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REDISTRIBUTED MANUFACTURING AND MAKERSPACES: CRITICAL PERSPECTIVES ON THE CO-INSTITUTIONALISATION OF PRACTICE

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Increasing digital connectivity and an evolving producer-consumer relationship has enabled contemporary shifts in expectations and experiences of products, production and consumption. Furthermore, the recent growth of shared machine shops has brought about a steady increase in access to the means of production at the local level. The convergence of such emergent digitally-connected technologies has become synonymous with hopes of new post-industrial production practices whereby information on how things are made travel globally, whilst the physical production of things occurs locally, on-demand. At this same time, the augmentation and intersection of ecological issues, technological capacities and economic concerns has given rise to the conceptualisation of Redistributed Manufacturing (RDM); the technology, systems and strategies that change the economics and organisation of manufacturing in ways that enable smaller-scale precision manufacturing, reduce supply chain costs, improve sustainability, and tailor products to the needs of consumers (RiHN, 2017).In recent years, proponents of RDM within academia (including the ESRC and EPSRC), industry (Including Digital Catapult, Innovate UK and the Ellen MacArthur Foundation), and policy (Including Nesta and BEIS) have sign-posted makerspaces or shared machine shops, and the communities who use them, as key actors for the practical embedding and progression of the discourse. The targeted endorsement of RDM at shared machine shops has spurred a significant level of interest, inquiry and tension amongst the communities who use them. As the RDM agenda continues to surround shared machine shops, a tension arises between peer-production practices that do and do not subscribe to the agenda. As the RDM discourse develops, so too does a resultant (un)privileging of particular materials, tools, techniques, and personas. The paper questions for what purpose individuals and communities within shared machine shops are engaging with the RDM agenda. In doing so, providing a case study analysis of how material flows, technical attribution, subjective experiences and context become shaped, unraveled, imagined, governed and institutionalized across peer production communities in relation to external agendas. Through a cross-comparative analysis, this paper will introduce and evidence the dominance of a digitally-legible assemblage of practices across UK shared machine shops in relation to the emergence of a digitally-dominant peer production technomyth. Advancing insights into the shifting hierarchies of the economic, environmental, and social concerns of RDM advocates and how such negotiations and co-constitutionary practices play out in relation to shared machine shops

Keywords: redistributed manufacturing, makerspaces, peer production, digital fabrication, networks

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by Liz Corbin & Hannah Stewart

INTRODUCTION

The convergence of emergent digitally-connected technologies and peer production practices has led to aspirations of post-industrial production practices whereby information on how things are made travels globally, whilst the physical production of things can occur locally, on-demand.

At the same time, ever-increasing labour costs abroad, high transportation costs, sensitivity to global production trends, material scarcity, complex supply chains and increased risk have renewed the

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focus on the social and environmental impact of manufacturing and its externalities (Policy Connect, 2015). The augmentation and intersection of such ecological issues, technological capacities and economic concerns has given rise to the conceptualisation of Redistributed Manufacturing (RDM). This is an intentional reconfiguration of the distribution of manufacturing, which seeks to utilise emerging digital standards and practices to transition towards a more sustainable and resilient industrial landscape.

Emergent RDM discourse advocates a transition towards a more sustainable industrial landscape through a recalibration of existing infrastructure and practices (Stewart and Tooze, 2016). From creative commons licensing, to machine sharing, to open APIs; RDM agendas have looked to develop and direct the technical, material and cultural capacities of emergent decentralised production practices in ways that question and restructure how products are manufactured, how waste is managed, and how cultures of consumption operate (Tooze et al., 2014; Corbin, 2015; Policy Connect, 2015; Dewberry et al., 2016). This shift away from globally fragmented supply chains towards more locally oriented, responsive production ecosystems would affect not just products and material flows, but also the distribution of risk and consequence, reward and value (Stewart and Tooze, 2016).

In recent years, proponents of RDM within academia, industry and policy have sign-posted shared machine shops, and the communities who use them, as key actors for the practical embedding and progression of the RDM agenda (Kohtala, 2015; Prendeville et al., 2016). From the networking of digital tooling and the sharing of production waste solutions, to the normalising of certain artefacts, projects and practices – shared machine shops have been positioned as demonstrative sites for RDM proof-of-concepts (Tooze et al., 2014; Distributed Everything, 2017). It is our observation as participant observers within these communities of practice and academic interventions that the targeted endorsement of RDM at shared machine shops has spurred a significant level of interest, inquiry and tension amongst the communities who use them.

As the RDM agenda continues to surround shared machine shops, the tension that arises is between community-based production practices that do and do not subscribe to this RDM agenda. Through a secondary analysis of a national survey dataset and a critical reflection of initial academic programming, this paper will consider how, when and to what impact emergent techno-myths and corresponding national agendas get taken up within shared machine shops. In this paper we will argue that over time, a process of co-institutionalisation has occurred between a digitally-dominant narrative of peer production and a growing national RDM discourse. We will explore how, as individuals and communities find ways to engage within this process of co-institutionalisation, particular hierarchies of technical, material, social and knowledge relations have begun to emerge from within UK shared machine shops.

SHARED MACHINE SHOPS AND THE TECHNOMYTH OF DIGITAL PEER PRODUCTION

In this section we will explore to what extent the emergence of shared machine shops across the UK, and the celebration of particular technosocial practices within them, is privileging a distinct assemblage of technical, material and social actors from the wider arena of community-based production. Through analysing the open dataset of UK Makerspaces completed by Nesta in 2015, we aim to illustrate the technological and material realities that such a technomyth has begun to engender within UK shared machine shops. We will conclude this analysis by asking to what extent the marrying of shared machine shops, and the peer production communities who use them, to notions of digital fabrication so closely may ultimately prompt the homogenisation of culturally complex sociotechnical practices into technologically deterministic modes.

