How to cultivate sustainable developments in makerspaces

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In October 2015, with help from many colleagues, we organised a workshop for researchers and practitioners to explore how makerspaces can help cultivate sustainable developments.

Findings from the workshop have since been presented to a variety of makerspace and research audiences in Buenos Aires, Barcelona, Bogotá, Helsinki and Tromsø during the intervening months, and are now presented more widely here.

What is a makerspace, hackerspace or fablab?

Makerspaces, which are sometimes referred to as hackerspaces or fablabs, are community-based design and fabrication workspaces where people meet to share resources and knowledge and to build and make things. This might involve computer technology, machines, science, digital art, electronic art or any other area involving collaboration and learning. Arguably, makerspaces can help develop social organization capabilities and furnish technologies, traditional and high-tech, for new forms of appropriation by people, and in pursuit of prototyping, production, care and repair, and consumption. As a result, makerspaces open up possibilities for exploring personal projects and social developments. Potentially, these can include sustainable developments.

Sustainable developments

Although participants in some makerspaces are experimenting with sustainability possibilities, sustainable development isn't inherent to makerspaces. The London workshop took as its point of departure an understanding of sustainable development first presented by the UN World Commission on Environment and Development (pdf) in 1987, and which noted that peoples' ability to create socially just livelihoods with environmental integrity depended upon the 'state of technology and social organisation' in societies. Observers and commentators have noted makerspace potential (pdf) for sustainable developments.

The workshop

The workshop was held at the Machines Room makerspace in London and involved around 80 participants from the UK and Europe. The workshop was made possible with support from the Centre for Innovation and Energy Demand, the STEPS Centre

(Social, Technological and Environmental Pathways to Sustainability), both at the Science Policy Research Unit at Sussex University, and the European Framework Seven project TRANSIT (Transformative Social Innovation Theory).

The workshop was motivated by the following questions:

- How can makerspaces sustain and expand their commitment to sustainable developments?
- Should sustainability initiatives scale-up or circulate more widely, and if so, how can they retain their core aims when moving beyond prototyping?
- How can makerspaces work with others to generate conditions for sustainable developments in the wider world?

Thought-provoking speakers on the first day talked about how they worked with makerspaces to promote sustainable developments. They raised issues that participants on the second day explored in greater depth through workshop activities.

The speakers

Invited speakers were organised into two groups. The first group consisted of people who work in makerspaces and are committed to engaging their space in sustainable developments locally. The second group of speakers are involved in sustainability initiatives that involve taking the practices of making, hacking and fixing out to different communities, wherever they happen to live, work and gather.

Collectively, the speakers have experience with a wide range of sustainable developments with makerspaces:

- Prototyping sustainable designs and systems
- Exploring issues of sustainable energy through hacking solar panels and building DIY home energy systems
- Incubating upcyling businesses and furnishing creative hubs for closed loop materials cycles
- Hosting repair cafés and 'Restart Parties', which aim to empower people to use products longer, including electronics devices, in order to reduce waste
- Building communities interested in making, repairing, repurposing and sustainability
- Hosting citizen science initiatives and building environmental monitoring systems
- Critical making that connects people to the political economies and material realities of production and consumption, and that explores alternative, more desirable futures
- Organising workshops for the social innovation of local sustainability

- Outreach activities that connect other sustainable development groups, and mobilising new thinking and action about technologies, sustainability and people
- Cultivating post-consumer identities, values and material cultures.

Key findings from the workshop:

- Whilst the potential is real, sustainable developments are relatively rare in makerspaces: those makerspaces committed to sustainability principles are pursuing a variety of pathways
- There may be a tension in the mission of *sustainable making,* created where a formula for introducing technology into communities has been adopted. This tension is created since flexibility and responsiveness emerge as features in successful local customisation, whereas formal programmes focus on technology skills development
- There is no such thing as an unstructured experimental space: unsustainable practices from the wider social world will be reproduced (unwittingly) in makerspaces unless explicit strategies are in place for sustainability
- Those practicing sustainable approaches are likely to focus predominantly on one or two aspects, choosing social justice, local livelihoods or environmental integrity for the mainstay of their efforts, since conflicts in these priorities are hard to resolve, not least for small volunteer-driven organisations
- Skills in developing and using makerspace tools and infrastructure need to be complemented with community development skills
- Intangible outcomes from sustainability initiatives are just as important as material outputs – new identities, relations, tacit knowledge, skills, awareness, as much as objects, products and services
- The cultivation of technological citizenship is an important intangible outcome
- Makerspaces can connect and confront the worlds of formal design, education, and business institutions with grassroots commitments and interests in sustainability
- There are a wide variety of possibilities for makerspaces to become hubs for sustainable developments, and relevant for different circumstances
- Imaginative, flexible and open-ended support and funding arrangements need to be created to realise the full possibilities for makerspaces to help cultivate sustainable developments.

