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3D PRINTING AND UNIVERSITY MAKERSPACES: SURVEYING COUNTERCULTURAL COMMUNITIES IN INSTITUTIONAL SETTINGS

Robbie Fordyce, Luke Heemsbergen, Paul Mignone & Bjorn Nansen

Abstract: *This article reports on an investigation into two experimental "Digismith" workshops held at an Australian university's School of Engineering that aimed to provide open source education in 3D printing to university students and the general public. The research employed semi-structured interviews and surveys of participants that mirrored previous work on 3D printing communities, while our discussion develops assessments of the political economy of the course curriculum and practice. We suggest the social practice of 3D printing arises from a twin tradition of industrial design and countercultural garage-workshops. As 3D printing becomes a more common subject for tertiary and secondary schooling, educators can take lessons from these histories to flesh out curricula. The Digismith workshops were informed by both classical lecture-discussion-application based models of learning as well as problem-based learning and more radical forms of peer-to-peer learning. We found the tensions between these sometime competing pedagogies to illustrate a peripheral, but fluid space interstitial to the teaching philosophy common to tertiary institutions and the more radical hacker maker spaces that the course attempted to emulate.*

Keywords: 3D printing, counterculture education, open source learning, participatory workshops

Introduction

Like many technologies, 3D printing has been propelled by a mix of radical countercultural movements and institutional support. Hacker cultures were fostered in the same computer laboratories at MIT that were funded by the US government to develop ARPANET. Similarly, the Homebrew Computer Club, which was integral in the development of Apple Computers (Wozniack, 2006), would now be recognised as both a space for connected learning (Ito et al., 2013), and a type of Maker Space: a dedicated, community focused space for interested locals to become involved in making and sharing technology. These divisions were catagorised as 'Ronald Regan vs the Hippies' in debates regarding the 'Californian Ideology' (Barbrook and Cameron, 1996). Barbrook and Cameron advocate for revolting against market freedom towards an 'impeccably libertarian form of politics [where information technologies are] used to create a new 'Jeffersonian democracy' where all individuals will be able to express themselves freely within cyberspace' (Barbrook and Cameron, 1996). 3D printing followed a comparable trajectory in that as patents for Stereolithography and Fused Deposition Modelling expired, processes of additive manufacture moved away from large industrial firms such as 3D Systems and Stratasys, to disruptive communities-turned-companies such as Makerbot. At the same time, so called 'DIY making' (Williams et al, 2012) communities and 'maker subcultures' (Ratto and Ree, 2012) that hacked various technologies embraced additive manufacturing in terms of both its direct utility and the ethos of digitally-converged self-sustained autonomous making.

This article locates this countercultural history and ethics in a current attempt by a large teaching and research university in Australia (subsequently referred to as the University) to foster the development of a 3D printing cultural space. 3D printing may currently be on the periphery of higher education curriculum, yet given the ways computing and digital technologies are bound up with the changing structure, organisation and politics of higher education (Selwyn, 2014, pp.125-141), it remains unclear how the potential value of 3D printing in research and teaching may be sustained, or impact upon the countercultural ethics of knowledge sharing.

The university's School of Engineering has held a number of open-access workshops aimed at educating and upskilling participants in 3D printing tools and software, and provides space for interested users. Drawing on data from participation, interviews and surveys, we consider this attempt at kick-starting a Maker culture, noting how other courses may learn from the pedagogical decisions in the 3D printing workshops, and some of the pedagogical assumptions within the course itself. The scope of research covers two series of open-access workshops held on campus as the Digital Blacksmith Summer and Winter Schools (Digismith, 2014). The Digismith workshops were open to all members of the public and provided no course credits, and thus sat at the margins of the curriculum and institution, but ostensibly were designed to more equitably engage a wider community. This article will first address the subcultural/countercultural divide that informs creative 3D printing, it will then explore the pedagogical structure of the workshop, before concluding with reports on participant experiences and speculations on the efficacy of developing countercultural practices and attitudes in institutional settings.

