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The maker movement in Europe: empirical and practitioner insights into sustainability

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Abstract

In recent years, ICT has revolutionized content creation and communications. Today, everybody with Internet access can produce digital content composed of virtual 'bits' and make it instantly available across the globe. The same is now happening to manufacturing for all people with access to tools like 3D printers. This interchangeability of bits and atoms is being called the maker movement, which started as a community-based, socially-driven bottom-up movement but is today also impacting mainstream manufacturing through increased efficiencies, distributed local production and the circular economy. The maker movement thus has significant promise for increasing social, economic, environmental and technical sustainability, but is it currently living up to this potential? The European-funded *MAKE-IT* project has examined these postulates through in-depth qualitative and quantitative empirical research.

1 Introduction

In recent years, ICT has revolutionized content creation and communications. Today, everybody with Internet access can produce digital content composed of virtual 'bits' and make it instantly available across the globe. The same is now happening to manufacturing for all people with access to tools like 3D printers. They are able to design objects as virtual 'bits' which can be shared globally, and then fabricate these as physical things ('atoms') which manifest themselves locally, thereby making the interface between virtual and physical blur if not disappear altogether. This interchangeability of bits and atoms is being called the maker movement, which started as a community-based, socially-driven bottom-up movement, but today is also impacting mainstream manufacturing through increased efficiencies, distributed and local production and the circular economy. It is claimed the movement reflects cultural shifts towards 'pro-sumerism', supports local community and social development through new jobs and re-cycling, and provides sustainability benefits across the economic, social, environmental and technical spectrums.

The European-funded *MAKE-IT* project examines these postulates through in-depth qualitative and quantitative empirical research[1]. This paper presents some results from *MAKE- IT* derived from part of the project's methodological approach using three analytical pillars: 1) the governance and organization of makers; 2) their peer and collaborative behaviors; and 3) their value creation and impacts. The paper starts with a background on the maker movement referring to the literature, provides a note on methodology, and then analyses selected results. Finally, it provides some overarching conclusions and recommendations.

2 What is the maker movement?

The Maker movement is a rapidly expanding field with innumerable perspectives, interpretations and definitions. In the specific context of the *MAKE-IT* project, the definition of the Maker movement focuses on the overlap between four main fields of activity (Figure 1).

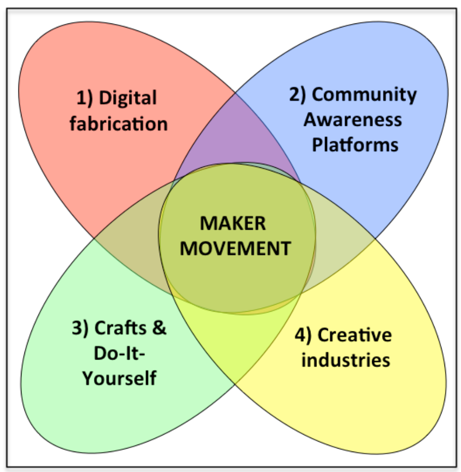


Figure 1: The four components of the maker movement

1. *Digital fabrication*: provides the technological base. Digital modeling and fabrication is a process that joins design with production through the use of 3D modeling software or computer-aided design (CAD) as well as additive and subtractive manufacturing processes. The initial focus on simple 3D printers has now progressed to an awareness that the real maker revolution comes when these are combined with laser cutters, precision mills, large and small format mills, as well as digital assemblers, re-assemblers and plotters. These use various combinations of feed-stocks in the form of pulverized, sintered or melted plastic, rubber, metal, glass, wood, ceramics, paper, etc., much of which is re-cycled, inexpensive and sourced locally. (Anderson 2012; Rifkin 2014) In this light, the new world of digital fabrication is indeed a cornerstone of the emerging so-called fourth industrial revolution. (WEF 2016; McAfee & Brynjolfsson 2017)

[1] MAKE-IT Project supported by the H2020 R&I Program of the European Commission, 2016-17: http://make-it.io

2. *Community Awareness Platforms (CAPs):* New movements, such as the makers, are building and exploiting ICT for collaboration, sharing and learning purposes. CAPs is the European Commission's initiative for piloting online platforms that create awareness of sustainability problems and offer collaborative solutions. These are based on networks (e.g. of people, ideas and sensors), thereby enabling new forms of social and sustainable innovation that aim to support behavioral change, reputational processes and self-regulation so they become trustable and effective. (Sestini 2012; Millard 2018a)
3. *Crafts, do-it-yourself, creative and learning activities*: The tradition of craft production is the process of manufacturing by hand both with and without advanced or power tools. Similarly, do-it-yourself presents gateway opportunities for the un-skilled or novice to build, modify or repair something without the direct aid of experts. They can also express themselves through developing an ethos of self-help, learning and competence building, often in shared and collaborative spaces like libraries and other public venues. Recent cultural perspectives see the idea of 'making' being more important than seeing people primarily as 'makers', given that making is taking place as just one activity intimately bundled with others. Thus making is only a part of a broader 'making culture' reflecting the burgeoning desire amongst many people to move on from a purely consumerist society to start again 'getting their hands dirty' and 'reconnecting brain and hand'. (Charney 2016)
4. *The creative industries*: Arising from craft and do-it-yourself cultures but distinct from these, many makers are today overlapping and working with the so-called creative industries derived from knowledge, arts and culture-based economic activities. These include economic activities that generate and exploit knowledge derived from architecture, art, cultural heritage, crafts, design, fashion, film, music, the performing arts, publishing, R&D, software, toys, video games and TV-radio. ICT tools play a significant role in boosting these industries as they enable, often for the first time, anyone to collect, preserve, organize and distribute creative and cultural content, ranging from languages to historical artifacts. They currently make up about 5% of the European workforce, as high as 12% in Sweden, and rising fast everywhere. (NESTA 2016)