After an introduction to the Machines Room from Nat Hunter, the workshop began with a presentation from **Susana Nascimento** from the European Commission Joint Research Centre. Susana investigates the burgeoning field of citizen science and grassroots making, and talked about the different kinds of knowledge production arising in makerspaces. Navigating more sustainable development pathways requires understandings of the world and of social issues that work across different disciplines and involve citizens much more actively in the production of knowledge, said Nascimento. Makerspaces can provide sites for the experimentation, collaboration and creativity that underpin such knowledge production. Working with the Vitruvius FabLab in Lisbon in 2013, Nascimento organised a week-long summer school at their makerspace on Sustainable Technologies and Transdisciplinary Futures. Participants explored how the tools and activities of making could stimulate debate local sustainability issues in the city at the summer school.

Richard Clifford from MAKLab in Glasgow spoke next. He discussed the development of MAKLab and its activities for empowering people through making. Richard's session demonstrated how makerspaces can work with different partners by aligning production facilities and possibilities with the aims of those partner organisations. His examples ranged from specific making projects to training programmes to research and scoping. These activities included working with socially disadvantaged groups, and some addressed sustainable developments. Such was the public and private interest in this approach that partners are helping to open MAKLabs in other cities in Scotland, as well as expanding the range of things these makerspaces can be and do.

Cindy Kohtala from Aalto University in Helsinki presented her research (pdf) into FabLabs and sustainability. Drawing upon visits to a variety of Labs around Europe, as well as more in-depth participant observation in others, Kohtala mapped out the various ways she saw FabLabs cultivating sustainable developments. Much practical effort to date has rested in thinking about materials use and the processes of making things, such as energy use and waste. However, there was also interest and opportunities to rethink material cultures and explore wider questions of production and consumption (see also the blogpost providing background to the workshop). Cindy thought this needed dedicated champions in FabLabs who could make the issues more visible and support user engagement in those issues in convenient, convivial and fun ways.

Diana Wildschut and **Harmen Zijp** next spoke about how they had created FabLab Amersfoort on a shoestring budget and with a strong commitment to grassroots sustainability. The Lab complements activities of the De War collective in bringing together sustainability projects combining the arts, open science, and hacking

technology. It also provides facilities for the Co-operative University of Amersfoort – a new and experimental grassroots research institution. The FabLab provides facilities and tools for working with other groups, such as Transition Towns, and citizen environmental monitoring and history. Diana and Harmen spoke about how this happens through a very open structure and invitations for participants to initiate self-

organised processes for realising their ideas. They noted that this can take some getting used to, and is not always successful. Yet for Diana and Harmen this principle of horizontal action is in itself a key component in hacking new systems (pdf) for social organisation and also a means of extending their personal potential and sustainability as a small fleet-footed organisation.

Sophie Thomas from the RSA Great Recovery project spoke next about being co-housed with FabLab London and the possibilities this presented for their campaign to promote design for circular economies. The Great Recovery project aims to create a more circular economy (thus reducing waste) through a wide variety of awareness raising and agenda setting activities. Included amongst these is use of FabLab facilities in product tear-downs and upcycling initiatives that allows people to design and make things better, and to value waste and reduce environmental impacts. Making, hacking and fixing allows people with practical ways to understand abstract concepts like the circular economy, and to raise awareness in a much more active and hands-on way.