Chief tension: institutional uptake of countercultures

The chief paradox within our research was the tension inherent in the development of an institutional education in 3D printing which was based in practices founded in non- or anti-institutional settings. This paradox has both counter cultural and radical pedagogical elements. As we have defined elsewhere, 3D printing is the social use of an industrial process (Fordyce, 2015). We can build on this, by noting that an education in 3D printing will be involved as much in a cultural practice as in a practical skills training. The concept of a social form of computer-based making emerges out of the countercultural and subcultural spaces of the Hacker and Maker spaces, which hijacked technologies for rapid industrial prototyping as a part of their hobbyist practices. As Sutherland (2014) notes, this claim flies against certain types of rhetoric around counterculture – specifically those informed by the work of Timothy Leary – that perceive institutional structures to be largely stagnant, inflexible, and creatively desolate, while simultaneously legitimating countercultural spaces as supposedly the source of all manner of cultural potentials, the like of which the world has never seen. Sutherland also notes that while a divide does exist between hegemonic culture and counterculture, framing the divide in terms of production or novelty tends to be a relatively weak distinction, and discounts a more complex relation with political economy. We go into more detail on the nature of the divide between the institutional patterns of production and countercultural practices of making in the context of 3D printing below, but in sum, distinctions between the institutional and countercultural uses of 3D printing reflect a difference in political economy not only of education but also productive practices. While hacker cultures seek to reconfigure extent objects (that are themselves dependent on industrial supply chains and their related forms of institutionalised labour), 3D printing as practice promises to reconfigure extant supply chains with potentially increasingly distributed ones with their own institutionalisations (Birtchnell et

al, 2013). We approached the setting of the two Digismith workshops with an eye to making an initial framing of how these concerns appear in an educational setting. We posed our thoughts around what aspects of countercultural practices we could perceive as extant, those that developed in participants, and particularly how an informal workshop setting based in Hacker and Maker spaces would take on the attributes of the institution that it emerged from.

Gelder's (2007, pp.2-4) work on subculture is informative in marking out a conceptual distinction with countercultures, informing makerspaces. Firstly, he describes how subculture is often defined by its idleness, having no productive aspects; subcultures have little relationship to labour or property, and much more of a relationship to territory and modes of dress and social behaviour. Secondly – and here Gelder riffs on Dick Hebdige's work from the 1970s – subculture is opposed to mass culture. Subcultures are not interested in having their agendas and interests distributed throughout society, and subcultural practitioners seek to remain separate and independent of mass cultural forms. Building on the work of John Robert Howard, Gelder notes that, in contrast, countercultures, "imagine that society's values ought somehow to reflect or absorb their own" (2007, p.22). Countercultures are as much about producing alternatives to mass culture as they are about changing the existing one. Within Gelder's definition this article argues that the Digismith workshops fashioned a space that engaged in countercultural practices of 3D printing.

The Digismith workshops took up many of the attributes of Hacker and Maker spaces in its design: workshop setting, populated with experts, minimal cost attendance, and a non-linear learning trajectory. Equally, the workshops made use of institutional university systems: hierarchical 'sage on the stage' teaching methods based around lecture/seminar style delivery, uniform software and machinery for all attendees, and group authority was at least partially determined by the university's stratified employment system (separating out by both tertiary qualification, and technical role within the institution). However, there were also aspects of the learning environment that suggest the space, and the community that grew within it, existed in opposition to traditional pedagogies of the university.

The design of the Digismith course explicitly brought together diverse spheres of interests, culture, and academic life in a space for learning 3D printing. Separate to the institutional background, this space was then able to incubate a community of makers in a fashion similar to what Ito (2013) describes as a method for connected learning. Specifically, the course design reflected Ito's hope to "build shared purpose [and] opportunities for production" (Ito et al., 2013 5) through and with the openly networked resources and infrastructure provided by the university and contributors to the course. Production in Digismith was literal as well as fulfilling more normative productive aspirations of connected learning: course material was posted on Github to equitably share openly with future learners, interest driven learning defined what students decided to create with the printers, and curriculum integrated academic subjects that would fuel these interests through 3D Printing (such as tensile strength of plastics and intellectual property law).

The varied approaches to learning sessions within the curriculum of the Digismith workshops suggest instead of lecture-discussion-test based scenarios, problem based learning (Barrows, 1986) made up some of the experience. Reflecting the University's institutional culture, some taught content was compartmentalized by discipline or field. Software literacy was taught separate from intellectual property, which was taught separate from the design constraints of the ABS materials used to print objects. However, the design of the curriculum included a final project that centred on learners applying their varied sets of skills and new learning to develop a product or solution to

problem, where they were, using Savery's (2006, p.9) understanding of problem-based learning (or PBL), empowered to "conduct research, integrate theory and practice, and apply knowledge and skills" towards an original creation. Strobel & Barneveld's (2009) meta-synthesis of PBL outcomes shows how PBL is an important factor in the negotiation and creation of potential countercultures within learning environments. This suggests that PBL is most effective in long term retention, skill development, and satisfaction for participants. Although we cannot measure the first two claims against our data, survey and interview data offer evidence that satisfaction for participants peaked during the PBL based learning activities. Regardless, these three traits of learning are crucial to creating sustainable community ties between learners in and out of the classroom, an affordance that serves both "connected learning" goals as well as community formation that can exist outside of institutional regimes. However, the role of new media technologies in facilitating these developments within Digismith workshops remain unclear, and were under-utilised in the Digismith experience itself.