The maker movement started in garages, basements and workshops, set up 'maker-spaces', joined and often became indistinguishable from 'hacker-spaces' and formed communities on the web. They have become platforms for learning, sharing and collaboration. Many observers thus point to the social sustainability of making, increasing the social cohesion, inclusion, wellbeing, and quality of life of those it engages. They see its potential to change behaviors towards more sustainable lifestyles. At the same time, they see possibilities for transformations in economic sustainability through new skills and jobs, innovations in products, materials and business models, for example where digital designs for physical products are shared and then used or extended by third parties. (Anderson 2012; Rifkin 2014; McAfee & Brynjolfsson 2017; Buxmann & Hinz 2013; Millard 2018b) This culture of experimentation is a powerful driver for innovations leading to both technical and environmental sustainability. Typically, products go through several design iterations reusing local material feedstocks, each adding new features which better suit specific needs as makers increase their understanding of the communities they work with. For example, a basic water purifier using solar energy that can be adapted with reusable parts made of biologically degradable materials to cater for wear and tear. (Unterfrauner & Voigt 2017; Unterfrauner, Hofer, Schrammel & Fabian 2017) Such 'collective awareness building' plays a critical role and makers are starting to recognize the potential to make design decisions which save energy and materials.

The most prominent current manifestation of the maker movement are Fab Labs which have emerged as spaces for democratizing digital fabrication. Here citizens learn how to design and make with tools and machines that work at the interactions of ICT, physical and biological processes and materials. (Menichinelli 2015) The maker movement and the Fab Lab network is now being envisaged and extended at city scale and networked globally for the purpose of ensuring that Industry 4.0 will be efficient, effective as well as socially and environmentally sustainable. According to the Fab City whitepaper (Fab City Global Initiative 2016), cities should rapidly move towards being locally productive and self-sufficient whilst globally connected. The current 18 members of the global Fab City network are committed to moving from the current linear industrial production model, which imports raw materials and products and exports waste and pollution, towards a spiral innovation ecosystem in which energy and materials flow locally within cities, whilst information and data (including on how things are made) circulate globally.

It is claimed that merging the bottom-up maker movement with distributed manufacturing at a larger scale will result in value and supply chains moving away from centralized mass production towards decentralized distributed manufacturing and mass customization. This would profoundly impact the future of manufacturing and our physical world, as well as of work, behaviour as well as local and city development, not to mention global politics. Perhaps of even greater significance will be the potential impact on the environment and sustainability more generally. If in the future the only economically traded (i.e. physically transported or communicated over large distances) commodities consist of i) talent (high calibre skilled people), ii) raw materials and energy inputs in cases where their occurrences are still geographically fixed, and iii) digital algorithms, this will have a hugely beneficial environmental impact as the number of physical goods transported over even medium distances shrinks. The social and sustainable innovation potential of making is thus of strategic importance. (Millard 2018b)

3 Methodology and approach

The *MAKE-IT* project has designed and operationalized a methodological framework that includes two research instruments, derived from the literature in section II, plus widespread consultation. First, a common set of open qualitative questions, plus 7-point Likert scale propositions for completion during conversations between a maker initiative and an independent expert. The analyses presented in this paper collate selected results from 42 completed questionnaires from the Barcelona Maker Faire in June 2017, comprising over 50% of the maker initiatives present, as a good representation of a large European city's maker activities. Second, this is supplemented by an analysis of ten in-depth qualitative case studies from across Europe based on interviews with four members of each case, i.e. the manager and three makers. The cases span a range of maker initiatives, from maker spaces and Fab Labs to a Maker Faire and companies rooted in the maker movement: Happylab Vienna, Austria; Danish Technological Institute Lab, Denmark; Fablab Barcelona, Spain; Arduino, Italy; Hochschule Ruhr-West Lab, Germany; Dezentrale, Germany; Mini Maker Faire Tartu, Estonia; Fablab Zagreb, Croatia; Smart Bending Factory, the Netherlands; and Create It Real, Denmark.

The first instrument provides data on the types and leadership of maker initiatives, the technology used, their ambitions and their actual achievements across the three analytical pillars. The second instrument complements these largely 'what' data with more detailed information on 'how' and 'why' the reported results might have been achieved. For example, the first instrument indicates gender gaps and differences, which is confirmed by the second instrument adding some qualitative understanding, e.g. the 'genderization' of tasks and objects in the maker space, differences in the use of machines, etc. (Voigt, Unterfrauner & Stelzer 2017)

In the following section, selected results and analyses are presented in relation to:

a) Gender, age, technology use and scale.
b) Pillar 1 achievements in organization and governance: examines the ways maker communities are organized, internally and externally, the legal and regulatory frameworks that promote or

retard them, and interfaces with institutional and policy environments. Results examined cover strategic vision, organization and decision-making, financial sustainability, openness and sharing, impacts on societal and institutional norms, and gender balance.

c) Pillar 2 achievements in peer and collaborative behavior: looks at generating awareness and leveraging peer pressure, that drive people's behaviors to take-up maker activity and/or establish or join a maker community, and to stimulate better lifestyles through behavioral and system change. Specific results examined cover reaching the intended user base, motivating users and developing user skills, collaborative learning, community development and business and commerce.
d) Pillar 3 social achievements: covering changing social opinions and behaviors, developing human capital, education, social inclusion and cohesion, quality of life, and how these contribute to social sustainability.
e) Pillar 3 economic achievements: covering improved work, employment, innovation in industry and the economy, as well as improved sharing, collaboration, co-creation in the economy and how these contribute to economic sustainability.
f) Pillar 3 environmental achievements: covering decreased greenhouse gas and other pollution, bio-diversity, sustainable consumption, the circular economy and how these contribute to environmental sustainability.