Didac Ferrer from the Tarpuna Co-operative in Barcelona has been working with the network of public FabLabs in the city known as Ateneus de Fabricació Digital. Didac described how they brought their experience in community sustainable developments into the design of activities with neighbourhood Ateneus. The key here was to work with local groups over a long period to explore how design and making might complement their expertise in knowing their neighbourhood and its sustainability needs. People are still working out how to develop this activity, which requires patience, but has great potential in making some of the grander visions for decentralised digital fabrication meaningful for local sustainable developments. The short-term nature of coming to a training workshop, playing with the digital fabrication tools and making a plastic memento of limited use needs to be resisted, said Didac, and the use of makerspace facilities attuned to the rhythms of community development. “¡No pongo!” as Didac put it, providing a catchy Spanish word for something others have called crapjects: the proliferating things we have around us that are neither beautiful nor useful.

Our second group of speakers, taking making, hacking and fixing to communities, was led by Max Wakefield from Demand Energy Equality. Demand Energy Equality is committed to all communities benefitting from the sustainable energy transition, and ensuring they have the knowledge and confidence to demand a stake. A key activity towards this goal is the organisation of workshops where participants can self-build solar battery chargers. This *making* activity is used as a stimulating and fun introduction to the basics of electricity, as well as providing a platform for discussion

that raises awareness about reducing energy demand in ways that are socially just. As demonstrated also by other speakers, making, hacking and fixing can be a vehicle for cultivating technological citizenship.

Janet Gunter, co-founder of the Restart Project, spoke next about Restart, a London-based network that supports the organisation of 'restart parties' internationally.

People bring their broken electronic goods to these parties, where volunteers with some repair skills support the party-goers in fixing their broken stuff, but also acquire the confidence and skills to fix things in the future. Restart founders were inspired by people in developing countries who often re-use and recycle their electronic and mechanical goods. Janet spoke about how her earlier work in development projects inspired the Restart project's community-based approach. She talked about how fixing activities often led to deeper set of consequences, such as empowering people to question the way things are made, and to challenge the designers and producers of electronics to enable people to have a more sustainable relationship with electronics. Fixing activities are seen as a route towards a more caring material culture and a means of asserting concern for the longevity and quality of material goods, which promises profound social as well as environmental benefits.

Trystan Lea from Open Energy Monitor talked about their open hardware project and online community developing energy monitoring services for households and businesses. Much of the community activity involves technical enthusiasts developing software, sensors, controls and a web platform that assists households in understanding, managing, and reducing their energy use. For example, the Open Energy Monitor is an open source energy monitor that allows households to monitor electricity generated by solar panels and household energy usage. Lea talked about how the households which adopted monitors became more confident and involved in their energy activity. With that in mind, Open Energy Monitor is collaborating with the community energy and outreach activities of Carbon Co-op in Manchester.

Justyna Swat, an organiser of the POC21 initiative, a community of innovators that aims to ultimately overcome consumer culture and "make open-source, sustainable products the new normal" next shared her reflections. POC21 seeks a 'proof of concept' of the "disruptive impact that collaborative production, open source and the maker movement can have on mainstreaming the means of sustainable living". It aimed to provide a practical approach to sustainable development, in contrast with the international negotiations and bargaining at COP21 – the climate talks in Paris. Swat talked about how POC21 brought together over a hundred makers, designers, engineers, scientists and geeks, on the site of a borrowed chateau, drawn from various international activist networks, who were committed to prototyping for a fossil-free, zero-waste society. Others joined in via social media and internet. A temporary innovation camp was created, equipped with the tools for prototyping a variety of technologies of practical and symbolic value for low carbon living. These prototypes made use of open source designs and instructions in order that others can access,

adapt and make use of these developments. Swat emphasised how it was not the prototypes per se that mattered, but the open forms of working, and the infrastructure for developing innovations and collaborative demands for sustainability.

Ann Light provided summary reflections to lead into workshop activities. Ann is Professor of Design and Creative Technology at Sussex University and uses

participatory design to work with diverse communities across the world. In her work on citizen initiatives, she has explored the 'relational asset' of a dense culture of sharing and how this promotes social, environmental and economic sustainability within localities. She talked about the way that the initiatives presented by speakers contribute to this collective social capacity and cultivate sustainable pathways. Commenting also on the need for self-care, she posed her own questions to take forward:

- How do we understand sustainability as situated within a cultural context or culture? How do different forms of sustainability (social, financial/economic, environmental, cultural) interact?
- What can we learn about policies, politics, practice, infrastructure, inclusivity and agency in these makerspace hothouses?
- What are good forms of diffusion – how far can they be scaled up, how far can they be replicated – and which aspects can be abstracted?
- How can a wider culture of sharing be promoted?
- How are global and local connected in this work?