Against the ideal of connected learning, Neil Selwyn's (2014) analysis of current trends in the adoption and use of computing and digital technologies in universities highlight how digital processes and practices are tightly bound up with the changing structure, organisation and politics of higher education. In particular, he notes their role in accompanying a shift in educational values from public and communal to individual and commodified. He describes how the threat of digital disruption compels universities to adopt and utilise digital technologies within curricula, yet rather than transforming education he argues this integration often occurs in limited and 'messy' ways (pp. 5, 56, 102). Selwyn, it seems, is aware of the critiques a previous generation of educators made with regard to the impotence of 'de-schooling' education (Illich, 1971) through 'new' media networks when the lager pedagogical project is tied to a political economy of consumption, and thus must reject neo-liberal techniques of control that would also require a society to 'de-office', 'de-factory' and even 'de-family' structures of production (Gintis, 1972). There are multiple implications of this analysis for 3D printing technology and knowledge in (and out of) the contexts of the institutions of academia. Clearly potential markets, both in research through IP and teaching through student enrolments, will drive institutionalisation. Yet, how a countercultural ethic of knowledge sharing can be sustained within such contexts, and how this effects the *production* of education, as opposed to its *consumption* is unclear.

Productive models of peer to peer learning enabled by digital technologies have been described by Rheingold (2012) as peeragogy and as paragogy by Corneli and Danoff (2011). For Rheingold, peer learning started as a way to enable him to redesign his own teaching through co-learning, while an end goal envisions the point where his role becomes facilitating others to self-organize learning. Coneli et al.'s (2014) recent Handbook to Peerology suggests that a synthesis of peer learning and production is available and indeed able to offer some of the more radical de-school/office/factory political projects that P2P scholarship has adopted. At the same time, scholars such as Brabazon (2014) have been explicitly critical of attempts to invest learning with peer-based approaches, noting that,

> it is cheaper to affirm the value of student-centred learning and deny the expertise of teachers. But the knowledge held by teachers and students is not equivalent. Teachers know more. They write and read expansively. They write and interpret curriculum. They set assignments. They moderate and examine. They study, think and translate complex ideas into the stepping stones of lesson plans. Students can enact none of these tasks. (2014, p.93)

Despite this, 3D printing as a social development is new enough to educational settings that most participants are involved in both sides of the educational process and possess diverse skills and expertise. Because of the transdisciplinary nature of the Digismith workshops, approximately a quarter of the class had significant experience with both the hardware and software aspects of 3D printing, with a number of other participants having software skills in 3D modelling. Some participants were able to provide education in the legal status of intellectual property rights in the context of Australian law, while others were able to demonstrate elements of coding and structural engineering.

The position of universities themselves in parlaying additive manufacturing into 3D printing practices in educational, industrial and innovation spaces should also be commented on. In the immediate research context, 3D printing has been offered as a service at the University for two years prior to the Digismith workshops. However, these services were run by what we will identify as the Information Technology Services (ITS) group, rather than a specific faculty or research centre. This service did not contain any formal teaching or curriculum, and instead offered limited consultations on design and materials regarding the capabilities of the printers on hand. More generally, Australia's innovative and industrial applications of additive manufacturing have, so far, mostly been centrally spearheaded by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), which serves as Australia's national science organisation and undertakes and collaborates on public and industry science projects. 3D printing innovations have not historically been driven by universities in Australia.

The tension of countercultural movements in relation to our educational research setting has a complex history, influenced partly by manufacturing industries, libraries, and the 'free and open source' movements, which we will now explore.

Hacking & Making Culture

The maker community is not homologous, and defines itself in different ways at different times. Conflicting edits on wiki pages such as Wikipedia.org and Hackerspaces.org point to the tensions in self-defining what makerspaces should be – with edits often reproducing the political economic allegiances within FLOSS and GNU communities. Importantly, one of the spaces that have seen the greatest growth in makerspaces is libraries. Proposals by Colegrove (2013) and Good (2013) both explore effective models for libraries to start their own makerspaces that encourage collaborative or entrepreneurial approaches for their participants. Makerspace.org has released their own Makerspace Playbook under a Creative Commons (BY-NC-SA) license that details a range of approaches to developing effective makerspaces. Yet, as the copyright page indicates, the project has been funded by the US Military's DARPA, like the funding of ARPANET years before. Despite this, the Maker movement has a long history of countercultural drive, which we explore below.

The separation between counterculture and subculture that Gelder notes is apparent in the genealogical distinction Maxigas (2011) makes between hacklabs, which are informed by explicitly anarchist subcultures cultures, and hackspaces, which foster values that allow multiple connections including civil society and private interests. These hackspaces mirror countercultures in that they are designed to spread the community norms from their space into larger hegemonic communities as counter culture.