Given lack of space, only some headline results are presented here, plus cross-matching with gender and scale variables, particularly drawing out some sustainability issues. However, the dataset has the potential for many more analyses, for example looking for comparisons and correlations between different variables. There are, as always, issues about the representativeness and validity of these data. However, the results from the two different sources do tend to corroborate each other in areas where there is overlap, and much care has been taken in data collection and preparation. All data and instruments are available on the *MAKE-IT* website in open format to support ongoing research[2].

4 Empirical results and analyses

4.1 Gender, age, technology use and scale

It is clear from Figure 2 that most maker initiatives are led by young males and that this is quite similar to the situation seen in the majority of technology-based start-ups and new enterprises. Female leaders constitute only 26% of all maker leaders in the Barcelona sample. However, these gender and age distributions are also in line with the results of the *MAKE-IT* case studies, i.e. the majority of maker managers are male (9 out of10), while the gender ratio among users varies from 80:20 to 60:40, and most are relatively young, between 20 and 40 years of age. Again, this gives some confidence that the sample reflects maker initiatives more widely. Other data show that, in terms of technology use, males and females are overall similar, but females do tend to use a wider range and to be less specialised as well as use more interactive and collaborative tools. Males are more likely to be using technology for commercial purposes, and seem more focused on technical ambitions than females.

Each maker initiative was assigned to a scale of organization and interaction: 1) single/individual makers operating alone; 2) makers with a limited set of regular partners; 3) medium-scale communities of makers and their users; 4) ecosystems of interacting, diverse but complementary makers and other relevant actors; and 5) maker networks which tend to be very large scale, often national or international in extent, consisting of maker relationships built on common needs and interests, for example for mutual learning. Figure 2 shows a good spread of scales that starts to

[2] MAKE-IT Project supported by the H2020 R&I Program of the European Commission, 2016-17: http://make-it.io

resemble a normal curve, indicating both that the scale definitions are likely to reflect the real world and that the sample seems relatively representative.

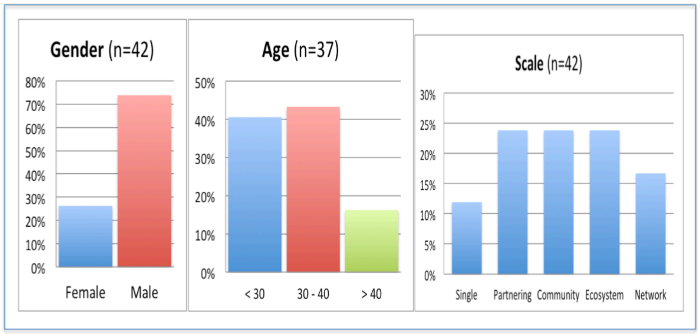


Figure 2: Characteristics of the maker initiatives

Figure 3 indicates that males and females are operating at quite different scales. Females are much more likely to work at the two extremes of the scale range, i.e. at the larger scales of ecosystems and networks and the smaller scale of singles, although they are also quite well represented in communities. Perhaps this reflects the desire or need for females, after they have started as a single if they do, to rapidly become anchored in a broader coalition of both similar actors (as in networks) or complementary actors (as in ecosystems) in order to start making, given the fact that making is still very much male dominated. Males, in contrast, operate much more than females in the middle two scales of partnering and community. They seem more likely to quickly move from the single stage to partnering, which is their dominant *modus operandi*, as well as in communities and a little less in ecosystems.

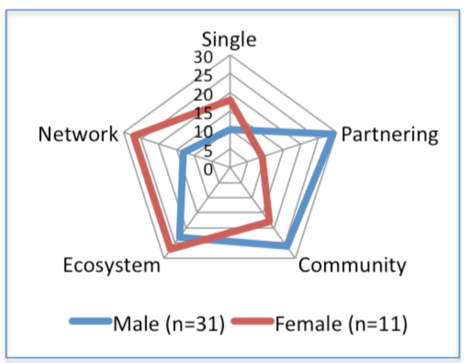


Figure 3: Gender and scale of the maker initiatives

The case studies also demonstrate gender differences, including that female makers tend to work on different tasks *"Woman make bio stuff; men make 3D prints"* (maker manager, Germany) and on different projects and machines (while 3D printers are mostly used by men, plotters are more likely to be used by females). There is no equal participation of male and female makers in the cases and many interviewees lack female role models: *"I do think that by having the Fab Lab attended by a girl, it makes other women interested in coming to the Fab Lab too"* (maker manager, Denmark). This aligns with Kanter's theory of homo-social reproduction according to which people are more likely to find their ways into social environments if people with similar interests are already participating. (Kanter

1977) Role models are needed not only on a management level but also among facilitators in the maker space: *"The problem is that if it's a man who is teaching, he would say it in one way, and a girl would say it in another way. They have role models, so if it is a woman saying it, it is great to look up to her and who she is. It really depends on who is standing there"* (maker, Denmark). Interviewing maker managers, however, also had an impact on their reflection of male dominated cultures: *"The visibility of women we never thought of, now it's on our minds. For some time now we have started thinking in these terms—how many girls we have, etc."* (maker manager, Spain).

4.2 Pillar 1: organization and governance achievements

Pillar 1 achievements, as shown in Figure 4, are mainly good, although overall the achievement rate is only 33% of those for whom such achievements are relevant, with some interesting differences between the various issues. Openness to and sharing with partners outside the maker initiative itself is the most positive result, perhaps reflecting one conclusion of Figure 3 that the partnering, community and ecosystem scales are the most common operational forms. As interviews with makers show, they are very keen on realizing openness as much as possible: *"Openness and sharing are the key principles that makers abide by. I haven't seen makers being overly protective of their IP. They are mostly willing to share their materials, designs to anyone who is interested"* (maker, Estonia). Openness is practiced by the sharing of ideas and designs locally, and by learning online in the wider community using multiple platforms for uploading designs and projects for other makers to use and adapt. However, for makers with commercial ambitions it is challenging to reconcile the value of openness and protection when running a maker business: "*We're of course in competition with other people. We're entering into a capitalist market where money is being made. And if we go there now and document every bit that we make and put it online, then we shoot [ourselves] in our own foot of course"* (maker, Germany). Thus, openness challenges the business model of makers.