Light began the second day with a chance for participants to speak about their own motivations and interests, inviting them to be present as individuals trying to make change as well as representatives of organisations and approaches.

Workshop discussion: How makerspaces help cultivate sustainable developments

Discussions on the second day followed the World Café format. Participants divided into groups, and each group worked their way around a series of tables, with a different question posed to them by a host at each table. In this way the tables accumulated insights and comments, as each group picked up where the preceding group had left off. In addition to the three questions opening the workshop, a fourth question (and table) was set up asking: *If makerspaces are the answer, what was the question?* This arose from earlier discussion and recognition amongst participants on the value of retaining a critical perspective and grounded pragmatism towards possibilities for sustainable developments.

Participants used flip-charts, sticky notes, sketches, and examples to convey their ideas at each table. An audio recording of discussions was also made. The following are one interpretation of these materials. Other participants wrote blogs drawing their own interpretations. (These can be accessed at the bottom of this page.)

1. How to sustain and expand commitment to sustainable developments in makerspaces?

This question was concerned with creating the conditions in makerspaces for sustainable developments to become a normal endeavour. Interestingly, whilst groups did consider the re-use of materials and emblematic sustainability projects, discussion quickly turned to a bigger agenda. The sustenance and expansion of

projects was seen as resting in engaging more people in makerspaces, such that makerspaces become a hub of widely connected activities for building social commitment towards sustainability.

Ensuring inclusivity, diversity and building an open community was seen as central. Makerspace strengths rest in the encounters they create and the ensuing cross-fertilisation of ideas, knowledge and practices. It was felt that building a critical mass and momentum requires strategies for continually drawing in a wide range of people.

There is scope for running makerspaces in ways that are more welcoming to groups that are poorly represented at present. Strategies will consequently need to be specific and meaningful to each group, as well as sensitive to the locality and the plural aspirations for its development.

Learning to listen was identified as paramount. That way, the risk of fetishizing tools in makerspaces - and seeing all problems as ones that technology can fix - is countered by considering the social basis of problems first, and only then thinking about how to bring different tools into play in the creation of solutions. In a sense, this is to bring a design sensibility into play where there has so far been a strong focus on materials and technical skills. But focusing on the social is also to make explicit the dynamics between (and ambitions of) the people constituting the space and the neighbourhood in which it functions.

There was a need identified for community development skills to supplement the technical skills that support growth of a different kind. Whilst the acquisition of such development skills can be demanding, the advantage is that both makerspaces and sustainability could become framed in ways that attract a wider base of interest and support and could come to have greater meaning, and perhaps resilience, in their local settings. Discussion and engagement keeps activity open to reflection in the light of putting the principles of sustainable development into practice.

Some of the practical consequences from this will be enhanced consideration of the material requirements and resource efficiencies amongst users of makerspaces. This was apparent in hearing the different stories of the day before. Opportunities could be created amongst suppliers of ‘waste’ materials from local production and consumption activities. Makerspaces could convene activities to attract the suppliers

of such materials into thinking creatively about how their waste resources could be used in projects by others, and thus develop a platform for discussing and experimenting with local circular economies. In these ways makerspaces can claim a role in sustainable transformations through the use of materials, innovation, and entrepreneurial practice.

Makerspaces could reach out beyond makers, fixers and hackers, and demonstrate a relevance to non-makers also. People could participate in more general discussion, and makerspaces could use activities like product tear-downs to explore wider themes

concerning the way things get made, and their social and environmental implications. Fieldtrips and films have been organised by some spaces as a way to engage people not themselves committed to making. Outreach activities can situate makerspaces as a social hub for information, contacts, and action to change the way things are designed and made in societies, who is involved in those choices, and what can be done to influence and change those decisions. This more critical role is often felt to be at odds with a creative capacity, but the ingenious projects described at the event show how making, fixing and reflecting can be incorporated into the same responsive agenda.

