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Exploring the interface between culture, technology and experience: a critical perspective on digital making in education

Final report for the Society for Educational Studies

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Introduction

This project started in September 2015 as an attempt to explore "digital making" in formal school settings. The research was made possible by a small grant from the Society for Educational Studies. Digital making is defined here as the process of creating a digital product or output. Although it is often associated with software programming, it can also involve modifying, adapting and personalising existing digital or physical tools to make something relatively new or original. Digital making is as much underpinned by technical skills as by the ability to work together, solve problems creatively, and think critically about technologies and what can be accomplished through them. According to the literature, there is a need to integrate digital making across formal school curricula if we are to realise the educational potential of emerging forms of technology-mediated creativity, which cannot be confined to single subjects but requires collaboration between teachers and students around shared pursuits (Sefton-Green 2013).

The project was based on an interdisciplinary approach which focused on making as a cultural phenomenon. Conceptually, the study was informed by cultural and sociological studies of technology in education and broader society. Making was thus approached and examined as a polyvalent phenomenon which occurs at the intersection of culture, technology and education. This is reflected in the organisation of this report. The first part will consider the historical and cultural contexts of making, the second part will describe a small study involving two schools in Leeds (UK). Drawing on qualitative data collected during design sessions with secondary students, the report will articulate an evidence-based picture that will complement the theoretical claims.

1. Making as a cultural phenomenon: a critical perspective on the available literature

While the profile of making, hacking and coding as educational activities keeps rising in the public discourse, as illustrated by media coverage, official policies and corporate initiatives, there is still little awareness that these phenomena are in fact situated in a complex socio-cultural and historical context. Currently, the emphasis is on the potential of making to engage students in creative inquiries in which technological craftsmanship enhances or completely replaces traditional forms of learning (Vossoughi & Bevan 2014). In this sense, the so-called "maker movement" spearheaded a range of practices whose impact on formal education is still unclear.

Activities that involve making and tinkering with technology have a long history, but they undoubtedly received a significant boost in recent years thanks to the increased affordability of "fabrication tools" such as 3D printers, laser scanners, paper-cutting devices, computer-controlled sewing machines, milling machines and so forth. This was accompanied by the exponential growth of freely available technical expertise on the internet, in the form of small and large networked communities of enthusiasts and hobbyists, who create and share development tools, standards and tutorials.

Making is now being vigorously framed as an educational practice - this is happening globally in most "developed" countries, but is especially visible in British and American educational debates. Making appears underpinned by the sort of learner-driven, inquiry-oriented and technology-enhanced pedagogies that developed during the 1980s but were,

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according to Blikstein (2013), sidelined by years of standardised testing and accountability-driven schooling. In this sense, Blikstein acknowledges the role of "seminal" studies and policy initiatives in American engineering education, such as the work of Seymour Papert around LOGO (Papert 1980), and the 2002 "technically Speaking" report (Pearson & Young 2002) which summarised a decade of research on inquiry-based learning using technology. These ideas kept exercising an influence on the more progressive sections of formal education in the US, but only now are beginning to come to fruition thanks to what Blikstein terms the "democratisation of invention" afforded by fabrication tools and accessible design knowledge. As such, making is now being branded as an inherently superior form of learner-driven inquiry, due to the aesthetic and playful connotations of working with accessible digital technologies and interactive interfaces, which lowers the barrier for participation (Blikstein 2013; Halverson & Sheridan 2014). Similar themes have become popular in the British educational discourse over the last years, such as the idea of "learning to code" which emerged at the intersection of policy and educational research (Williamson 2015).

Alongside these very positive and enthusiastic accounts, more critical readings of making are available in the literature (e.g. Ratto & Boler 2014). The focus here is on so called "DIY citizenship" and the ways in which creative and grassroots engagement with technology may open up new opportunities for political participation and democracy. According to Ratto and Boler (ibid), the roots of this view can be traced back to the American counterculture of the late 1960s, which was in turn informed by the individualist and anti-establishment values that, to an extent, shaped certain aspects of the American psyche. The term "DIY citizenship" was in fact introduced by John Hartley (1999) to extend the traditional forms of citizenship first theorised by Thomas Marshall (1950). Famously, Marshall described three types of citizenship which developed in different historical moments but converged in modern times: civil, which is about rights and freedoms; political, which is about democratic representation; and social, which is about welfare. To these types, Hartley added a "Do-It-Yourself" citizenship, which was later reframed as a manifestation of identity politics (Jacka 2003): a form of individualised engagement with the liberating affordances of media and consumption in order to build a distinctive identity: (DIY citizenship) is thus based on "the practice of putting together an identity from the available choices, patterns and opportunities on offer in the semiosphere and the mediasphere". (Jacka 2003: 185).