Shared machine shops have been heralded as ‘occupied factories of peer production theory’ – as sites for the realisation of a fourth industrial revolution wherein emergent forms of peer production[1] and grassroots digital fabrication[2] can take hold of previously inaccessible production power towards more democratic ends (Dougherty, 2012; Anderson, 2012; Journal of Peer Production, 2014). Dale Dougherty, founder of Maker Media and token ‘father of the Maker Movement’ reinforces this emerging assumption, explaining it is through the democratisation of digital tools, that ‘making’ has become a universal element of human identity (Dougherty, 2012). This growing narrative is also commonly placed within academic writing on the topic; for example, when Taylor et al. describe ‘makerspaces’ as the most visible manifestations of an emergent maker culture, as “they provide communal facilities in an openly accessible space, giving access to digital fabrication and open electronics, which have been collectively hailed as enabling a revolution in personal manufacturing” (Taylor et al., 2016). The wedding of those peer production practices found within shared machine shops to digital fabrication technologies continues to circulate across the Western world – from academic journals and conferences[3] to popular technology publications and outlets[4]. In echo of Braybrooke and Jordan, we argue that in this way the maker movement and it’s digitally dominant narrative has become a neatly-packaged and widely disseminated way of understanding a myriad of peer production practices presently bubbling up from within shared machine shops throughout the Western world. In keeping with McGregor et al., Braybrooke and Jordan refer to such a phenomenon as a ‘technomyth’ whereby technologies are ‘narrated’ in ways that create a larger story about society whose key component is a determinism of our experiences of the world through our experiences of technology (2017). Advancing from McGregor, Dourish and Bell argue a technomyth acts as a foundational story by which a mythical future is constructed and then predicted simply by inventing it (2011). Dourish and Bell evidence the self-fulfilling nature of the technomyth through an exploration of the narrative that drove contemporary practices surrounding ubiquitous computing in the early 1990s. In this analyses Dourish and Bell argue that the techno-tale of progress which surrounded ubiquitous computing in the early 1990s became itself foundational to scholars in computer science and related fields – framing one’s understanding of ubiquitous computing as a transformational force which would “change social relations, social order and daily life” – thus, in turn, shaping future innovations akin to this image (2011, p. 3).

We wish to argue here that the importance placed upon digital fabrication technologies within such narratives of the revolutionary nature of peer production has begun to form a technomyth about peer production communities and the sociotechnical practices that constitute them; a technologically deterministic narrative wherein computer-controlled and Internet-compatible digital technologies become a definitive frame.

ANALYSES OF THE OPEN DATASET OF UK MAKERSPACES

The open dataset of UK makerspaces, completed by Nesta in 2015, proves a useful mechanism for revealing the types of materials, tools, and users characteristic of shared machine shops across the UK[5]. An analysis of the dataset makes clear that shared machine shops across the UK vary greatly from one to the next. They are formed of diverse communities that consist of a broad range of social actors, from machine manufacturers and material developers to individual practitioners and special interest hobby groups. They are home to a diverse set of tools and technologies, from 3D printers and engineering lathes to jacquard looms and potters wheels. They can accommodate a rich palette of materials, from recycled plastic filament to clay, stone and glass. Yet, what also clearly arises from the dataset is a distinct pattern; a specific subset of material, technological and social actors that hold the foreground across the network of spaces – playing a lead role in shaping the practices that flow within and between these spaces.

Through reflecting on these foregrounded practices, we hope to make tangible the way in which the pervading technomyth of digital peer production has begun to engender within UK shared machine shops. To better illustrate this argument, we share a summation of the Nesta dataset through three interrelated analytical frames: tools, materials, and users.

Tools

There are 16 unique production technology categories represented across the 97 shared machine shops surveyed in the dataset. These categories include: digital fabrication, woodwork, electronics, computing, fabrics, metalwork, plastics, printmaking, photography and film, ceramics, fine metalwork and jewelry, audio and music, science and chemistry, painting and graphic arts, sculpture, and glass. When measuring the relative prominence of each category, a significant disparity can be observed between the number of spaces that cite having the most prominent categories – digital fabrication (62 sites), woodwork (54 sites), electronics and computer (50 sites) – and the number of spaces that cite having the least prominent categories – glass (2 sites), fine metalwork and jewelry (7 sites), and ceramics (7 sites) (refer to table 1, section 1). Furthermore, an analysis of the tools found across the 97 shared machine shops surveyed reveals a total of 185 uniquely different tool types. When measuring the relative prominence of each tool, the prominence of digital fabrication technologies becomes clear as 47 sites house 3D printers, 43 sites house laser cutters, and 30 sites house CNC milling / routing machines. Whereas only 9 sites house welding equipment and only 4 sites house potters wheels (refer to table 1, section 2).

Materials

There are 16 unique material categories represented across the 97 shared machine shops surveyed within the dataset. This includes; wood and derivatives, paper and card, plastics, electronics, fabrics, yarns, paints, inks, metals, ceramics, clay, stone, chemicals, biological or organic, glass, and resins. When measuring the relative prominence of each category; the most cited material categories are wood and derivatives (58 sites), paper and card (56 sites), plastics (52 sites), and electronics (51 sites); and the least prominent are biological or organic (7 sites), glass (1 site), and resin (1 site) (refer to table 1, section 3). Again, note the significant disparity between these two poles.

Users

Out of the 97 surveyed shared machine shops in the dataset, 60 spaces contributed gender-related data. From these 60 spaces 55% registered a membership that was equal to or greater than 70% male. Only 18% of spaces that contributed data cited a membership that was equal to or greater than 50% female (refer to table 1, section 4). Furthermore, out of the 97 surveyed shared machine shops in the dataset, 49 spaces contributed data relating to the representation of ethnic groups across memberships. From these 49 spaces 96% registered a white majority, with 78% of spaces citing a membership that was equal to or greater than 80% white. For all other ethnicities – mixed or multiple ethnic groups; Asian or Asian British; and Black, African, Caribbean or Black British – all but one space cited a minority representation, with most spaces citing less than 20% representation across all groups (refer to table 1, section 5).