Maxigas' (2011) historiography of hacking labs and spaces highlights an ideological division that has separated hacklabs, which are informed by explicitly anarchist cultures, from hackspaces, which foster more libertarian values that allow multiple connections including civil society and private interests. Yet, Maxigas argues it is in combining the

'wide possibilities of transversal cross-pollination of hackerspaces with the social critique of the hacklabs' (Maxigas, npn) that we might envision the countercultural creation of worlds anew. That is to say that the fluid practices of making that the university attempted to incorporate to its pedagogy cannot be uniquely understood as 'hacker culture' or an 'open maker space'. The sometimes agonistic divisions present in these terms express a separation that continues within maker cultures – which we can broadly categorise by the countercultural maker and hacker spaces, and the subcultural hackerlabs.

Research by Schrock (2014) details a number of conventions related to existing countercultural movements that organise around 3D printing and other related productive practices. Hacker and maker spaces, referred to by Schrock as HMSs, are collective grassroots organisations. Their origins lie in the hacker movements of the 1980s, particularly the German hacker group, The Chaos Computer Club. These movements were highly exclusive, possessing esoteric jargon and significant technical knowledge that limited the engagement of others. As 3D printing technologies and related technical skills became more widespread, HMSs became less restrictive. Indeed, the 'open-access' nature of HMSs contradicts the subversive and exclusive aspects of hacker subculture (Schrock, 2014, pp.4-5). The informal nature of HMSs means that they are often organised through "democratic or meritocratic conventions", and generally eschew "top-down" organisational systems (Schrock, 2014, p.1). This is an important point for this article, as the attempt to not just create a makerspace, but to actively imbue a culture of 3D printing from an institution like the University is somewhat at odds with the anti-institutional origins of HMSs.

Kostakis, Niaros and Giotitsas (2014) extend Schrock's work by noting how anti-institutional and commons-based approach to counterculture assists to accelerate innovation and growth; there were nearly 900 active HMS worldwide in 2013, compared to less than 40 at the start of 2007. They suggest HMSs are exposing and exporting hacker culture across the globe, making for a broad spectrum of anti-institutional, collective communities. Important qualities within these HMSs communities are "sharing, abundance of resources, intrinsic positive motivation, openness, collaboration, bottom-up innovation, community accountability, autonomy, communal validation, distribution of tasks, and common ownership of the results" (2014, p.5). Finally, drawing upon the work of Axel Bruns, the authors centralise the figure of the "benevolent dictator" in helping guide the growth of the community. In this sense, the University setting and the anti-institutional nature of HMSs butt up against each other without being fully resolved. The University's benevolence provides materials, tools, space, and staff, while the participants create community through activity, production, and educational aspects of the Digismith workshops.

Like many digital technologies, such as the Tor Project and the internet itself, it would seem that HMSs should not be thought of as solely institutional or radical, but rather having investments of both agendas and resources at once. If we follow Gelder's interpretation then, the important countercultural aspects of HMSs are the fact that they provide an alternative mode of culture, and wilfully hope to have this cultural form adopted by a broader majority. This article will now explore how the University's School of Engineering attempted to develop a suitable pedagogical model for fostering a 3D printing Makerspace and accompanying countercultural attitudes and practices.

Structure and drive of the Digismith workshops

The Digismith workshops were developed with the University's ITS Research department in order to build a 3D printing community within the University. Planning

involved developing a practice-based agenda of 'awareness' as effective means of meeting that goal. By making participants aware of the available software and hardware, educators hoped to demonstrate the potential that 3D printing held; participants were not given a didactic educational structure, but instead encouraged to innovate and develop their own projects. At the same time, activities revolved around problem-based learning that introduced design, computational and material problems, and then utilised participants' experimental practices to drive group learning. Furthermore, designations between learners and teachers were sometimes fluid as participants with specialised areas of expertise were called on to shift between educator and student roles as and when their specialisations became more relevant. This formal institutionalisation of co-learning was separate from the more informal communal chatter and exploration that happened within the group during the workshops. The teaching space of the workshops was also decentralised such that groups congregated around shared machining tables and workstations, and independently organised whose projects would be printed first.