Examples of such outreach activities include the Great Recovery activity with FabLab London, and the meet-ups or "restart parties"organised by the Restart Project. In addition to the eco-entrepreneurial activities noted above, environmentalists might be interested more generally in how partnerships with makerspaces could mobilise a growing material consciousness into social pressure on manufacturers, regulators and retailers for more sustainable production and consumption. Residencies, for example, could be encouraged that involve environmentalists, community activists, and social entrepreneurs unfamiliar with makerspaces, to open-up the imagination, ideas, networks and skills of all concerned. So, these spaces can be seen as mobilisers of political alliances as well as incubators for entrepreneurship.

Ultimately, people have to find their own way to sustainability, and it always helps if the path is fun, exciting and fulfilling for them. The relevant tools, resources and activities for doing this in makerspaces need to be laid out conveniently for participants. Improved sustainability might be a secondary, satisfying feature to projects and involvement in activities motivated by other reasons. A measure of success over time will be if makerspaces are not dedicated specifically to sustainability, but rather to creating a community presence and space, if they become the place to which people turn locally for personal and social development, with sustainability an intrinsic part of this process.

How can sustainability initiatives prototyped in makerspaces spin-out into the wider world?

Makerspaces can act as a radar for sustainability ideas circulating globally through networks and on 'making' platforms. Makerspaces can develop ideas and examples circulating globally, and they can adapt and emulate them in local situations and contexts. They can promote the more relevant and interesting advances in circular economy practice and green materials options to local businesses.

Workshop participants discussed how the characteristics of the sustainability 'thing' created in makerspaces affects the way it moves outwards into communities and businesses. It was felt that there are several paths for diffusion, depending on the 'thing' developed, each with its own needs. Replicable outputs may take the form of devices, objects, practices, attitudes and more. For instance, with the example of

upcycling: If the 'thing' is a practice, like upcycling furniture, then the processes for moving it beyond the makerspace could be through training activities, and would take time, as people developed the skills and put them into practice. If the 'thing' in focus is rather upcycled furniture objects, then diffusion of the objects might work through the participants commercialising the activity and diffusing objects through sales.

The prototyping activities prevalent in makerspaces cultivate many intangibles whose movement beyond the space can be significant for sustainable developments. These intangibles could be skills, experience, knowledge, people, issues, or ideas generated through prototyping projects, relevant for advancing sustainable developments in local communities and businesses. With the example of upcycling practices, the intangible skills and ideas underpinning the practice are recognised and valued, and captured in programmes to train others in that practice. It is important to acknowledge the cultivation and movement of these intangible things and plan for the particular characteristics of their circulation as well as maintenance.

Makerspaces can help by seeking partnerships and alliances with groups that have the capabilities and resources to connect with the communities, businesses, and institutions embedded in the social worlds into which the things from makerspaces are seeking to diffuse. And shared learning and alliances are needed, not simply for diffusion into social worlds, but to play a part in transforming those worlds and making them more sustainable.

Practically, this means not only documenting and learning about the products, projects, skills and so forth incubated in makerspaces, but also documenting experiences with diffusion outside makerspaces, and sharing knowledge about the who, what, why, where, how and when of working with allies in communities, business, and institutions. Whether this is through instruction manuals and guides, videos about projects, testimonies of people, social media fora, themed meet-ups, analytical reports, stories, or other means, an open source, commons-based platforms

needs to develop social tools and resources for navigating and negotiating diffusion pathways.

Workshop participants noted how important it was to appreciate the longer time spans needed for the diffusion of ideas and technologies. Some initiatives may move quickly and are very visible while other initiatives may diffuse much more slowly; it is less easy to see the hand of the makerspace in promoting these ideas. That said, the hosting of public events, design fairs, or entrepreneurship days on the theme of sustainability, for example, can be organised relatively quickly, and immediately engage a wider audience of potential adopters, partners, and investors. We already see this in the buzz at Maker Fairs. But building on those encounters, and creating networks, partnerships and alliances for follow-on activities takes time, resources, and capabilities. Prototyping through to product development takes time, as can involvement in a local regeneration initiative. One example was makerspace facilities being used for modelling and consulting on the refurbishment of a green space,

training people to do the refurbishment, and build the objects needed in the refurbishment. All sides need to recognise the patience and time required.

Discussed in this way, it becomes apparent that diffusion beyond casual exchanges at events like ours requires an extension to makerspace capabilities, beyond design, tools and making, and into community and business development. Of course, all this activity requires people, commitment, energy and resources and can take away from what is perceived as the key focus.