Out of the 97 surveyed shared machine shops in the dataset, 48 spaces contributed data on user-types. User-types include; student, hobbyist, visitor or observer, start up, sole trader or micro-business, corporate or large organisation, teacher, and SME. When measuring the relative prominence of each user-type; the most prominent user-type is hobbyist with 25 sites citing hobbyist as the majority of their membership; and the least prominent user-types include SMEs and Start ups, with 2 sites citing Start ups and zero sites citing SMEs as the majority of

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their membership (refer to table 1, section 6). Out of the 97 surveyed shared machine shops in the dataset, 52 spaces contributed data on activity-types. Activity-types include; to socialise, to receive training, to get an introduction to making, to make something specific, to prototype, to make one-off pieces, to network or find a maker/partner/designer, and to do small-batch production. When measuring the relative prominence of each activity-type, the most prominent activity-types are to socialise (21 sites citing this activity-type as the majority of their membership) and to receive training (18 sites citing this activity-type as the majority of their membership); and the least prominent activity-type is small-batch production, with one site citing this activity-type as the majority of their membership (refer to table 1, section 7).

Section 1. Relative prominence of cited production technology categories	
Production technology categories	*Number of spaces citing this category*
Digital Fabrication	62
Woodwork	54
Electronics	50
Computing	41
Fine Metalwork and jewelry	7
Ceramics	7
Glasswork	2
Section 2. Relative prominence of cited tools	
Tool types	*Number of spaces citing this type*
3D printers	47
Laser cutters	43
CNC milling / routing machines	30
Welding equipment	9
Potters wheels	4
Section 3. Relative prominence of cited materials	
Material categories	*Number of spaces citing this category*
Wood and derivatives	58
Paper and card	56
Plastics	52
Electronics	51
Biological or organic	7
Resin	1
Glass	1
Section 4. Gender representation across membership	
Percentage of spaces	*Percentage of membership*

55% of spaces	≥ 70% male
18% of spaces	≥ 50% female
Section 5. Ethnic group representation across membership	
Percentage of spaces	*Percentage of membership*
96% of spaces	> 50% white
78% of spaces	≥ 80% white
69% of spaces	< 10% mixed or multiple ethnic groups
76% of spaces	< 10% Asian or Asian British
68% of spaces	< 10% Black, African, Caribbean or Black British
Section 6. Relative prominence of cited user-types	
User-type	*Number of spaces citing the user-type as a majority of membership*
Hobbyist	25
Students	8
Visitors and observers	7
Sole traders and micro-businesses	3
Start ups	2
SMEs	0
Teachers	0
Corporates and large organisations	0
Section 7. Relative prominence of cited activity-types	
Activity-type	*Number of spaces citing the activity-type as a majority of membership*
To Socialise	21
To receive training or learn a skill	18
To make something specific	17
To get an introduction to making	11
To prototype	9
To make one-off pieces	9
To network or find a maker/partner/designer	3
To do small batch production	1

Table 1. Analyses of the open dataset of UK makerspaces

THE MANIFESTATION OF A TECHNOMYTH

Analyses of the UK makerspace dataset shows how a dominant assemblage of user, tool, and material has emerged across the UK shared machine shop network. The dataset proves a useful mechanism and evidence base to demonstrate tangibly how a

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distinct assemblage of social, technological, and material actors has begun to form within and between shared machine shops in the UK, mirroring the dominant technomyth of digitally legible peer production. We argue that the UK's emergent culture of digitally dominant peer production and this increasingly homogenous set of practices are therefore entangled within a cyclical dynamic of producing and being a product of the technomyth of digital peer production.

As this technomyth continues to encapsulate shared machine shops, so too does a vision of future community production predicated upon computer-controlled and Internet-compatible information technologies. In light of this, we argue it is crucial to consider to what extent similar-yet-different open access community-based workshops risk becoming excluded from the mix because the sociotechnical practices and communities they seek to support are outside of those which are digitally legible – reflecting on the impacts this exclusion may have upon the wider UK shared machine shop community. Consider, for example, to what extent those many open access print studios,[6] shared bike shops,[7] sculpture workshops,[8] and open wood / metal workshops[9] that mirror the organisation and governance models of shared machine shops yet remain largely absent from the growing technomyth of digital peer production. Many such sites operate based upon an open access model – each offering full access to workshop facilities and peer-to-peer communities at a cost comparable to those of shared machine shops. Many operate based upon a members-led governance model and shared-use policies whereby members not only share access to the workshop and its facilities, but also skills and technical know-how freely with one another. The core distinction is the communities of practice these spaces seek to support (printmaking, carpentry, blacksmithing, ceramics, and book arts, etc.) and therefore the types of production technologies and sociotechnical practices they house. In light of this, there is a need to deploy a critical lens to the formalisation and institutionalising affect of the digital peer production technomyth. For in contrast to the revolutionary proclamations of the digital peer production, there is growing criticism that such categorisations, in practice, are in fact lending to the systematic homogenisation of a heterogeneous set of cultural practices (Maxigas, 2014; Nascimento, 2014; Braybrooke and Jordan, 2017).

In *Challenging the Digital Imperative*, Wyatt argues 'people who choose not to use digital technologies remind us all that things "might have been otherwise"' (Wyatt, 2010, p. 11). For Wyatt, non-users play a crucial role within digital cultures as they 'sketch out alternative development paths that technologies could have taken' (Wyatt, 2010). We argue that the posing of alternative development paths, and the resultant challenge to technologically deterministic assumptions which occur in tandem, can engender what Maxigas terms *critical faculties* within a community – particularly when made by sophisticated non-users of a community (Maxigas, 2017). As Maxigas argues, even if the overall critique-and-recuperation logic of capitalism[10] cannot easily be challenged, everyday rejection of micro-changes – for example, the non-adoption of commodified technologies by non-users – can possibly help a community bring to light and navigate these problems through the all- important lens of critical reflection (Maxigas, 2017). In keeping with such arguments, we find concern in the growing dominance of the digital peer production technomyth across UK shared machine shops. As the evolution of such technotales have often lent to the homogenisation of heterogeneous sets of cultural practices (Maxigas, 2014; Nascimento, 2014; Braybrooke and Jordan, 2017). We therefore ask: to what extent might a loss in the diversity of users or the heterogeneity of sociotechnical practices that constitute UK shared machine shops lead to a loss in connection between adopters and non-adopters? And what impact might this loss of connection have on a community's critical agency and capacity for reflexivity and reflection?