The course syllabus for the Digismith workshops has been released online on GitHub in an attempt to contribute to open access for 3D printing education. Furthermore, the entirety of the course slides has been released as a 265 page PDF for more schematic information. These slides cover a wide range of areas, and belie both the institutional and the countercultural influences within the school. Despite the limitations of the linear format of PDFs, the material is modular in nature. The course content is fully directed towards giving participants a sufficient knowledge for going further in a number of areas, and covers such areas as printer maintenance, 3D Computer-Aided-Design across a range of software platforms, the use of social download sites, the theory and principles that connect the software to the hardware, the legal fundamentals, and the technical aspects of photogrammetry. At the same time, however, many pages are stamped with the logo of the University. Furthermore, while the course is available on GitHub as an open access project, the PDF file is far more developed, and far less alterable. Both institutional and non-institutional perspectives are present at an educational level, yet the institutional framework is certainly privileged in this case.

The first workshop, held in January 2014, was a week-long summer school. The course was free to attend, open to the public, and all costs were covered by institutional stakeholders within the university. Volunteer mentors internal and external to the University from a range of backgrounds, including engineering, cultural studies, political science, library studies, vet science, and business ran the course through a set of modular introductory units. Some of the mentors were already involved in HMSs within Australia, including Melbourne's Connected Community Hacker Space and the Hacker Summit at the Melbourne Maker Faire in 2014, with one mentor contributing code to the open source 3D modelling program, Blender. Despite the institutional drive of the ITS research project, the Digismith project managed to include active participation from some groups that are a part of the counterculture software movement. The second workshop, held over June/July 2014, used the same overall structure as the first. However, funding from the University had been reduced, and two changes were required: the workshop was reduced from five days to four, and a cost of $100 was introduced. The second workshop was less successful at creating a community: interviews with the workshop coordinators indicated that the new transactional nature of the course might have led participants to being less interested in the project overall; furthermore, there was a noted lack of community and a number of participants stopped attending prior to the conclusion of the workshop. Nonetheless, many of the original volunteers returned to provide aid for the second workshop. The researchers on this article were involved in both workshops as participant observers. Researchers drew

on existing literature and their observations in the first workshop to build a methodology for surveying and interviewing participants in the winter Digismith, the method and results for which we will now address.

Research methods

The research design included three stages conducted over an eight month period and employed primary methods of semi-structured interviews and online surveys with key informants within the Digismith workshop, including both students and employees – although as we have noted, these categories became blurred.

Stage one involved exploratory work during the first Digismith, with researchers embedded in the workshop engaging participants in informal discussions regarding experiences and expectations. This period allowed the researchers to develop the scope and direction of an interview and survey-based inquiry into participant experiences, while also reflexively considering the pedagogical outcomes of the program.

Stage two synthesised a literature review with preliminary participant observation data to further develop an interview and survey schedule. Questions regarding prospective importance of various Australian industry sectors were integrated in order to map participant expectations about personal 3D printing, and its carry-on effects into the future. Other research questions related to existing survey research of 3D printing communities, in particular the work by Moilanen and Vadén (2013). A final set of questions were designed to examine normative preferences regarding claims of intellectual property that surround 3D printing.

Stage three involved data collection and a second round of participant observation during the second Digismith workshop. From this workshop of twelve attendees, researchers carried out semi-structured interviews with individual participants (n: 9) over the first three days of the Winter School workshop, while surveys (n: 11) were completed anonymously online on the fourth day of the workshop. Due to the small survey size, the below analysis is not comparable to Moilanen and Vadén's work to any degree of statistical significance, however the results still enable a window into understanding the experiences and motivations of people participating in 3D printing workshops, especially when set against the previous quantitative work's large sample sizes.

Results and observations

The results that we observed from our data are mixed. The survey given to participants was modelled on similar research by Moilanen and Vadén, which involved global surveys in 2012 and 2013 of non-corporate users of 3D printers. Our survey was comparatively modest. Moilanen and Vadén's research showed a clear trend towards participation in HMSs as a conscious part of a cultural movement (54%), yet only a quarter of participants consciously identified with a cultural movement. This is instructive as all but one of our participants reported having either previously printed a 3D object, or having one printed for them, while only a minority had never designed a 3D object. Across both years of the Moilanen and Vadén survey the top five self-reported use cases for 3D printing were the same: functional models, artistic items, spare parts to devices, research/educational purposes, and direct part production. Our own data suggests that workshop participants overwhelming wanted to create "artistic items" with a large subset wanting to use 3D printing for research and educational purposes - this latter result is not surprising given the academic context.

We also sought to uncover participant motivations in 3D printing projects with the aim of interrogating agendas and practices that could be used as proxies for describing hacker and maker counterculture, without participants necessarily self-identifying previous involvement with these movements. Some participants felt isolated, with one stating "I could see myself as a part of the community, but not at the same time." One participant, however, was extremely enthusiastic, saying, "I want to set up my own workshop for others to come and be a part of a community - sharing tools. This is my dream." More often than not, participants shared this drive, but also felt like the existing structure did not support such outcomes, with one reporting that "it'd be wonderful to be a part of a 3D printing group", while another adamantly stated "I definitely don't see myself as a part of a community."