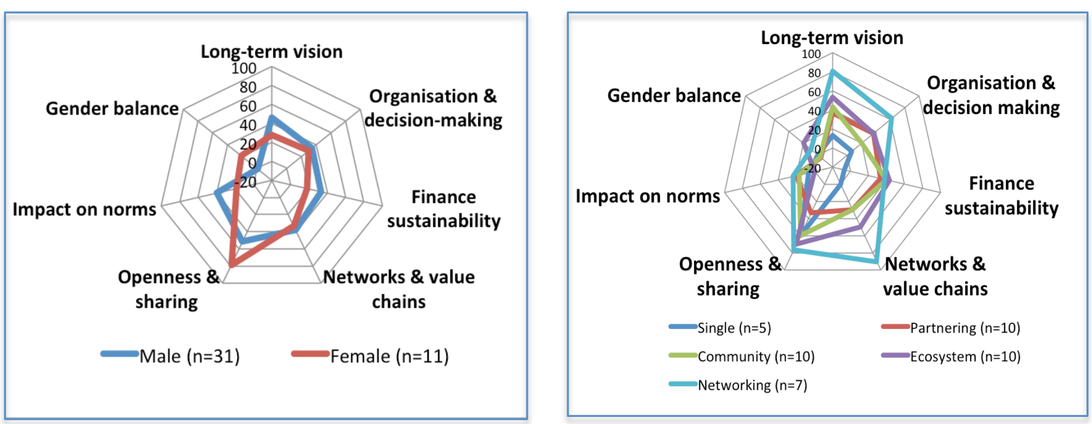


Figure 4: Pillar 1, organization and governance achievements (33%)

Financial and organizational sustainability is less positive, although still generally achieving some good results, perhaps because of this tension between openness and business. In some contrast, however, the maker initiatives' gender balance is relatively poor, even when disregarding those initiatives for which this is not a relevant goal. Overall in pillar 1, the more bottom-up, informal aspects seem to be more important than the more top-down and formal aspects, perhaps indicative of the early stage of maker development.

In terms of gender contrasts, Figure 4 clearly shows that females have greater achievements on gender balance compared to males, though this remains on the low side, and also perform better on openness and sharing. Males, in contrast, feel they are achieving more on changing prevailing norms, policies and regulations, on their long-term visions and on financial sustainability. The two largest scales, networks and ecosystems, both report the biggest achievements, with quite a strong overall positive correlation between increasing scale and increasing achievement. This points to the conclusion that scale matters and the larger scales seem to achieve the best results.

4.3 Pillar 2: peer and collaborative behavior achievements

Achievements in pillar 2, as shown in Figure 5, are generally very positive, and overall are greater than in pillar 1, with an average achievement rate of 40%. This may be because many makers are still at a relatively informal stage, experimenting and playing with the technology and with co-creative, collaborative and self- and group-learning activities, so this result perhaps shows this early phase of maker development. The most positive results relate to the motivation and engagement of users, collaborative learning and knowledge, and individual user skills and competences. This probably mirrors the conclusion above that these types of achievement reflect the current preoccupation and focus of most makers. In contrast, achievements related to intended business and commercial goals are much lower.

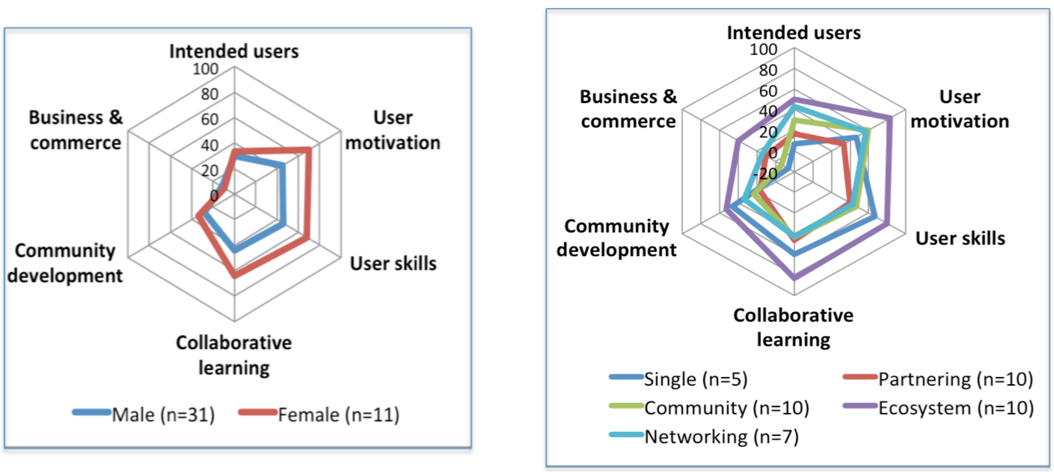


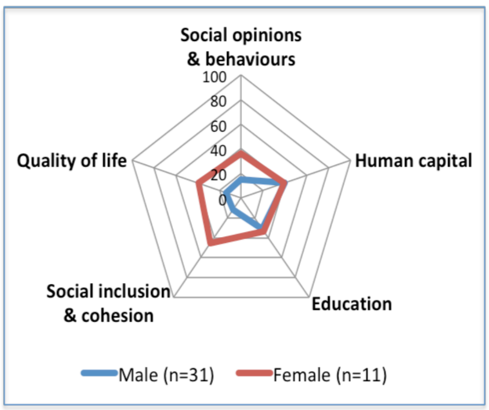
Figure 5: Pillar 2, peer and collaborative behavior achievements (40%)

Gender contrasts clearly show that females are in practice achieving much more on user motivation, user skills and collaborative learning, compared to males. This conclusion, i.e. that female-led maker initiatives are achieving more, and are thus generally more successful, than male-led initiatives, is further reinforced in much of the data presented below. In relation to scale effects, the two largest again predominate, but this time with ecosystems claiming the biggest achievements, with networks second, and a generally clear overall positive correlation between increasing scale and greater achievement.