THE EMERGENCE OF REDISTRIBUTED MANUFACTURING AND FUTURE

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MAKERSPACES

In the following sections we will illustrate how the technomyth of digital peer production is aligned with, mirrored by and legitimated through the dominant narratives around the future of manufacturing (Berg, 2016), with both redistributed manufacturing and distributed production proponents championing and depending upon the assumption that digital technology is equal to efficiency and accessibility as well as a redistributive force for the 'democratisation of manufacturing' (Lawton, 2017). Advocates of digital peer production within shared machine shops gravitate towards, take up and support the formalising of a relationship between shared machine shops and redistributed manufacturing. We argue that as this coupling strengthens a co-institutionalisation process occurs wherein both the technomyth of digital peer production and the realisation of redistributed manufacturing practices mature and are formalised. We argue this process is beneficial in terms of its potential to aid in the legitimisation and expansion of peer production practices specifically, and shared machine shops more broadly. Yet, also argue that this benefit is not without danger. For should notions of RDM and peer production continue to mature through the technologically deterministic narrative of digital technologies, so too will an othering process wherein less Internet-compatible, digitally-driven actors and practices are rendered invisible.

The concept of Redistributed Manufacturing does not have a standard and widely accepted definition (Escalante and Rahimfard, 2016). The initial appearance of the term is in the 2013 UK EPSRC (Engineering and Physical Sciences Research Council)[11] RDM workshop report where it has the broad working definition of "technology, systems and strategies that change the economics and organisation of manufacturing, particularly with regard to location and scale" (Pearson, Noble and Hawkins, 2013). Subsequent definitions emphasise 'localised production' (Soroka, Naim, Wang and Potter, 2016), 'customisable production units' (Prendeville, Hartung, Purvis, Brass and Hall, 2016), decentralisation (Harrison, Ruck, Medcalf and Rafiq, 2017) regionalisation (Munguia et al., 2016) and geographic dispersal (Soroka, Naim, Wang and Potter, 2016).

The characterisation of RDM, refers to an increasingly distributed and varied manufacturing ecosystem and 'on-demand economy,' where the factory of the future may be 'at the bedside, in the home, in the field, in the office, and on the battlefield' (Foresight, 2013). These local manufactories and the associated decentralised business models change both markets and supply chains, with wide ranging implications and challenges (Pearson, Noble and Hawkins, 2013), it is in emphasizing these societal impacts that the 're' became part of the naming convention. The understanding of distributed manufacturing itself has been historically fluid, evolving from MacCormack's smaller scale plants serving regional markets (MacCormack, Rosenfield and Sloan, 1994), to decentralised production approaches (Kühnle, 2010), manufacturing at the point of use (Devor et al., 2012), and mass customisation and digital manufacturing (Kohtala, 2015) now being synonymous with orchestration of manufacturing though the cloud and digital networks (Zaki, Theodoulidis, Shapira, Neely and Teple, 2016).

NEGOTIATING NATIONAL / GLOBAL AGENDAS AND INTERESTS

The opportunities of the conceptualisation of redistributed manufacturing, moving toward shipping data rather than materials and producing closer to the point of need is a global one, responding to global imperatives and the opportunity of computational networks. However, the research funding infrastructure endeavoring to facilitate such a shift is itself subject to borders and national agendas, enabling a shift towards more sustainable future distribution of manufacturing in a targeted manner that reflects the interests and perspectives of both the funder and the funded. The EPSRC funded Redistributed Manufacturing Networks were funded in order to stimulate an

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academic agenda around these ideas, including both academic and user communities in order to better position the UK to respond to the challenges and opportunities facing the UK's manufacturing industry (EPSRC, 2017a)[12]. The breadth of the challenges and potential impacts of RDM, was recognised by RCUK to go beyond the technological, and an advisory group was appointed that included both the funding body EPSRC and representatives from the ESRC with a focus on the socio-economic implications of changing how and where we make things (EPSRC, 2017b).
There is little doubt the activity and outputs of these six networks (EPSRC, 2017a) affected the discourse on distributed production, both with and without the prefix of the 're'. Collectively the RDM networks commissioned over 35 feasibility studies, ran in excess of 20 events and have published in a range of journals, capturing the interest and efforts of a diverse range of UK academics from multiple disciplines including engineering, urban development, design, sociology, computer science, etc. (EPSRC, 2017b). The RDM agenda alongside recent technology and social imperatives has given new relevance to earlier academic works on the orchestration of production and work, with the joint position paper of the EPSRC RDM networks calling for these historic frameworks and academic works to be adapted and reimagined in order to better grasp and respond to the phenomena of distributed production (Srai et al., 2016).

In framing, reframing and interrogating the prior works on distributed production, stimulating new research with an emphasis on enabling a UK benefit from RDM and developing and delivering targeted interdisciplinary end user research it is clear that emergent RDM discourse both produces and is a product of an agenda for the intentional redistribution of knowledge and capital. This intentional redistribution is in tension and sometimes in conflict with other iterations or possible futures of distributed manufacturing. Although the RDM networks met frequently over their two-year funding period to discuss and align conceptualisations of RDM and the associated challenges, opportunities and enablers it would be remiss to portray them as in agreement, as each network has a distinct understanding, disciplinary lean, and agenda.

