails extracted with regard to their content.

Data Analysis

Analysis of our collected data was based on the Fallery and Rodhain (2007) approach, where four main types of qualitative data analysis, such as lexical, linguistic, cognitive or thematic analysis, are defined. Thematic analysis is relevant for our study as it enables us to take into account the information gathered during our research and elaborate different themes and categories for the purposes of the coding process. The unit of analysis in our case was a piece of a sentence or a phrase (Weber, 1990).

Our observations within fablab led us to effectively note down the gender imbalance (Figure 1). Interview questions investigated an individual's perception regarding women's underrepresentation in Maker culture, the root causes of gender imbalance, and solutions to overcome this issue. Interview analysis led us to pin down the themes, such as an acknowledgment of the gender imbalance by male Makers, female attitudes towards the same issue, and possible measures at the co-working space level to tackle gender

6. Average 3877 words per interview; font style *Arial*, size *10*, single line spacing.

inequality. Moreover, these themes allowed us to discuss the root causes of women's underrepresentation in Maker culture, such as general gender stereotyping, male-dominated environments, and a lack of female role models.

The results of the email communication analysis indicate that female Makers initiated approximately 27% of online communication. From the overall number of email threads, 34% are shown to have at least one message generated by a female Maker but almost 75% of these messages originated in the same source. Moreover, the majority of the threads show that women have a tendency to get involved and discuss topics related to organizational matters rather than the technology or engineering fields.

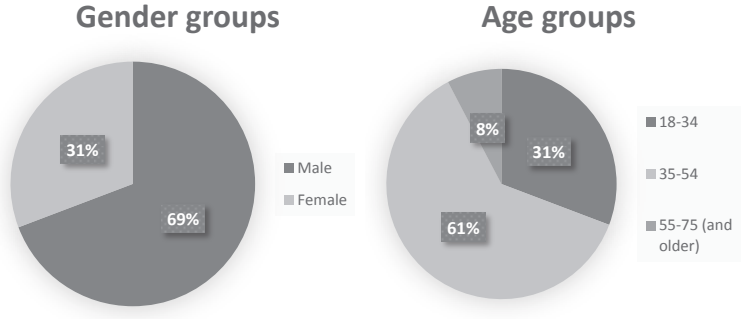
***Table 1* – Interview's sample group data—Maker is likely to be a male person aging between 35 and 54 years old**

Interview code	Age groups	Gender (F-female/M-male)	Pages	Duration (minutes)
INT1	18-34	F	5	26
INT2	35-54	M	4	28
INT3	35-54	M	8	49
INT4	35-54	F	7	0*
INT5	35-54	M	5	29
INT6	35-54	M	11	47
INT7	18-34	M	6	31
INT8	55-75	M	6	40
INT9	35-54	M	5	24
INT10	18-34	F	4	18
INT11	35-54	F	8	37
INT12	18-34	M	6	32
INT13	35-54	M	3	16
Totally transcribed pages and interviews duration:			**78**	**377**
Average transcribed pages and interview duration:			**6**	**29**

* Demanded to reply exclusively by e-mail.

** Slightly shaded fields—Makers from Montpellier; shaded fields—Makers outside of Montpellier.

***Figure 1* – Sample group data by: a) gender, b) age**



Findings

Fablabs are inclusive co-working spaces for people from various cultural and professional backgrounds, age groups or genders. Based on the principles of gender neutrality, fablabs should nurture equal gender representation, indicating that Maker culture should be a gender-neutral global movement. However, our research findings indicate the opposite and the root causes can be linked to several thematic areas.

Firstly, analysis of our collected data led us to elaborate the current gender state-of-the-art in the Maker community. Secondly, this led us to investigate the background of women's underrepresentation in Maker culture, identifying topics such as gender stereotyping, male dominance within co-working spaces, the lack of female role models, and female attitudes towards gender imbalance. Lastly, the results of our study noted a set of measures or initiatives at the fablab level that could be generalized at the global Maker community level.