3. How can alliances with partners help makerspaces influence public debates about sustainability?

As with the other questions, the discussion went deeper than naming specific allies or partners for influencing public debates. Participants considered which public debates makerspaces felt they could meaningfully engage with. There was recognition that it was hard to be prescriptive about specific partners, and that alliance building is driven by the points that makerspaces wish to debate, the situations they find themselves in, and the resources they can bring to those debates. Partners and alliances can only then be sought, and will more likely involve building upon or joining in with existing initiatives, and contributing a maker element to those alliances.

One public debate where makerspaces might fruitfully contribute is notions of citizenship and people's rights and responsibilities in a heavily manufactured world. Makerspaces cultivate new meanings and belongings for people in relation to objects, activities and other participants: what does it mean to be a maker (or fixer), to belong to an open source project collaboration, to a workshop with an ethos for sustainability, and/or to a global movement committed to empowering people through access to tools. How these questions relate to notions of technological citizenship is something that could be discussed. These discussions form the basis of

oversight of and participation in technological developments, production systems, and new consumption patterns, since they provide insight, confidence and pathways to action. This point acknowledges that some of this activity is already implied in makerspaces; it is simply not recognised as citizenship. What is currently seen as 'tinkering' or prototyping, might simultaneously be an act of technological citizenship in the making, and becomes a new form of citizenship when it connects to issues like sustainable developments.

Thus, makerspaces can also contribute to debates about ecological citizenship, through activities that explore peoples' place within the making, consuming and disposal of things reliant upon our material world and connected within complex ecosystems. This is already apparent in debates about how the relations of production and consumption might be reconfigured, such as through initiatives in local circular economy. Activities might, for example, be staged for citizen-material-scientists exploring the resources available in their bioregion and the purposes to which they might be put in substitution for unsustainable material consumption.

The commons was another public issue raised to which makerspaces make a contribution. Makerspace practices in openness and collaboration have resonance with ideas of the commons. Makerspaces often create products that are open source, that is, manuals are provided allowing anyone to make and create the product for themselves, or to build upon the product, for example, with open source software. As such, makerspaces can provide fruitful places for exploring norms, incentives, and practices, looking, for instance, at how practices developed through free software translate into open hardware and the material world, and can contribute to debates about the access, rights, and care for complex commons technologies and resources.

The positive attitudes towards building open source products for use by the commons in makerspaces might support discourses that historically have lamented the destruction of many commons. Environmentalism has long recognised a need to move beyond doom and gloom diagnoses, and there is a reviving commitment to building up the commons as part of meeting other agendas. Makerspaces can support these developments and could bring new possibilities to activism. POC21, which created dialogue based around the development of practical sustainable solutions, provides an example.

The final public issue was the process of 'making' or manufacturing. Beyond the broader question of whether encouraging making is in any way sustainable, discussion considered the advantages of makerspaces relating to mainstream manufacturing, and the space provided for entrepreneurial activity and prototyping services. This was compared to the merits in remaining outside the mainstream, or perhaps attempting some hybrid evolution between the two. The discussion concerned whether collaborating with mainstream manufacturing communities was a better source of influence for promoting sustainability compared to insisting on being part of a movement building new systems. Engaging with manufacturers and markets to try and promote sustainability involves compromises, but has the advantage that

innovations have the potential to diffuse widely. However, this opened up other concerns, such as whether manufacturing communities are interested in partnerships with makerspaces, and, if so, might makerspaces be reduced to a kind of tech shop providing services. There was an overriding vision that exploring how to use more ecological materials and new processes for design and prototyping could be conducted in a commons-based, peer-produced way.

4. What is the question that a makerspace is the answer for?

The point of asking this question was to recognise and reflect on the many assumptions made about makerspaces, including those in preceding questions. Why do we need makerspaces? Why have they emerged? What gap or need or aspiration are they fulfilling? What was going unresolved before, and what are makerspaces seeking to solve now?

We can first note the diversity of makerspaces, makerspace situations, their histories, the activities within them, the motivations of participants, members and sponsors, and the networks in which each sits. Beyond some abstract general features, makerspaces are not really a singular thing. This was also apparent in the diversity of speakers and their goals, despite some high-level shared values.