SHARED MACHINE SHOPS AND REDISTRIBUTED MANUFACTURING AS A CO-EVOLUTIONARY

The Future Makerspaces in Redistributed Manufacturing network (FMS RDM)[13] set out with the explicit intention to establish the role of makerspaces in enabling a transition to redistributed manufacturing, stating in the proposal that the characteristics of RDM were already established within makerspaces and maker culture. This proposal and pitch framed makerspaces, and shared machine shops more broadly, as being an emerging phenomena akin to the early internet – a networked, distributed and ad-hoc type of manufactory – embedded within neighborhoods and communities, changing the dynamics of who had access to make and manufacture. In recent years, proponents of RDM within academia, industry and policy have sign-posted shared machine shops, and the communities who use them, as key actors for the practical embedding and progression of the discourse, as site within which to 'hothouse' sustainable and innovative new approaches to manufacturing and distribution (Prendeville, Hartung, Purvis, Brass and Hall, 2016). From the networking of digital tooling and the sharing of production waste solutions, to the normalising of certain artefacts, projects and practices that promote redistributed practices – shared machine shops have been positioned as demonstrative sites for RDM proof-of-concepts, the future of work and livelihoods, economic saviors and regional regenerators. Therefore, the FMS RDM bid stated it was "timely to explore and define the potential of makerspaces to become an integral part of UK manufacturing and service industries, and to evolve as key contributors to re-distributed manufacturing in its widest sense" (Royal College of Art, School of Design, 2015).

In the context of the UK it becomes clear notions of

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peer production are becoming entangled within and constituted by digital fabrication technologies. Sifting community-based production cultures through a definition of peer production that holds a dependency on digital fabrication and Internet-compatibility and thus generating a highly curated viewpoint of community production that formalises distinct sociotechnical norms. For advocates of this technomyth, the concept of redistributed manufacturing along with its corresponding agenda and institutionalised constituents becomes a useful mechanism in pursuit of the tale.

This resonance between the technomyth of digital peer production spaces and the maturing dialogue of redistributed manufacturing can be seen in an analysis of the tools, practices and knowledges highlighted by authors of RDM discourse (refer to table 2). The descriptors of RDM practices and tools lack specificity, leaning instead towards to the abstract and conceptual (Harrison, Ruck, Medcalf and Rafiq, 2017, p. 3). Whilst the tools themselves remain largely ambiguous, it's important to recognise the benefits of redistributed manufacturing are characterised by sustainability, smaller scale production and shared prosperity, which are not exclusively digitally dependent aspirations. Yet, the USP and value-add within the RDM narrative currently centers around the mass customisation of products and supply chains and remains dependent upon increasing data capture and accumulation – thus favoring future sites of production that are computer-controlled and Internet-compatible.

Citation	Tools	Practices	Knowledge sets
Harrison, Rafiq and Medcalf, 2016	Cyber-physical systems. These include next-generation manufacturing, logistics and supply chain management, smart networks, automation and big data.	Networked machines to leverage collective computing power and interconnectivity with the end goal of intelligent and responsive systems interconnected industrial environments.	The anticipated systems will govern themselves, take preventative or corrective actions without human intervention and coordinate supply chains automatically. Facilitate replicability of manufacturing quality across a network of manufacturing sites by removing communication and distance as an obstacle. Teams are likely to have fewer operators with high technical expertise per member.
Soroka, Liu, Han and Haleem, 2017	Machine tool monitoring systems, network based control systems.	Manufacturing: improved demand forecasting, supply chain planning, sales support, developed production operations, web search based applications, data mining, machine learning, neural networks, social network analysis, signal processing, pattern recognition, optimisation methods and visualisation.	Wide variety of tools, techniques and disciplines could make it difficult if not impossible for a manufacturing (non-IT) SME to implement without expert guidance.

Munguia et al., 2016	Office-friendly 3DPrinting units.	Two different possible strategies: manufacturing close-to-patient, and manufacturing in-the-home.	Resident expert with enough basic knowledge of non-electronics manufacturing and assembly would be "outsourced" to the patient's home. 3D file integrity checks, 3D printing trials and materials testing before the medical device files are released to the public.
		A strong link between mass customisation and distributed manufacturing was identified in the literature and some cases. Mass customisation would implicate changes on a facility layer which is still driven by the incentive to produce high volumes and cut costs.	The term 'redistribution' in this context means a higher involvement of the consumer in the process of design or production.
Ford and Minshall, 2015		On-demand, mass personalisation, localised, flexible and more sustainable production.	impact of 3DP on RDM and vice versa will depend on a variety of interconnected aspects that go beyond the technical performance issues.
		For a decentralised manufacturing system to succeed, the technology must be robust and reproducible and there must be significant process and product understanding.	The relationship between the variation in properties of the starting material, the control strategy for manufacture and the product features must be well understood.

Table 2. A taxonomy of RDM technologies, practices and know-how

The RDM emphasis on cyber-physical systems that can 'govern themselves, take preventative or corrective actions without human intervention' (Harrison et al., 2016) has found a human-friendly front within shared machines shops and the technomyth of digital peer production, with both narratives mutually legitimising the other. Moreover, notions of redistributed manufacturing compliment, formalise, legitimise and augment the institutionalisation process that the fascination of peer production amongst shared machine shops has already begun.

This marrying is a technologically deterministic institutionalisation process that, on the one hand, has proven a useful mechanism enabling communities of users to take up and co-opt RDM agendas, informing and shaping the understanding of RDM practices held by the funding bodies through participation in its early definition. On the other hand, RDM and its kin narrative 'industry 4.0' sacrifices those cultural and social practices of community production that do not fit within the internet-compatible, digitally-driven techno-normative modes of digitally powered peer production.

The institutionalisation of community production by and through the wedding of shared machine shops and redistributed manufacturing could be considered as predatory. We position the FMS RDM

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network as a mediator of this dynamic, delivering a program of work that sought to foreground RDM processes and practices within shared machine shops and to explore, test and validate what relationship between RDM and shared machine shops might be useful, possible, and preferable – informing both the role of the shared machine shop and the definition of RDM.

Although the research program was around establishing the roles of future makerspaces in redistributing manufacturing what it delivered in parallel was a program around futuring in makerspaces, questioning the futures presented and promised for makerspaces to date, and valorising and championing a future makerspace (or shared machine shop) that was connected, networked and capable, moving beyond makerspaces as serendipity engines and building them a formal and post-symbolic role within the future redistributed economy. This narrative of redistributed manufacturing and future integration into the manufacturing and policy landscape, had a resonance with a core set of shared machine shops. While many spaces would attend, discuss and participate within the symposiums and events, a core few took their involvement further – proposing studies, partnering with academics, and reorienting or reframing the activity they already undertook in alignment to the emerging RDM discourse. In this way the programme evolved over time, both in network makeup and in its understanding of what RDM and its enablers within makerspaces was and also what it could and should be.