Gender State-Of-The-Art in the Local Maker Community

The fablab membership base grew from approximately 380 to 450[7] members during the period of our study. Interest in becoming a member of the co-working space varies in terms of needs and expectations, but the principle motivations are linked to the digital technologies available in the fablab facility. The approximation of the gender ratio among the members, especially among the lead members or the members of the fablab administration board, is in favour of men (see Figure 1).

As noted during the period of our observations, men constitute the main membership base and play leading roles in the community. Through the fablab historical overview, gender equality was not found to be a central topic in the development strategy, nor did women play a major role in the association's executive positions. Some exceptions could be noted in the responsibilities regarding communication, social media and website content management or in the development of certain workshops for the general public. However, it seems that women are hampered in accessing the association's major administrative positions.

Moreover, when speaking about the organization of seminars and workshops, the central point for public interaction with the technologies available in the fablab, the majority of the workshops are held or organized by male

7. *Annual report* 2015/2016.

members. Female members have indeed taken leading roles in the organization of workshops dedicated to children, for instance, but, with this exception, women seem, intentionally or not, to have a marginal impact on fablab organizational matters.

Causes of Women's Underrepresentation in Maker Culture

Hence, our findings suggest that an interplay of socio-cultural barriers could explain women's underrepresentation in the Maker community, such as gender stereotypes, male dominance within the co-working space, and a lack of female role models.

Male members are, interestingly, aware of female underrepresentation in the fablab. Even though they acknowledge the existence of the gender issue, they do not prioritize it as a major topic in the fablab milieu. Men rather assign it to a larger socio-cultural context related to modern society: "*The number of women is still low, but it is higher now when I think about it. Even for such a technical place, for the subjects related to technology and geeks, there are women [present]! Less than men, of course, but there are (…)*" (INT13, p. 2).

As such, existing gender stereotypes could probably be the most obvious reason for women's underrepresentation within Maker culture. A number of factors influence young peoples' perception concerning future professions and career choices, where gender stereotyping defines positions that are well suited to women or men. Girls, when they reach adolescence, seem to drift away from STEM fields within educational systems and are less likely to pursue STEM-related careers, leaving these as more masculine areas. This mentality is then reflected in the general gender approach towards new digital technologies and Maker culture, where men, due to their larger presence in STEM, are likely to be the ones who experiment with the fablab's ICTs or EFTs.

As a fablab member made clear, the space is not strictly reserved for men, but the number of women remains low: "*Despite everything, it [number of women] remains weak, but it changes gradually. At first, it was a different thing to come and to integrate in [the community]. We had one or two [female members] at the start. And now, it's [the number] growing gradually, I think like around 30% (…)*" (INT3, p. 8).

Due to the gender divide rooted in gender stereotypes, we have clarified that men are more likely to dominate in STEM disciplines. This leads us to define the second possible barrier hampering women's inclusion in Maker communities—male-dominated environments. Our findings indicate that, due to the evident male dominance in numbers (70-30%), co-working spaces

could be an intimidating environment for any new female member where full integration in the community requires a certain amount of engagement and dedication to overcome the initial acceptance obstacles. These obstacles could be the use of techno-language, as explained further in the text and related to the technologies that demand sound technical and engineering expertise, or an acquaintance with the internal dynamics of the community.

However, on the other hand, men's attitude to the fablab as a male-dominated area is rather linked to their perception of the fablab as a space to disengage from daily routines and domestic obligations. As is noted on one occasion, and in a rather informal conversation between a couple of fablab members, fablab is seen as a sort of escape route from everyday domestic/family obligations (Personal Observation, November 2015). Fablab, in the male perspective, is seen as a sort of get-away 'leisure destination' to step aside from daily routines, meaning that the *laissez-faire* attitude leads to an acceptance of the current gender situation without the need to question its causes.