In many respects, makerspaces are part of a perennial need for communal and unstructured spaces for doing things together. The continued erosion of space in public ownership or control has surely contributed to the increasing popularity of makerspaces. The creativity possible in common spaces has caught the attention of a wide variety of institutions including schools, universities, libraries, museums, business incubators, training providers, development agencies, local authorities, firms, and other institutional bodies. They have all seen in makerspaces a means to reviving some aspect of their traditional activity.

Final remarks

We finish this report with some more personal reflections from the Machines Room workshop within the context of the broader politics of sustainability.

An attractive claim for makerspaces is the provision of unstructured spaces for experimenting with the design and prototyping using the versatile combination of digital fabrication technologies, electronics, and the more conventional tools on offer. The makerspaces aim to create settings where people can playfully and creatively explore new design and fabrication possibilities. There is an ethos of encouraging people to be open, collaborative and imaginative, and to freely pursue their curiosity and aspiration – to 'be awesome', as a slogan popular among hackerspaces puts it.

As a result, directing people along certain (sustainability) pathways in makerspaces appears to contradict the cherished spirit of openness and autonomy found in them.

And yet, we live in a structured world: a world that makes it easier for some groups to access and make use of makerspaces in particular ways, and discourages or excludes the aspirations of other users, actual or potential. Dominant social, cultural, economic and even political relations can and do exercise influence in makerspace activities. The limited gender, class, race, age and educational diversity in makerspaces attest this concern. There is no simple 'openness' that does not reproduce the status-quo of privilege and exclusion implicit in most arrangements, because it takes structured work to challenge this.

Similarly, there are pressures to demonstrate the value of makerspace facilities in terms of start-up incubation and entrepreneurship over social goals. We see, for example, how consumer culture enters makerspaces in the tendency towards the mass personalization of objects, throw away production of 'crapjects' or 'pongos', and inattention to the complex and contradictory scale efficiencies associated with decentralised production. Making could continue to be deeply unsustainable.

This tendency is aggravated in those networks, such as some associated with the Fab Foundation, that lean towards a fairly technocratic philosophy and define specific attributes, or even the tools and behaviours, to be adopted in working areas. For instance, if a bank of 3D printers must be included in every makerspace as a means of spreading certain technical practices and joining an international 'club', then the space for negotiation with members and users – or developed in response to the locality and its needs – will be limited. An emphasis on only some types of making and a formula for spreading these ideas worldwide comes at the cost of versatility, without which sustainability cannot flourish. Of course, these tools are versatile. The Fab Foundation, to continue the example, has carefully chosen a suite of digital design and fabrication tools for making 'almost anything'. And there is an impressive commitment to making the tools as widely available as possible. Nevertheless, one should be aware that even versatile tools carry the likelihood for working in particular ways more readily than others. There may be valid reasons locally for approaching things with other tools in mind and hand. Nor should having the tools and competencies to make almost anything mean one has licence to do so. Nor should these tools become a prerequisite for having a say in what gets made and how it is made.

Both the leaning towards uncritical creative 'openness' and the contrary trend to pin down technical structures potentially obscures the potential for more sustainable outcomes to emerge from the makerspaces. Without strategies within makerspaces to actively counter wider structural influences, then experimentation and development could reproduce rather than transform social mores. Countering these pressures requires strategies for structuring makerspaces for sustainable developments. Examples exist, for example, of how feminist spaces have been organised deliberately to promote diversity and an ethic of care. The layout, vibe and expectations of conduct can be made conducive to the inclusions and considerations central to sustainable developments: care for other people, care for materials, and care for the consequences of fabrication, good and bad. Discussion at the event, shared in this report, indicated how some makerspaces are already working out sustainability strategies in this area.

Any counter-structuring of makerspaces needs to be flexible, place-specific and thoughtful. It would be unfortunate if dogmatic views on sustainability snuffed out the kind of situated creativity and dynamic relationship building identified above. The Machines Room workshop indicates a number of eminently practical ways in which flexible structures makerspaces can adopt in order to cultivate sustainability. Our concluding point is merely to point out that this does not happen automatically, and that considerable effort by people, organisations and institutions hitherto not as committed as our workshop participants is required in order to emulate their activity and achievements.