FMS RDM allowed shared machine shops to self-select and self-identify as aspiring towards being part of the future distribution of manufacturing. This is not to say many weren't excluded, the narrative of RDM favored spaces where design decision-making was evidenced as happening, where the aspirations of the makers within them extended beyond the doors of the lab, beyond hacking and making domestically to making, producing and manufacturing at scale. The types of sociotechnical practices valorised by RDM includes those that build upon the digital distribution of product and process data in a way that is compatible with the creation of goods or services – predictably most often centered around digital fabrication technologies such as CNC, 3D printing, laser cutting, and distributable licensing.

During the final stages of the FMS RDM project, a final study (known to its participants as the 5×7) was commissioned that took the reports and insights generated by the five feasibility studies and exposed them to the critique and feedback of a panel of makerspaces to establish if the insights and experience were familiar to them, how they could inform the practice of RDM within their makerspace, and if the state of makerspace making and manufacturing practice rang true to their primary experience as makerspace founders, managers and users. This taking place two years after the initial Nesta dataset again set out to elicit written responses from spaces themselves, asking them to self-report the occurrence and relevance of the practices identified within their shared machine shops, and asking them about their aspirations and challenges in adhering, or not, to RDM and the associated peer production digitised processes. The participants in this study were selected based on geographic spread and their varying levels of participation in the FMS RDM network[14].

When asked explicitly how the RDM agenda applies to their space and its utility, responses varied from highlighting that "the jargon is exactly what 'makerspaces' run away from," to "[we] can be said to be naturally adopting the characteristics of a redistributed manufacturing ethos though still in a nascent stage," through to "the concept is at the core of what we do" (Corbin, 2018). Even those spaces that did not firmly identify as enabling RDM, did consider themselves to be contributing to a diversification of the manufacturing landscape, "we're also already seeding the metropolitan manufacturing ecosystem," "this vision fits well with our future goals for [our space] and we hope to become a 'hothouse' for RDM," "[we] could certainly be described as a dynamic production environment capable of creating customisable or multivariant products" (Corbin, 2018). Certain spaces aligned fully their short-term strategies to that of the RDM agenda, "as we have a research interest we are making-real this prediction. We are excited by the potential of these trends so are steering ourselves towards them as goals and select members who share these aims" (Corbin, 2018). Many recognised their own positioning as champions and purveyors of RDM discourse and demonstration, "[we have] been positioned over the last five years to be at the forefront of this 'new' wave of thinking. We've been highly active in propagating that concept and are now recognised as being key stakeholders … in how this will develop over the coming years" (Corbin, 2018). At multiple points RDM was highlighted as a stabilising force for shared machine shops, a raison d'être that could take a somewhat fragile business model and provide bread and butter income. For some spaces the research itself provided an income generation strategy, for others the validation of existing practices and a name to hook themselves onto proved useful. To this end, survey evidences how where and when RDM is taken up by a shared machine shop it's because there has been a significant amount of agency from within the space to make this happen, with members championing the RDM concept. Respondents noted the challenges in aligning a space's activity in this way, as one put it 'difficulty comes from the peripatetic nature of institutional support. We find ourselves moving from one partner's agenda to the next and losing energy when projects lose funding' (Corbin, 2018). Therefore, we argue that the adoption of and alignment to the RDM concept is a voluntary and active institutionalisation process, a co-option rather than externally imposed.

In regard to the institutionalisation of shared machine shops, we would argue that the situation and dynamic is not as binary as many would assume. Who and what sets the course is a multi-actor game. Habitual practices and the evolution of such is a process of co-option directed by multiple stakeholders and thus a combination of multifarious agendas. Yes, RDM as a concept was initially developed by academics, universities and research councils and is now of interest to various governmental departments, but the concept itself in this initial form is only that of a kernel – a seed of a concept, and one that is far from fully developed. In many ways, the current fluidity and ambiguity in how both shared machine shops and RDM are defined has allowed those actors involved significant agency in the shaping, defining and co-opting of two concepts – evolving the shared narrative over time in step with the maturation of agendas and visions. RDM is brought to life, realised, twisted, redirected, refuted through real-life practice by individuals, groups and organisations in situ, given their own interests and agendas. We therefore argue that in positioning those who run and use shared machine shops as being unaware of and naive to external agendas (unable to push back, reframe, re-appropriate, take advantage of, etc.) is undermining and discrediting those individuals.

In interrogating the respondents of our study as to how each shared machine shop arrived to an alignment and foci with RDM it became apparent just how 'slippery' shared machine shops are. Respondents reported that the "biggest challenge is always embedding something into the culture of the space" because there exists an inherent tension within shared machine shops as to 'who' – if anyone in particular at all – makes the decisions for a space and its community (Corbin, 2018). The highly decentralised governance and organisation models of most shared machine shops means that the power and influence of any agenda will be limited – with RDM certainly being no exception to this rule. Decisions as to orientation of the space and its practices are driven by "both ideological and economic" reasoning, "100% of the direction is set by the members' interests, and it's just that some of those interests are 'pay the rent'" (Corbin, 2018). Of those spaces that can be evidenced to have taken up the RDM agenda, incorporating it into their operating practices and rhetoric a clear alignment – both in terms of ambition, sociotechnical practices, and everyday financial incentives – can be observed. We therefore argue that where RDM is getting taken up by shared machine shop communities it is not out of externalised pressures to do so, but rather it is because there has been a significant amount of agency from within the community itself – it is a voluntary, active, and co-optional process of institutionalisation. Therefore, we would like to argue against the narrative undercurrent we find within even critical maker discourse, the notion of the makerspace as underdog, subject to the dominant agency and agendas of institutions. We argue this discredits and undermines the agency and influence such spaces and their communities have within the institutionalisation process itself.