Moreover, makerspaces and fablabs are relatively recent constructs whose similarities can be linked to the early development of home computing, when fellow techno-peers would meet in garage-like workshops to experiment with technologies and develop new solutions. Such workshops would consequently develop certain sub-culture characteristics with a use of techno-language that would seem strange or unappealing to outsiders. This might make it extremely difficult to integrate into the community if there is a lack of mastering group values: "*The Makers universe is clearly more masculine than feminine. You have to be a bit of a geek deep inside, and I believe that men have more of that spirit of engineering anchored in their blood (…)*" (INT4, p. 5). Therefore, Maker culture is not only a male-dominated environment but could have certain sub-culture characteristics with a strong techno-language where a level of self-confidence is required to step into the game.

Finally, due to male dominance and the sub-culture characteristics of the Maker community, we speculate that a lack of female role models also influences the gender imbalance. Female role models within Maker culture are not thoroughly promoted, nor do they receive a sufficient level of media attention to awaken the interest of girls and young women in STEM education or in career paths. Media publicity devoted to female Makers could positively affect the perspectives of the female audience and possibly increase the number of girls in Maker culture: "*(…) you have to familiarize them [women about the fablab], so it's [the information] diffused. And when we have 3-4 [female members] who are regularly here, well, when new [female members] arrive they get along much easier! It's less scary than when they arrive and there are ten guys! [laughter]*" (INT3, p. 8).

Female Attitude towards Gender Issues in Maker Culture

Interestingly, though generally few female participants took part in our research, they acknowledge the existence of the gender imbalance within a local fablab and Maker culture. They also link the issue with a general societal context: "*Yes, indeed, there are more men, because it is a question of technologies connected to robotics, automation, mechanics and engineering which are much more masculine professions*" (INT10, pp. 3-4).

Surprisingly, they highlight the questioning of the gender imbalance within Maker culture as a *clichéd* question: "*(…) there are also girls in the fablab [laughter]... No, there are many! And I think it's a cliché to say that this area [Maker culture] is rather masculine, because there's no reason to have more men than women in these kinds of places*" (INT10, pp. 3-4).

Following the claim that it is a *cliched* question, female perspective links women's underrepresentation in the Maker culture with a generally lower female interest in technologies. As they highlight, there are no obvious barriers to women's participation in the Maker community: "*There is a need to spread the news (…) when I came in person [to the fablab] I saw active women there. (…) However, they are not numerous, so what! It's not a big deal!*" (INT11, p. 7).

In fact, as one interviewee indicated, she is reluctant about the idea of specially dedicated workshops or special treatment within Maker culture solely because of affiliation to one gender group. In her perspective, Makers should be treated on an equal basis by adopting a gender-neutral attitude: "*(…) I saw that there is a workshop for women. But no, I do not define myself as a woman! (…) I define myself as a person!*" (INT11, p. 7).

Finally, as is evident from the female attitude towards gender discrepancies in Maker culture, there are no reported purposeful gender discriminations within the co-working spaces. These insights provide a narrative to understand the factors surrounding the gender issue and possibly provide solutions to tackle gender inequalities.

Fablab Gender-Related Initiatives

As elaborated in previous sections, both male and female participants in our research acknowledge that Maker culture could be seen as a dominantly masculine sphere. Thus, the local Maker community actually introduced a few voluntary initiatives to improve the inclusion of women and other marginal groups.

The first initiative was devoted to school-age children where the fablab members, aware of gender stereotyping dating back to an early age, consider

that the problem should be tackled during school years. They indicate: "*(…) boys grow up being told about and playing with tools, wrenches and so on. And women [girls] don't grow up like this. So I would say it is more the collateral impact on how people grow up than the actual interest they have*" (INT8, p. 6).