The instrumental interests that drove participation were mixed. When asked about desire to "give back to the community" responses were grouped around a neutral response. Yet, when asked about community-building practices, respondents were highly enthusiastic regarding the 'fun' of 3D printing, sharing and learning new skills, and to a somewhat lesser extent, the collaborative elements of the experience. We can expect that those that do not identify with a 3D printing culture cannot 'give back' to it, while there are still strong indicators of practices of cultural creation. Questions regarding prospective importance of various Australian industry sectors were most interesting in terms of what participants did not think personal 3D printing would influence; namely government and defence, utilities supply (gas, water, communication). However, there was a strong indication that cultural and recreational services, health and community services, and goods production industries would be strongly influenced by personal 3D printing.

We noted two tendencies which identify attitudes in our participants that parallel countercultural agendas and hackerspace realities; a lack of financial incentive and complex but subtle motivations around sharing the community. Firstly, in terms of the counter-cultural aspects of the hacker and maker identity, there was little interest amongst our participants for monetary gain, with less than a third of respondents agreeing or strongly agreeing with the suggestion of financial motivation. A majority did, however, suggest their interest in 3D printing was instrumental rather than intrinsic. Importantly, many respondents were interested in seeing the development of legal protections for individual users, at the expense of large corporations. In this regard, a couple of users expressed fears around the domination of users by corporate entities, one participant stated that "a company has all the patents on medical equipment […] but they make it inaccessible for copyright reasons, and people die. […] I see that as an ethical problem." Another respondent noted,

> *you can print it, but it doesn't say anything about where you got it […] that's something that's very easy to take advantage [of] by big companies […] you can see people have a passion for printing, for 3D drawing, but that doesn't mean that companies are going to respect that, especially in this capitalist society that we have.*

Others suggested that intellectual property rulings be discarded in their entirety:

> *Personally I believe that if they got rid of intellectual property rights for small scale users, it would make everything a lot less confusing.*

In particular, peer-based sharing was seen to be an extremely important issue for many people. One respondent remarking that in a legal context, "I think STL files should be very very easy to share" (STL files are the instruction files used by most 3D printers).

Such a sentiment was very common among users, one noting that "it's great - I think they should be encouraged." Despite this, another participant reported concerns about greater proliferation of 3D printing, in terms of increased access to weapons, as much as large scale effects on employment:

> *Well I guess there this problems with [sharing] if we're speaking about weapons […] it's scary to think about how many people would be put out of work, if things were shared. It's scary to think about what would happen if it really took off.*

In contrast, some thought of it as desirable for the Australian economy envisioning a case where "manufacturing moves out of China to here because the resources are already here and it's cheaper to move finished products."

Finally, in reference to intellectual property regimes relating to 3D printing objects and files, there was a strong preference for sharing in order to produce objects that followed a Creative Commons Share-Alike licensing structure, where modifications are allowed, as long as credit is given to previous contributors and the license is kept under the same terms. Interestingly, the survey results might suggest that workshop respondents identified the sharing and printing of 3D objects as sharing others' work, rather than creating derivative works of their own, even if modified. This is a key aspect of what Schrock and Kostakis, et al, identify as the meritocratic elements of maker communities, it is also a key element in the work being performed by Angela Daly, who notes that the exact legal status of most aspects of 3D printing are extremely unclear (Daly, 2016). In terms of sharing in order to distribute 3D models, respondents tempered some of their acceptance of 'copyleft' intellectual property regimes for commercial distribution, but remained proponents of sharing for purposes of distribution overall. The drop off in acceptance of commercialised sharing mirrors the tension in hackerspaces as countercultural elements negotiate the spread of their own values and cultural products to larger systems that might not maintain the original value. This distinction remains an important difference to sub-cultures, which do not propagate their cultures further afield. Counter-cultures of 3D printing must negotiate the paradox of support and autonomy that comes with the peripheral hackerspaces they inhabit, and eventually grow out of.

Discussion

It is clear that participants did not consider themselves part of a community. We attribute this to the artificial nature of the institutional program, the lack of existing relationships within the group, and the lack of connected media the sessions offered from which participants could continue their relations. A reasonable degree of diversity of interests meant that there was little common ground between participants beyond the technology itself. Despite this, we read many participants as hoping to contribute to a culture of 3D printing, insofar as they wished for greater protections for individual users, at the expense of corporations. Some were concerned about the effects of 3D printing on social conditions, such as economic stability and crime, but these individuals were in the minority.