CONCLUSION

In many ways, notions of redistributed manufacturing compliment, formalise, legitimise and augment the growing technomyth of digital modes of peer production that surrounds UK shared machine shops. We argue that the institutionalisation of community production by and through the wedding of shared machine shops and redistributed manufacturing should be considered as a process of co-option that is both beneficial and problematic. On the one hand, institutionalisation could mean that the seeds of change are starting to take root and grow. Consider online sharing platforms such as MyMiniFactory and WikiFab, or public/open copyright licensing models like Creative Commons and the Mozilla Public License reaching the critical mass necessary for them to mature into viable, even mundanely normal, components of the production chain. Imagine informal communal production provisions like shared machine shops, Repair Cafés and tool libraries that become embedded in, understood and supported by regulations and policies. Such promising examples could be understood as cases of evolutionary 'niches'[15] that instigate the restructuring of 'regime'[16] constellations (Grin et al., 2010; Smith and Raven, 2012). On the other hand however, early signs of such institutionalisation processes could also be a foreshadow of potentially transformative agents being mediated, enfolded and ultimately asphyxiated by the very institutional structures they sought to change. Such examples could be seen as yet another display of incumbent regimes exerting their tendencies towards not systems change, but system stabilisation and reproduction (Geels and Schot, 2007).

We therefore ask what are the potential impacts of such a co-constitutionary dynamic between shared machine shops, a national RDM agenda, and a growing technomyth of digital peer production? Within his analyses of social movements, Hess applies three hypotheses as a framework for analysing technology- and product- oriented movements (TPMs) – two of which we feel are pertinent to this discussion. Firstly, the 'private-sector symbiosis' hypothesis postulates that the emphasis on technology and product innovation leads to the articulation of social movement goals with those of inventors, entrepreneurs, and industrial reformers. A cooperative relationship emerges between advocacy organisations that support the alternative technologies/products and private-sector firms that develop and market alternative technologies (Hess, 2005). This speaks to and compliments the benefits of 'collection action framing' as argued by Söderberg when he states 'it is not obvious which side in a conflict can draw support from a deterministic narrative' (Söderberg, 2013, p. 1289). As Söderberg explains, 'collective action framing' within social movement theory refers to how social movements construct narratives interpreting the world in a way that gives meaning to their struggles. This dynamic recognises the active role of social movements themselves as producers of meaning, not just recipiants of prescribed narratives and myths, but co-constitutors of that meaning-making and narrative framing. Framing can be understood as a process through which spaces of struggle are continually created, contested and transformed (Snow and Benford, 2000), and both RDM and the digital peer production technomyth can be understood as forms of 'collective action framing'. As Söderberg argues, what technological determinism influences is the freedom of maneuver of the political adversary. If a social movement can claim such a position in their

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collective action frame, then it might contribute to grassroots mobilisation. The collective action we evidenced through the two forms of survey included above showcases elements of how symbiosis with institutions and formal agendas brings legitimacy and visibility to the 'grassroots causes' and motivations of shared machine shops, acting as a stabilising force to enable greater impact and a common ambition.

While much could be gained, we also need to consider what can be lost through the continued entanglement of the technomyth of digital peer production and RDM agendas within UK shared machine shops. As Söderberg's points out, the literature on collective action framing has been criticised for its relative neglect of how pre-existing cultures influence framing processes (Söderberg, 2013; Hart, 1996). As Plekhanov notes, if we consider how a person who disagrees with the given phenomenon and technomyth may be affected – it is likely that their energy will be lessened by knowing that their resistance is futile, that they and their practice is something which is less legible and less valorised in the context of an emerging homogenous agenda (Plekhanov, [1898] 1940). We see this evidenced in the decreasing visibility of non-digitised making practices evidenced in both survey analyses. As we argued above, we agree with Wyatt and Maxigas, that the importance of retaining a connection to non-adopters should be seen as crucial to a community preserving its analytical capabilities – or critical faculties. Without that, spaces and actors within them may quickly lose the sense of agency that Boltanski and Chiapello (2005) deem crucial when closing their work with a call for 'sociology against fatalism' (Boltanksi and Chiapello, 2005, p. 536)[17].

Using the 'incorporation and transformation' hypothesis within social movement theory, Hess postulates that there is a tendency over time for established industries to absorb the innovations of the TPMs, but in the process they also alter the design of the technologies and products to make them more consistent with existing technologies and with corporate profitability concerns (Hess, 2005). Hess concludes that community demands and development of technologies happen in a *private-sector symbiosis* (Hess, 2005). Even where these movements succeed in pushing a technology to the consumer market, they are recuperated in the process, resulting in 'object conflicts' about their proper design and use (Söderberg and Delfanti, 2015). The academic and community positions on RDM and the varying adoptions, co-options and rejections of it as a term through the FMS RDM project reflects this pattern of object conflicts – going from an outside critique of the consequences of modern manufacturing and global supply chains, to a recuperation as a hopeful narrative of future manufacturing and the implementation of such through an entanglement with shared machine shop communities through tests, trials and studies, and ultimately resulting in increased digital legibility and commodification of both the communities of practice involved and RDM as a praxis. Maxigas argues the process of critique, recuperation and implementation entangles technologies and the communities who use them within an endless cycle of commodification resulting in the loss of trust between users and technologies (Maxigas, 2017). This cycle of co-production and co-option presents a dilemma in considering how users could possibly more critically navigate, even infiltrate, such an endless cycle. As Maxigas argues, in his study of technology-oriented and product-oriented movements, understanding the critiques of users within shared machine shops and their recuperation by commodified means is instrumental for mapping the dynamics between political struggles and the technological, cultural and ethical innovation driving the evolution of capital. Without criticality, mediation and conflict between peer production communities and firms remain highly vulnerable to recuperative logics.