In such a context, education is a much more effective tool for achieving gender equality. However, not considering the topic solely as a responsibility of educational systems and schooling, fablab provided a number of workshops for school-age children to bring more girls and boys into the fablab environment and offer them hands-on activities with the tools in the facility. For this particular purpose a workshop was held in December 2015 with the aim of boosting children's creativity and introducing them to digital technologies, particularly 3D printing and electronics skills. The workshop was designed for a smaller group of school-age children of both genders, led by two female coordinators, who were in charge of the workshop organization. A few other male fablab members acted as a support on technical matters. The idea was to expose children to EFTs and organize a fun workshop on a particular theme: "*(…) I wanted to introduce them basically to electronics and to 3D printing. So we needed to make it [the workshop] really short and gather the kids around it (…)*" (INT1, p. 2).

The workshop also offered parents the possibility to get involved with their children, as a form of parent-child activity. Due to the fact that the workshop information was distributed through the fablab internal mailing lists, the final group of participants was limited to three children (two boys and one girl) participating with their parents. There were numerous effects of the workshop—not only were children introduced to the fablab environment along with their parents, showing that a fablab was an interactive playground, but the workshop was equally aimed at the inclusion of children of both genders.

The second initiative introduced by the fablab and noted during the course of our study is the specific opening hours devoted to women. The practice of experimenting with opening hours was shown to be successful in the spirit of entrepreneurship and Small and Medium Enterprises (SMEs) by dedicating the fablab facility and technologies to entrepreneurs who are willing to invest more time in the research and development of their projects. A similar practice was introduced to increase and attract female counterparts within the Maker community.

Moreover, the fablab offered special workshops, announced in advance, to facilitate women's inclusion into the Maker community and to introduce them to digital technologies: "*(…) we have workshops dedicated to laser cutting and which are rather oriented towards women. Based on our [fablab] statute, we*

try to integrate women into project ideas, etc." (INT3, p. 8). The workshops were intended to establish a sense of community spirit through experimentation with fablab artefacts and digital fabrication tools in a more gender-safe manner. As a result, women do not consider the fablab to be a male-dominated workspace but a way of gaining experience and experimenting with digital technologies with their fellow female peers. The aim is to provide a safe, non-intimidating environment and a supportive peer-community that encourages women to learn, make and craft.

Unfortunately, due to its status as an association, fablab does not explicitly manage gender data, nor assess if there is a deliberate increase in female memberships because of these workshops. Moreover, during our study we did not report repeated women-oriented workshops. Furthermore, it is important to indicate that these workshops took place before our study started. This makes it hard to generalize our findings on this subject as a best-case practice. However, from the results obtained in the present investigation, we presume that the reasons for a lack of workshop repetition could be the fact that fablab members organize workshops on a voluntary basis and depending on public interest (pre-registration for an event is required). If there are only a small number of interested members (females in this case), the workshop is cancelled.

Discussion and contributions

Discussion of Results

In our study we have focused on the question of women's underrepresentation in Maker culture, which, in our opinion, represents a contemporary challenge to achieve gender equality in the twenty-first century (Cooper, 2006). Our research approach was based on previous studies which addressed gender-related topics in Maker culture, such as Bean *et al.*'s (2015) exploration of women's engagement in the makerspace, Lewis's (2015) study on barriers to female inclusion in the makerspaces and hackerspaces, or Faulkner (2014) and Faulkner and McClard's (2014) general studies on women in Maker culture.

The findings of our research indicate gender imbalance in the local Maker community in France (approx. 70-30% in favour of men). Observations and interviews performed in the fablab in Montpellier enabled us to discuss the reasons and identify the possible obstacles that hamper the greater inclusion of women in Maker culture. Our findings, interestingly, report measures coming from the local Maker community aimed at tackling gender discrepancies.