The case studies show that the level of engagement of makers depends strongly on their willingness to participate in regular activities and their unwillingness to invest in high cost projects. The lack of trust that inhibits unlimited access to some maker spaces was mentioned as a barrier to deeper involvement. However, makers stated they were driven by open access to equipment and knowledgeable professionals. The more the makers were able to test and use these services and tools, the more they become engaged in making. Thus, it seems that maker engagement is mainly dependent on their personal characteristics, e.g. high motivation and interest, in the context of access and opportunity.

4.4 Pillar 3: social impact achievements

Figure 6 shows that social impacts have an overall achievement rate of 35%, with improved human capital, improved social inclusion/cohesion and education the most positive overall, probably related to the questions on collaborative learning and knowledge, and individual user skills and competences, referred to in pillar 2. Improved quality of life, and achievements on changed social opinions and behavior show less impact although are still important. These latter two issues tend to be broader and less concrete than the others, so there is likely to be both more uncertainty in scoring them as well as greater difficulty in assessing them in the wider community.



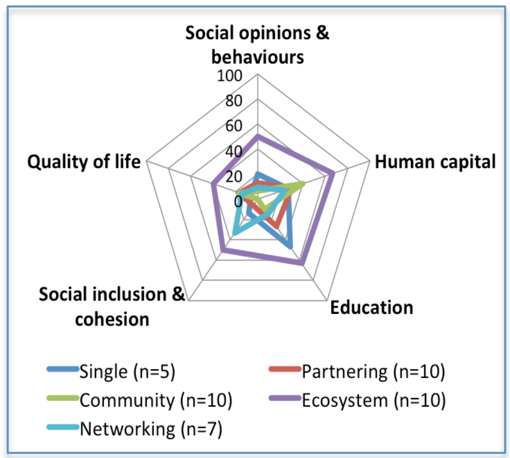


Figure 6: Pillar 3, social impact achievements (35%)

Looking at gender issues, female-led initiatives are again having much greater success in achieving social impacts, particularly in relation to social inclusion and cohesion, quality of life and social opinions and behaviors. In fact the last two would score quite high overall except for the fact that male-led initiatives perform badly. However, both genders perform relatively well on human capital, which can be more readily related to measurable outcomes like skills, as well as on education. Turning to scale differences, it is again clear that ecosystems score, very decisively, the highest across all issues. Other scales tend to be more random in their achievements, with networks scoring best on social inclusion and cohesion, communities on human capital and quality of life, and singles on education. These all appear relatively rational, as does simple partnering which scores lower than all others across most issues given they tend to be quite focused on activities which do not normally include social goals.

The case studies attest all these social impacts, especially in terms of education, training and innovations addressing social challenges. Education is described as the core aim of maker spaces, with all cases offering workshops for educational institutions, from kindergarten children up to university students*: "(...) Part of the task, which we set ourselves is of course to try to break barriers, especially for pupils who would never get the idea to study because they grow up in a social environment where they have no contact at all to universities. (...) social origin determines the educational career a lot here"* (manager, Germany). Thus, making might have an impact on career choices as well as an empowering effect*: "Something that is very remarkable is the fact that whatever happens in our lab, our advisory service is all about the empowerment of people, providing people with knowledge and tools that make them become more valuable, whatever they do. It is giving them knowledge, practical tools and approaches that strengthen their capabilities"* (manager, Denmark). There are also numerous examples of maker innovations that tackle social challenges and enhance the quality of life, from printed prostheses for people with disabilities, to mobile maker spaces in disaster zones for developing products to tackle immediate necessities[3].

4.5 Pillar 3: economic impact achievements

Economic impacts, shown in Figure 7, are a little lower than social impacts with an overall achievement rate of 31%, and they also have less impact overall because the percentage of initiatives for which these questions are not relevant is 29% compared with only 17% for the social impact questions. This indicates that, for those fewer initiatives that have economic impact goals, they are achieving them relatively well, whereas there are more initiatives with social impact goals and all these are achieving them even better. There are also interesting differences between the issues, with improved sharing, collaboration and co-creation in an economic context the most positive. This probably relates to the highly positive impact questions on collaborative learning and knowledge, and on individual user skills and competences, shown in pillar 2. In contrast the questions on improved work and employment and improved innovation in industry and the economy are somewhat less positive. As concluded earlier, the improved sharing, collaboration and co-creation issue directly reflects the main activities in the current stage of maker development, i.e. focused more on experimenting and playing with the technology and with co-creative, collaborative and self- and group-learning activities. The other two issues reflect impacts that probably require longer time horizons and changes to more established institutional structures and activities.