We therefore argue there is a need to retain non-users within peer production communities and a danger of excluding them through the increasingly formalisation and co-institutionalisation of the digital peer production technomyth and RDM agendas. A

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loss in diversity within shared machine shops could lead to the loss of connection between adopters and non-adopters. Which could, in turn, result in a loss of critical faculties, agency and awareness. Without a diversity of practice and of community, UK shared machine shops (and the peer production communities who use them) are at risk of losing the ability to remain critically engaged and involved within the co-institutionalisation process. The risk of UK shared machine shops aligning with the digital production technomyth and RDM agendas is that the default model becomes an echo chamber of homogenous adoption. Whilst we are not arguing that diverse communities are immune to technological determinism, a diverse community can generate a better position for individuals and groups to be more critical and recognise the broader relationships in the landscape. There is a need for critical friction, to highlight the edges and tensions between this increasingly dominant assemblage of practices and those practices which are less visible, less digitally legible or less valorised. Critical friction is productive, it provides the opportunity for social movements to self-check, self reflect, be critical and question the wider impacts of their practices. We conclude by reiterating the need to deploy a critical lens to the co-institutionalisation of UK shared machine shops and the peer production practices that flow within them to national RDM agendas. Further research is needed in order to assess what is gained and what is lost, and how we can better navigate the process of co-institutionalisation.

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NOTES

[1] Following Benkler (2013) and Benkler et al. (2015), we define peer production as a form of Internet-mediated open creation and sharing performed by groups that: set and execute goals in a decentralised manner; harness a diverse range of participant motivations; are particularly non-monetary motivations; and separate governance and management relations from exclusive forms of property and relational contracts (i.e., projects are governed as open commons or common property regimes and organisational governance utilizes combinations of participatory, meritocratic and charismatic, rather than proprietary or contractual, models).

[2] Following Smith et al. (2013) we frame grassroots digital fabrication as the confluence of digital fabrication technologies (e.g. 3D printing, open-source and web-based design tools, electronic kits, computer controlled milling machines and laser cutters), new business models (e.g. ‘personalised manufacturing’), and grassroots movements (e.g. ‘makerspace’ community workshops).

[3] Such as Gershenfeld, 2012; Hielscher and Smith, 2014; Journal of Peer Production, 2014; Richterich and Wenz, 2017; University Arts London, 2017.

[4] Such as Anderson, 2012; Morin, 2013; Hagel, J. et al., 2014; Hatch, 2014; Banerjee, 2015.

[5] The dataset was commissioned by an open tendering process in 2014 by UK think tank Nesta (National Endowment for Science, Technology and the Arts). Researchers Andrew Sleigh and Hannah Stewart, both researchers with a personal background within the UK makerspace scene, undertook the work over a period of four months. This consisted of defining the fields or data desired into appropriate questions, aggregating known locations of spaces through desk based research and ‘snowballing’ the survey through social media and their own networks. The method for the dataset’s framing and the research approach was documented through a series of blog posts on the Nesta website (Sleigh, Stewart, and Stokes, 2015), and both the list of questions and an initial dataset

were released as a public beta, evolving in response to community suggestions. The resulting dataset contains validated details of 97 spaces, with spaces primarily discursively representing themselves. The definition of makerspace established by the commissioner and researchers specifically excluded private workshops and studios, and defined it as an "open access space (free or paid), with facilities for different practices, where anyone can come and make something".

[6] For example, East London Printmakers, London Print Studio, and Spike Print Studio.

[7] For example, London Bike Kitchen, Bike Works, and Access Bike.

[8] For example, London Sculpture Workshop, Glasgow Sculpture Studios, and Cyan Clayworks.

[9] For example, Blackhorse Workshop, Building BloQs, and Makers Quarter.

[10] Following Boltanski and Chiapello (2005), Maxigas defines 'critique' as the unmasking of the hermeneutic contradiction between the meaning of institutions and how they work in practice, making it possible to challenge the reality of reality (Maxigas, 2017). Maxigas then defines 'recuperation' as a cyclical logic in capitalism; whereby on the one hand, critique is absorbed into capitalist ideology and practice, and on the other, things that were previously not part of the capital accumulation process start to be valorised. In this way, capitalism answers to critique through restructuring in a way that simultaneously implements, but also neutralises and eventually undermines that critique (Maxigas, 2017).

[11] EPSRC is the UK government agency responsible for funding research and training in the areas of engineering and physical sciences. The RDM networks are part of the EPSRC's funding theme area of the Future of Manufacturing.

[12] The remit of these two-year funded networks, included; advancing thinking around end user involvement and interest in RDM, supporting feasibility studies and actively seeking contributions from a range of experts and disciplines.

[13] Future Makespaces in Redistributed Manufacturing was an EPSRC funded RDM network facilitated by Design Products at the Royal College of Art. This hub specifically explored the possible roles of makespaces, and other similar informal sites of manufacturing could play within a future redistributed manufacturing landscape.

[14] Our analysis of the Nesta dataset used the prominence of practices evidenced through the discursive response to demonstrate the emerging dominance of a set of peer production practices aligned to the technomyth. This later study with curated participants evidences the extent to which spaces legitimise their practices in a manner that is adherent or counter to both the technomyth and RDM agenda. Given the rich data provided by each participants, we have chosen to again use a discourse to analyse the prominence of a variety of perspectives and practices.

[15] Niches have been conceptualized as protected spaces, i.e., specific markets or application domains, in which radical innovations can develop without being subject to the selection pressure of the prevailing regime (Kemp et al., 1998).

[16] In keeping with Kemp et al., we define regime as "the whole complex system of knowledges, practices, processes, technologies, characteristics, skills and procedures, and institutions and infrastructures that make up the totality of a technology" (Kemp et al., 1998, p. 182).

[17] For as Boltanski and Chiapello highlight, "as a century and a half of the critique of capitalism has demonstrated, the two critiques – the social and the artistic – are at once contradictory on many points and inseparable, in the sense that, stressing different aspects of the human condition, they mutually balance and limit one another. It is by keeping both alive that we can hope to confront the destruction caused by capitalism, while avoiding the

excesses that each of them risks inducing when it is given exclusive expression, and not tempered by the presence of the other" (Boltanski and Chiapello, 2005, p. 563).

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