The findings also demonstrate that women's underrepresentation in Maker culture can be linked to traditional gender stereotyping and socio-cultural influences that date back to the early years of education, and which affect women's career choices (Schiebinger, 2000, 2008; Schiebinger, Schraudner, 2011). Our findings highlight that, due to the lower involvement of women in STEM fields, co-working spaces result in male-dominated environments. This fact may further hamper desirability and influence women's decisions to join co-working spaces. Therefore, women may develop less of an interest in novel digital technologies or EFTs and this could result in a digital divide based on gender (Cooper, 2006). This may cause a loss of talent and diversity of ideas, since the cohesion of gender perspectives is positively linked to innovation behaviors and innovation outputs, which may be particularly relevant for the Maker culture context and co-working spaces (Hill *et al.*, 2010; Pons *et al.*, 2016; Torchia *et al.*, 2011).

Interestingly, our female respondents confirmed that women are not as equally present in Maker culture as men. However, as one of our research participants indicated, research on the gender divide in Maker culture could be seen as a sort of *clichéd* question since, in her view, women are not in any way excluded from the Maker community. Maker culture should be, by its very definition, considered as a gender-neutral community of people with equal rights to access technology and knowledge. Thus, female Makers link the lower numbers of women in the Maker culture with the lack of general interest by the female population towards new technologies and STEM disciplines. Therefore, bearing in mind the gender-neutrality of Maker culture, researching gender-related issues and implying the need for special measures for one gender may be seen as a sensitive topic and result in polarizing effects for the Maker population. Moreover, it remains difficult to determine whether female perception of the question about women's underrepresentation in the Maker culture as a *clichéd* question is a single case of the occurrence of what is known as *Queen Bee* syndrome (Ellemers *et al.*, 2004), or if it is an attitude commonly shared among a larger base of female Makers.

Nonetheless, grounds for optimism in Maker culture initiatives can be seen in the development of workshops for children. The aim of the Maker community initiative of a workshop targeting school-age children, for instance, was to boost children's interest in exploring the fablab environment and EFTs. Allowing children to discover fabrication tools and equipment was shown to boost their Do-It-Yourself and Do-It-With-Others attitudes, which might positively influence their interest in STEM disciplines (Blikstein *et al.*, 2017). Interactive workshops and the practical application

of theoretical lectures is an approach recently highlighted as highly desirable within the student population in France (UNICEF, 2017). So the fablab initiatives devoted to children could be used to contribute to official educational systems and to foster the transformation of traditional school models.

However, due to the fact that the fablab is an association where all members, including the administration board, function on a voluntary basis, all the initiatives discussed in our paper are not part of a more structured or institutional approach aimed at the inclusion of women or other marginal groups in the Maker community. They remain isolated cases of voluntary approaches and their outcomes are a debateable topic. Moreover, gender imbalance, as a topic in the context of the development of a local Maker community, remains overshadowed by other high priority challenges, such as ensuring funding sources and investments in new technologies. Finally, even though Maker culture and co-working spaces are gaining global momentum, their initiatives to tackle gender inequality can be a debatable subject due to their overall marginal and limiting social outcome.

Limitations and Future Perspectives

Our study has a number of limitations. First, a common limitation for most qualitative studies is the generalization of our key findings, which should be made with caution. The second limitation could be the geographical positioning of our study where we focused on the Maker community in Montpellier. Due to the differences in community cultures, findings from other co-working spaces in France or worldwide could be significantly different. Moreover, although we have made an effort to include as many female Makers in our study as possible, our sample group of women remained small. Development of our sample group was based on the *word-of-mouth* principle and through our interaction with the lead members of Maker culture in Montpellier and France.

As such, possible future research perspectives and enhancements could be described. For instance, to minimise any possible researcher bias on gender and location, a comparative study of co-working spaces in other locations in France and abroad could provide interesting insights to complement or enrich the debate of our study. Moreover, another possible future research path would be to focus exclusively on female Maker perspectives and establish a homogenous point of view on gender imbalance in Maker culture. Lastly, our findings could be further externalized through quantitative studies based on a wider sample group within the Maker community.