We observe from this that participants, and therefore the Digismith workshops, were peripheral to genuine countercultural movements, and that interest in HMSs was nascent, rather than fully developed. For the short time that it existed, the Digismith community seemed to share an interest in the traditional virtues of Peer-to-Peer cultures. While there was only some hostility to hegemonic culture, there was a strong interest in counterculture practices. We infer from this that the Digismith workshops

fosters something of a countercultural attitude amongst its participants, but lacks the firm community grounding that is so important to the countercultural practices of other HMSs.

The lack of a coherent shared vision about the cultural or instrumental use of 3D printing presents the primary challenge to educational workshops. This is particularly pronounced in institutional settings, such as universities, that seek to foster cultures that are primarily found in settings that are informal and democratic. Survey and interview data does inform this understanding beyond what existing literature indicates, insofar as it identifies that participants held latent interests in the ethics and practices of countercultural movements, such as an appreciation of sharing and peer-to-peer practices, and an interest in legal protections for creative developers over large corporate entities.

On the basis of these observations, it becomes clear that Matt Ratto's (2011) work on 'critical making' should be an important touchstone for educational practice related to 3D printing. Unlike other practices, Ratto frames a project-based approach to learning, in that participants should work towards a particular goal or output to frame the learning, rather than working towards the goal of learning in and of itself. This project should be, according to Ratto, theoretically grounded but not necessarily have a pragmatic use. The useful application of 3D printing comes later, as Gauntlett and Holroyd note, "The stronger that 'maker' culture becomes, the more confident people will become in their own skills and in using the things that they've made" (2014, p.16). We believe that this crucial aspect – a clear and purposive approach for students to work towards – is what is missing from the institutional framework for the Digismith workshops. Purpose-driven, or problem-based learning approaches are fundamental to involvement in HMSs, and are largely missing from the Digismith workshop curriculum, and in the event that future courses build on the Digismith curriculum, we believe that these courses should necessarily include goal-based projects for students to work towards. At the same time, the lack of course credits in the workshops may have led to reduced engagement from some students, particularly given the timing of the second – and slightly less successful workshop – at the tail end of the first semester of the year, just after an intensive period of examination.

Conclusion

To conclude we offer some speculation towards how educators could more successfully establish community and peer-to-peer styles of learning via 3D printing curriculum. At the micro level, group problem-based learning projects that are presented and then subsequently remixed by other groups as part of peer assessment might afford students the opportunity to grapple with the political economy of HMS vis-à-vis institutional settings and expectations – including assessment. At a macro level, institutional engagement with not only HMS, but other public institutions (such a libraries and civic centres) that run informational 3D printing sessions may allow some pedagogical theory and practice to permeate in peer-to-peer spaces that are less along a counter-cultural spectrum. These spaces might be on the one hand more receptive to 'institutional' pedagogy while on the other, still effect peer-based learning with intrinsically motivated individuals.

From the experience of Digismith, curriculum design seems to currently be constrained by learning how to leverage both the complex motivations behind sharing, and the power of purpose-driven learning opportunities. At the same time it should be noted that, currently, institutional 3D printing learners are mostly intrinsically motivated. As 3D printing practices become (further) institutionalised into mandated

curriculum, extrinsic motivation, and a subsequent curriculum shift, will have to be taken into account. Learning 3D printing may offer a novel way to combine the intrinsic motivations of making and sharing with extrinsic motivations of critique and purpose driven assignments. How peers navigate these sometimes conflicting motivations offers opportunity for much experimentation and further study. The data presented here are a part of a preliminary inquiry into the state educative aspects of consumer-level engagement with 3D printing, and act as an indicator for future areas of research. Some areas exposed by this research would be better suited to certain types of market research, rather than education and cultural studies. This research does, however, show how the complex relations between counter-culture and institutional priorities affect learning environments and practices. The experimental Digismith workshops did not present an ideal connected learning experience for participants hoping to build social support networks as they learned. However, in some cases, student projects enabled learners to link to their own academic, civic, and career goals. The counter culture techniques associated with radical pedagogy such as peer based learning were, to some extent, subsumed into institutional logics. Here, peer learning enabled more efficient and less costly programs to be created under the University's brand, while the need for the HMS itself remained within the institution and radical forms of production - either in plastic or pedagogically - were snuffed. In this sense, Gintis' (1972) critique of 'deschooling' society remain pertinent; the political economy of learning and production tied to the university as institution presided over the major outcomes of a course designed to live at the institutional periphery.

References

Barbrook, R., & Cameron, A. (1996). The californian ideology. Science as Culture, 6(1), 44-72.

Barrows, H. S. (1986) A Taxonomy of Problem-Based Learning Methods. *Medical Education 20* (6), 481-486.