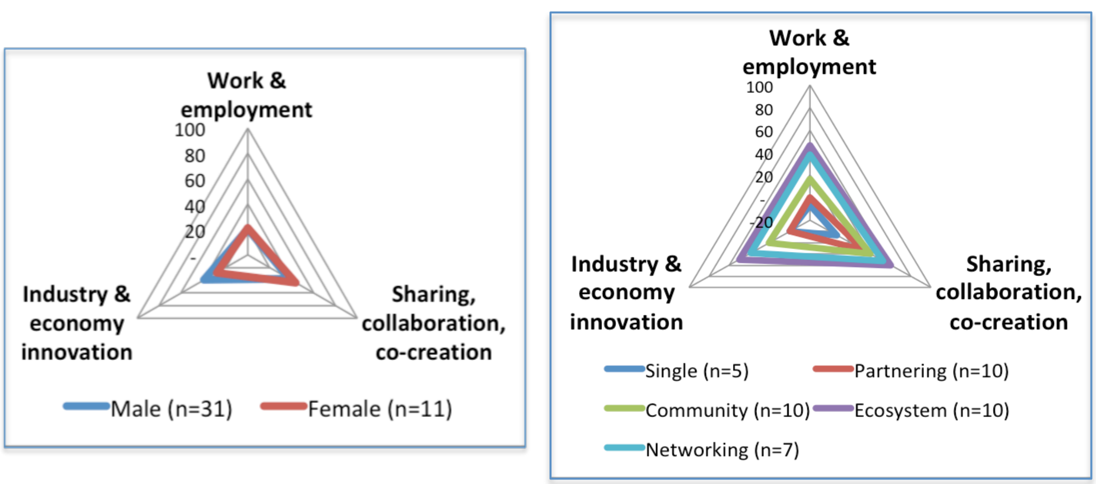


Figure 7: Pillar 3, economic impact achievements (31%)

There are only minor gender differences related to economic impacts, with the most prominent being greater male achievements in industry and economy innovation, but slightly less than females on sharing, collaboration and co-creation. Looking at scale differences, however, again shows a very

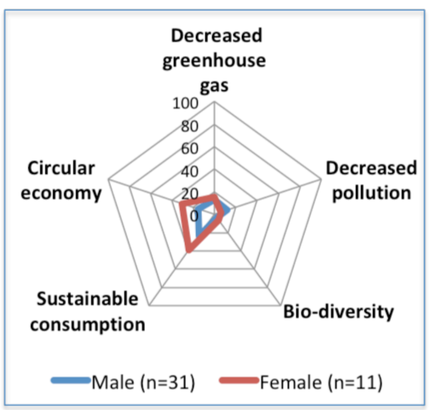
[3] Fieldready.org

strong positive correlation between increasing scale and increasing impact across all three issues, and once more with the flip between ecosystems and networks. Thus, both in terms of social and economic impacts, ecosystems are clearly the most successful scale, followed not far behind by networks and then the smaller scales progressively performing less well.

The case studies show that economic impact is mainly generated through easy prototyping and the drive for innovation, as well as impacts on the labour force. Using digital fabrication tools, prototypes can be easily developed and ideas tested before needing substantial funding: *"I think they [Fab Labs] are a kind of nucleus for products in general, because you can develop your ideas with no risk. If you have an idea, you just come here and try it out. If you figure out that it did not work, then it just does not work, but you did not buy a laser cutter for €30,000 before trying. No start-up business could afford that"* (maker, Austria). Thus, products find their way to the market faster and ideas can be tested before searching for investment, showing that making is a driving force for innovation. Indeed, many start-up companies have their roots in the maker movement, whilst impact on the labour force comes from local job creation and up-skilling the work force.

4.6 Pillar 3: environmental impact achievements

Compared with both social and economic impacts, environmental impacts are significantly less impressive. They have an achievement rate of only 15%, and a percentage of initiatives for which these questions are not relevant at a huge 60% compared to 29% for economic impacts and only 17% for the social impacts. This strongly indicates both an overall lack of ambition in this regard as well perhaps the difficulty for bottom-up maker initiatives in undertaking environmental evaluations. There are, however, important differences between individual environmental issues, as revealed in Figure 8.



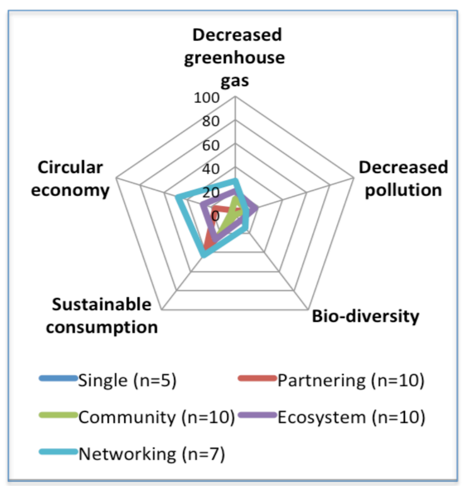


Figure 8: Pillar 3, environmental impact achievements (15%)

Figure 8 shows that more sustainable consumption has the greatest success, perhaps related to the strong material re-use and high resource use efficiency of makers. Circular economy impacts are also generally positive although less than sustainable consumption, even though the two relate together, probably because the former are more likely to be part of broader industrial systems into which only a minority of makers are currently incorporated. In contrast, impacts related to decreased greenhouse gas emissions and of other types of pollution, as well as of improved bio-diversity, are only marginally positive, again perhaps indicating the difficulties in understanding in practice how bottom-up makers can contribute directly to these goals.

These results perhaps reveal a weakness in the methodology here, as there are two issues which perform well and on a par with many social and economic impacts, but these are coupled with three which perform much less well, thereby significantly reducing the average achievement. Although decisions about the issues to address has been derived from desk research and widespread consultation with makers, the actual choice can obviously affect the average result. Clearly, there are some quite good environmental impacts arising from maker initiatives shown by these results.