Global Trends

Our study indicates that the inclusion of women in the local Maker community is generally not seen as a key strategic point in its development strategy. This attitude in a global Maker culture context sparked female rebellion initiatives. These initiatives offer a more proactive approach towards gender-related issues in the Maker community.

Although there are some differences in the approach towards gender imbalance in the Maker community, they all stream towards the same goal. For instance, open tables and forums were organized to discuss the status of female Makers or to allow women to have easier access to new digital technologies (see for instance Fablab London[8] and Trójmiasto Solidarity Fablab[9]). Moreover, US-based Maker initiatives such as Double Union[10], Mothership Hacker Moms[11], Prototype[12] or Seattle Attic[13] are examples of co-working spaces established and run by women and with the aim of actively transforming the male-dominated image of Maker culture. These projects, among commonly encountered tools within the co-working spaces, offer activities such as sewing or child-oriented activities to promote the spirit of feminism and the sense of inclusion without sexual discrimination. MakerGirl[14], on the other hand, illustrates a project devoted to school-age girls with the aim of boosting their interest in topics related to STEM fields, innovation companies and digital technologies.

All of these initiatives are mostly bottom-up approaches targeting gender equality within Maker culture and definitely require more academic attention. However, we do not claim that Maker community initiatives can replace the importance of educational systems or official policies as more effective tools to ensure gender equality. Our study suggests that bottom-up Maker initiatives can provide alternative ways to achieve the same goal. In the short term, understanding how makerspaces, hackerspaces and fablabs can be used to alleviate the gender imbalance could lead to significant improvements in the status of women within Maker culture and the STEM workforce.

8. http://www.fablablondon.org/2016/08/wemake2016-women-in-makerspaces/
9. https://www.fondationorange.com/Solidarity-FabLabs-the-Maker-Woman-project
10. https://www.doubleunion.org/
11. https://mothership.hackermoms.org/
12. https://prototypepgh.com/
13. http://seattleattic.com/
14. http://makergirl.us/

Conclusion

Gender inequalities, gender imbalance and women's underrepresentation in certain scientific and research fields are subjects that are present on the development agendas of modern industrialized societies. STEM disciplines are widely regarded as critical to any national economy since they enhance innovation and entrepreneurship outputs, so investigating gender equality and the inclusion of women or other marginal groups in technology-related fields is highly desirable.

In our study, we focused on Maker culture, a contemporary community of technology enthusiasts who nurture a collaborative and sharing mentality. Our claim is that the gender issues in the Maker culture can be linked to general gender discrepancies encountered in the STEM fields. We thus conclude that the two are intertwined due to similarities in the fields of science, technology, engineering and mathematics. Based on the literature review, which confirmed the evident lack of gender-related studies in Maker culture, we explored the reasons for women's underrepresentation in the local Maker community.

Our comprehensive set of findings indicate that there is an obvious gender discrepancy at the level of the local Maker community, making it a male-dominated area. Moreover, reasons for such a state of affairs may be linked to general socio-cultural implications and gender stereotypes present from the early stages of education and resulting in women's lack of interest in STEM fields. This leads to a lower inclusion of women in STEM careers and consequently results in women's underrepresentation in Maker culture. Female status in Maker culture is even further hampered by a lack of female role models that could be publicly popularized to influence future generations of young female Makers. Interestingly, research participants of both genders acknowledge the existence of gender discrepancy and several initiatives have been introduced to tackle this issue at the local Maker community level. These are voluntary measures in the form of workshops exclusively for women or children to boost their interest in fablab activities.

Finally, the purpose of this article was to raise awareness about women's underrepresentation in Maker culture and discuss the possibilities to tackle this issue. We believe that our paper successfully draws on previous studies regarding gender-related issues and provides a solid background for future research perspectives. This could increase the level of academic interest in the topic of gender equality and Maker culture and, more importantly, lead to an intense debate from different angles and disciplines.

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