Birtchnell, T., Urry, J., Cook, C., & Curry, A. (2013). Freight miles: the impact of 3D printing on transport and society ESRC Project ES/J007455/1: Centre for Mobilities Research.

Brabazon, T. (2014) Learning to leisure? When social media becomes educational media. *Digital Culture & Education 6* (2), 82-97.

Colegrove, T. (2013) Editorial board thoughts: Libraries as Makerspaces. *Information Technology and Libraries 32*(1), 2-5.

Corneli, J. and Danoff, C. J. (2011). Paragogy. *Proceedings of the 6th Open Knowledge Conference, Berlin, Germany*.

Corneli, J. and Danoff, C. J. eds (2014). *Peeragogy Handbook V2*: Peeragogy Books.

Daly, A. (2016) *Printing Freedom: Socio-Legal Aspects of the 3D Printing Revolution*, Palgrave Macmillan: (forthcoming)

Digismith course resources. GitHub (2014) Retrieved from: https://github.com/resbaz/digismith

Fordyce, R. (2015) 'Manufacturing Imaginaries: Neo-nazis, Men's Rights Activists, and 3D printing' *Journal of Peer Production 6* (1).

Gauntlett, D. and Holroyd, AT. (2014) On Making: Sustainability and the Importance of Small Steps. *Conjunctions: Transdisciplinary Journal of Cultural Participation 1*(1).

Gelder, K. (2007) *Subcultures: Cultural histories and social practice*. London and New York: Routledge.

Gintis, H. (1972) Towards a Political Economy of Education: A Radical Critique of Ivan Illich's Deschooling Society. *Harvard Educational Review 42*(1), 70-96.

Good, T. (2013) Three Makerspace models that work. *American Libraries 44*(1), 45-47.
Illich, I. (1971) *Deschooling Society*. New York: Harper & Row.
Ito, M., Gutiérrez, K., Livingstone, S., Penuel, B., Rhodes, J., Salen, K., Schor, J., Sefton-Green, J. and Watkins, S. C. (2013) *Connected Learning: an agenda for research and design*. Irvine, CA: The Digital Media and Learning Research Hub. Retrieved from: http://dmlhub.net/sites/default/files/ConnectedLearning_report.pdf
Kostakis, V., Niaros, V. and Giotitsas, C. (2014) Production and governance in hackerspaces: A manifestation of Commons-based peer production in the physical realm? *International Journal of Cultural Studies*. Advance online publication. DOI: 10.1177/1367877913519310.
Maker Media. (2013) *Makerspace Playbook*. Retrieved from: http://makered.org/wp-content/uploads/2014/09/Makerspace-Playbook-Feb-2013.pdf
Maxigas (2012) "Hacklabs and hackerspaces – tracing two genealogies" *Journal of Peer Production 2*.
Moilanen, J. and Vadén, T. (2013) 3D printing community and emerging practices of peer production. *First Monday* 18(8).
Moilanen, J. and Vadén, T. (2013) "Results from 3D printing survey 2013." *Peerproduction.Net*, Retrieved from: http://surveys.peerproduction.net/2013/09/3d-printing-survey-2013/
Ratto, M. (2011) Critical Making: Conceptual and Material Studies in Technology and Social Life. *The Information Society 27*(4), 252-260.
Ratto, M., & Ree, R. (2012). Materializing information: 3D printing and social change. First Monday, 17(7).
Rheingold, H. (2014) Toward Peeragogy. *Digital Media Learning Central*. Retrieved from: http://dmlcentral.net/blog/howard-rheingold/toward-peeragogy
Savery, J. R. (2006) Overview of Problem-Based Learning: Definitions and Distinctions. *Interdisciplinary Journal of Problem-based Learning 1*(1), 3.
Schrock, A. (2014) "Education in Disguise": Culture of a Hacker and Maker Space. *InterActions: UCLA Journal of Education and Information Studies 10*(1), 1-25.
Selwyn, N. (2014) *Digital Technology and the Contemporary University: Degrees of Digitization*. London: Routledge.
Strobel, J., & van Barneveld, A, (2009) When is PBL More Effective? A Meta-synthesis of Meta-analyses Comparing PBL to Conventional Classrooms. *Interdisciplinary Journal of Problem-based Learning 3*(1) DOI: 10.7771/1541-5015.1046
Sutherland, T. (2014) Counterculture, Capitalism, and the Constancy of Change. *M/C Journal 17*(6).
Williams, Amanda, Alicia Gibb, and David Weekly. "Research with a hacker ethos: what DIY means for tangible interaction research." interactions 19.2 (2012): 14-19.
Wozniak, S. (2006) *iWoz: Computer Geek to Cult Icon: How I Invented the Personal Computer, co-founded Apple, and had fun doing it*. New York and London: W. W. Norton & Company.

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