Distinctions in environmental achievements related to gender show again that females are more successful than males in relation to sustainable consumption and the circular economy, and marginally less successful in terms of decreased pollution, the latter perhaps being a more technically specialist issue. Looking at scale differences, Figure 8 shows that there is again, in general terms, a clear link between increasing scale and impact. However, in relation to environmental as opposed to social and economic impacts, networks do perform better than ecosystems, but also partnerships generally perform better than communities. This seems to reinforce the evidence above that networks and partnerships are more suitable for the more specialist technical and commercial issues. Environmental challenges are perhaps a good example of this, being able to exploit either small strong ties, as in partnerships, as well as perhaps looser though very wide-ranging ties, as with networks. It is also noteworthy that singles do not appear in Figure 8, because none of the five interviewed could answer the environmental questions, unlike all interviewees at other scales and unlike all the other questions that they did respond to.

Some of the case studies addressed environmental challenges with maker inventions (e.g. a water purification tool using solar energy, an energy-harvesting flower-pot, etc.), others experimented with environmentally friendly materials (e.g. mushroom-based textiles replacing leather) or developed substitute parts. While not all makers in the cases were environmentally conscious, there were many examples of makers keen on up-cycling, re-cycling or repairing things in their maker space. (Unterfrauner, Hofer, Schrammel & Fabian 2017)

5 Conclusion and recommendations

There are a number of clear and significant conclusions, including relating to sustainability, arising from an examination of the maker initiatives investigated in Barcelona, and through case studies drawn from across Europe, most of which appear to be complementary. These are grouped into achievements by analytical pillar, the importance of gender and the importance of scale. In addition, some recommendations are provided.

5.1 Achievements by analytical pillar

Achievements actually being delivered are much higher for pillar 2 (peer and collaborative behaviors) than pillar 1 (organization and governance) activities, whilst together they are achieving more than the three pillar 3 impacts. This pattern seems to underscore the still relatively early stage of development of many maker initiatives, i.e. that the more bottom-up and sometimes informal individual aspects of pillar 2, like user skills and motivation, sharing and learning, currently have greater focus and are better developed than the more top-down and formal organizational aspects of pillar 1, like management, decision-making, impact on wider institutional norms, including policies and regulation. Both pillar 1 and pillar 2 are, however, concerned with the operations of maker initiatives, whereas pillar 3 focuses on the wider societal impacts of these operations and are clearly lower than the achievements to date of pillars 1 and 2.

In both pillars 1 and 2, the most positive results come from questions on the motivation and engagement of users, collaborative learning and knowledge, and individual user skills and competences. Business and commercial goals have the lowest achievements, although there is some good progress on these and most makers do think such goals are very relevant, but the gap between this and actual achievement to date is quite large. It can be concluded from this that the social sustainability potential of making is already demonstrating good progress at this relatively early stage of development. Most maker initiatives seem to have started with community and social goals and are still prioritizing experimentation and play, both with the technology and with co-creative, collaborative and self- and group-learning activities. The most positive results relate to the motivation and engagement of users, collaborative learning and knowledge, and individual user skills and competences. Although the economic sustainability potential of making is less advanced than social sustainability at this stage of development, its progress is still strongly visible and there is clear evidence of a burgeoning clash between social and economic goals. Makers are seeing the increasingly need for improved business and commercial strategies, both to ensure better financial sustainability but also greater job creation. The awareness of this tension and attempts to resolve it has become more evident in the last few years.

In terms of the pillar 3 impact issues, social sustainability is again shown to be the most impressive overall. Improved human capital, social cohesion and inclusion are the most positive social impacts, probably related to the questions on collaborative learning and knowledge, and on individual user skills and competences, referred to in pillar 2 above. Economic sustainability impacts are also important, especially related to improved sharing, collaboration and co-creation in an economic context. Fewer impacts are currently being achieved in relation to improved work and employment and on improved innovation in industry and the economy. The most important environmental sustainability impacts are more sustainable consumption, perhaps related to the strong material re-use and high resource use efficiency of makers, as well as due to general awareness raising, whilst circular economy impacts are also positive. In contrast, impacts related to decreased greenhouse gas emissions and other pollution, or improved bio-diversity, are only marginally positive, perhaps indicating the difficulties in understanding in practice how makers can contribute directly to these goals. Such environmental sustainability goals are also more technical and require longer term commitment with large scale collaboration, as well as being subject to more challenging political and regulatory constraints, than either social or economic sustainability.

In general for pillar 3 societal impacts, there are both very good social and economic achievements, but there are many more of the former that are rated as relevant, so the overall social impact is greater. As noted above, there are good sustainability consumption and circular economy impacts, although environmental impacts overall have lower levels of achievement, perhaps because they are more difficult to understand and engage with.

Thus overall, the current status of maker development in Europe seems still to be at an early stage with a lot of enthusiastic, community- and social-led innovative activity, just starting to make significant progress on more formal internal organization and management and becoming embedded in wider governance and institutional contexts. A clear, and arguably logical, trajectory of development can thus be discerned for making, starting, as it did, as a relatively small-scale, bottom-up movement. Beginning with a strong focus on community and social sustainability, moving to more formalized and professional economic and technical sustainability, and increasingly now also exploring issues of environmental sustainability that require even greater scientific, technical and professional knowledge and focus. Given this, it is important that policy focuses on nurturing the maker movement to help it better achieve its potential across the wide spectrum of social, economic environmental and technical sustainability, that it is already starting to deliver. The increasingly important links with, and impacts on, mainstream industry as it begins to move towards distributed manufacturing business models, is also extremely important.

5.2 The importance of gender

Most maker initiatives are led by young males which is quite similar to the situation seen in the majority of technology-based start-ups and new enterprises. However, as demonstrated below, females generally achieve better results than males. In relation to pillar 1, females report both greater achievements and greater relevance on gender balance when compared to males, as well as on openness and sharing, whilst males feel they are achieving a little more on changing prevailing norms, policies and regulations, on their long-term visions and on financial sustainability. For pillar 2 activities, females report much higher aspirations and are in practice achieving much more on user motivation, user skills and collaborative learning, compared to males. Overall, females have a higher focus on social and educational issues, on openness and sharing, skills and quality of life, whilst males focus more on technology, industry/economy innovation and changing regulations, norms, etc.

In terms of social sustainability impacts, female-led initiatives are having greater success, particularly on social inclusion and cohesion, quality of life and changing social opinions and behaviors. However, in terms of economic sustainability impacts, male-led initiatives achieve more in industry and economy innovation, but slightly less on sharing, collaboration and co-creation in an economic context. For environmental sustainability impacts, females are also more successful than males on sustainable consumption and the circular economy, but marginally less successful than males in terms of decreased pollution, the latter perhaps being a more technically specialist issue.

The maker initiatives that females and males lead operate at quite different scales. Females are more likely to work at the two scale extremes of ecosystems and networks and as singles. Males, in contrast, are more likely to lead the middle scales of communities and partnering, with the latter seeming to be their dominant *modus operandi* and where greater economic and technical specialization seems to take place.

The overall conclusion is that female-led maker initiatives are achieving more, and are thus generally more successful, than male-led initiatives. The reasons for this are difficult to unravel, especially as expectations might point to the opposite in such a male dominated context. As a generality, females can often bring unique skills and insights which complement male ones. However, a contributing factor might be that only high caliber females lead maker initiatives, precisely because of the barriers against them, whilst the range of male leaders is much wider because there are more of them, so their average level of skill, determination and ambition may be lower, leading to fewer achievements overall. Also of possible relevance is that most makers are currently still at the more informal, experimental, socially focused and non-commercial stage of pillar 2, which is precisely the areas in which women seem to do best. Whatever the reasons, females are in most cases underrepresented in most maker initiatives. To change this, there is a need to actively promote a culture that promotes diversity (not only females, but also other groups which tend to be left out, such as the elderly) and to install a respectful and supportive culture in maker spaces. (Voigt, Unterfrauner, & Stelzer 2017)

5.3 The importance of scale

The analyses above show that the five scales used to examine maker initiatives do seem to have credence in practice. Single/individual initiatives appear to be quite random in their technology use, their ambitions and achievements, compared to the other four scales, each of which do seem to demonstrate distinct characteristics. Perhaps this is because singles can be highly diverse, but possibly also because their sample size for this analysis is the smallest at only five initiatives. In contrast, partnering initiatives tend to use 3D printing, robotics and modeling technologies more than other scales, and electronics and IoT less which are commonly used at the larger scales of communities, ecosystems and networks. Partnerships are also more likely to be better organised formally and specialized on commercial and environmental issues, compared to these larger scales. Partnering is perhaps better able to provide the close bonding and trusting relationships necessary for makers to set up good commercial relationships in the maker context and to focus on more specialized issues like the environment. Also distinct are communities that tend to consist mainly of individual, though sometimes several, maker initiatives but each having close relationships with large numbers of users. These relationships are mainly non-commercial, and the overall ambitions and achievements of communities are also more focused on social rather than economic impacts.

The larger scale ecosystem and network initiatives almost always achieve much bigger impacts than the others. However, ecosystems outperform networks in terms of social and economic sustainability impacts, perhaps because they consist of well functioning local or regional clusters of complementary and diverse actors. Networks, however, outperform ecosystems in terms of pillar 1 and environmental sustainability, possibly because they sometimes have an even larger scale and greater learning between similar initiatives given the need to challenge many more incumbents, infrastructures and norms than pillar 2, social or economic impacts, at least in the early stages of maker development. Even though ecosystems are not necessarily at the largest potential scale, they can be thought of as exhibiting the most intricate, comprehensive and developed set of relationships between diverse, but complementary, actors at a relatively large scale. Such relationships are typically at the heart of an innovative milieu.

Thus, to maximise the successful operation, societal value creation and sustainability impacts of maker initiatives, it is clear that ecosystems and networks, both formal and informal, should be supported by policymakers and strategies at different levels and sectors. This does not mean that the smaller scales are not important nor valuable, as they provide good routes into making and can achieve much on their own, but encouraging and linking them towards greater and larger scale awareness and cooperation can provide win-wins all round.

5.4 The status of the maker movement in Europe

In conclusion, the maker movement in Europe today is driven more and more by a supporting ecosystem with new platforms, service providers and increasingly strong involvement in the value chains of larger companies, many of which are moving towards a distributed manufacturing business model. However, many makers remain as hobbyists, enthusiasts or students and are often amateurs, but they are also wellsprings of innovation, creating new products and producing value in the community, and some become entrepreneurs and launch start-up companies. Making is often still dominated by the latest gadgets, technical prowess and playful experimentation which are nonetheless of strategic importance for innovation. Although the sustainability impacts are not yet significant on a large scale, they are clear and increasing at a rapid rate.

Globally, the maker movement is no more than ten years old, and in many parts of Europe much less. Despite this, the evidence shows that when individual maker initiatives become embedded in medium- and large-scale ecosystems and networks, their sustainability impacts start to become important. This is also due to the fact that their links to large-scale industry, as it transforms towards distributed manufacturing, is increasing. This is well exemplified in the case of Barcelona, from whence the sample of 42 in-depth interviews, used as some of the evidence for this paper, has been derived. Barcelona, as the home of the Fab City movement (Fab City Global Initiative 2016), and on the basis of these interviews, shows the full range of maker types and scales. Apart from the five single initiatives in the sample, the vast majority have their only or main links within the city and its close hinterland, rather than at greater geographical distances. They clearly constitute a well functioning metropolitan ecosystem and network, pushing the city towards its Fab City vision of making as many things locally as possible, using locally re-cycled materials, creating local jobs and working closely with local educational and research institutions. The city is showing how making can start to achieve increasing sustainability across its manifold manifestations.

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