The framing of the making movement as political and progressivist - a technologically mediated process through which individuals can freely and democratically define their place in society - is also shaped by the notion of participatory technological design at the heart of the open-source movement, itself a product of American counterculture, at least to a certain degree. Open-source means that software is distributed with its source code for no more than the cost of distribution, open to everyone to modify and redistribute without royalties or licensing fees. Since the first pioneering initiatives in the early 1980s, such as Richard Stallman's GNU project[2] and the establishment of the Free Software Foundation[3], the open-source movement progressed during the 1990s and 2000s with communities of programmers and "hackers" forming around a broad range of collaborative projects.

The reading of making and open-source practices as forms of technologically-mediated citizenship is important from an educational perspective because it helps us understand the broader socio-cultural context in which they are situated. Indeed, these practices need to be interrogated as historical and political phenomena, not to be reduced to a collection of discrete "educational opportunities" that present themselves fully formed and ready to be applied by keen teachers and entrepreneurial young people. So, for instance, it is important to be aware that two forms of political ideologies tend to converge (often becoming confused) in the discourse of open-source, hacking and making (Selwyn 2013): a left-wing one which emphasises democratisation and the emergence of "new" forms of property. The two key aspects of this approach are collaboration and the shared ownership of the means of digital production (software development tools and access to "source code"), and an emphasis on the "new commons" of the digital age. At the same time, a neo-liberal and libertarian reading is

[2] https://en.wikipedia.org/wiki/GNU_Project

[3] http://www.fsf.org/

also present - one that emphasises utilitarian notions of independence, entrepreneurship and freedom from state control. The underlying assumption in this case is that centralised forms of governance and regulation are a hindrance to individual creativity and agency. This is therefore a more “corporate” version of openness, in which access may be indeed open, but content and platforms are controlled and locked under proprietary agreements.
The political nature of making and hacking is not only reflected in broad “ideologies”, but also in the power imbalances in the actual participatory development processes – which are often overlooked. Far from being “flat” or distributed, communities of makers, hackers and grassroots designers are organised around “rigid hierarchies of privileged and authorised elites of charismatic leaders and core users who oversee and moderate the creative process” (Selwyn 2014: 77). The implications of such imbalances in education are significant. In other words, we cannot ignore that open production processes require considerable levels of skill, professional confidence and motivation, and that only the most technically gifted individuals can truly engage in meaningful participation. As Selwyn reasons, “it would seem naively optimistic to imagine the open production of software and other content taking place within heterogeneous communities of experts and non-experts sharing common interests and goals” (ibid: 77).

1.1 Exploring further the historical and cultural contexts of making

In this section, we will go further in our attempt to develop a cultural and historical account of making. As noted earlier, some prominent advocates of making and fabrication in education contributed to a fairly limited historical understanding of these practices by placing them against a narrow, mostly US-centric backdrop. The evolution of engineering curricula from the late 1980s or thereabout certainly played a role, and the influence of pioneers such as Seymour Papert cannot be denied. Similarly, a constant stream of policy initiatives (taking the UK and US contexts as examples), driven largely by economic considerations (to foster innovation, employability and so forth), contributed to a renewed emphasis on engineering education. It is also true that the growing availability of fabrication devices such as 3D printers, laser cutters – as well as the appearance of streamlined and accessible software design tools and languages - played a part in “democratising” design practices that, until not long ago, were confined to specialist R&D labs. In this section, we will begin to expand this cultural-historical backdrop. Our account will not be exhaustive but will instead prioritise critical perspectives rooted in the tradition of cultural studies and science and technology studies. In particular, we will draw on Jean Baudrillard’s early work on the “Systems of Objects” (1996), in which he explored the relationships between consumerist culture and the design and usage of technological artefacts, as well as Andrew Feenberg’s critical and historical analyses of technology in society (Feenberg 2010).

1.2 Making as material connotation

In his early reflections on the “system of objects”, The philosopher Jean Baudrillard (1996) talks about two “planes” of technological artefacts which can be described using a semiotic analogy based on the classic distinction between denotation and connotation, that is, between the literal meaning of words or objects and the socially mediated alterations of that meaning (i.e. “a red rose” is denoted as a flower and connotated as a symbol of passionate love). This logic works well when applied to artefacts: there exists, for Baudrillard, a “structural” plane in which the material properties of an artefact are “denoted”. Baudrillard argues that this plane is real but, in actuality, it can only be studied in abstract, because the “integrity” of objects’ materiality is continuously “disturbed” and, indeed, modified by the sociological and psychological realities – the direct experiences of meaning making, which he equates with the linguistic process of connotation. Connotation is the meaning which is developed and negotiated as a social and cultural process. Talking about technological artefacts, Baudrillard suggests that they are in a “perpetual flight from their technical structure (denotation) towards their secondary meanings, from the technological system towards a cultural system (connotation)” (p6).
There is however a key difference between denotation vs. connotation in linguistics and denotation vs. connotation in the study of technologies. While linguistic connotation never

actually alters the literal meaning of a word, technological connotation has a profound effect on the underlying structural properties of a technology. Moreover, connotation is not something that happens to objects *post-hoc*, but is instead embedded in the design and development of technological artefacts from the outset. It shapes the process of industrial production, it underpins research and development (R&D) as well as professional craftsmanship and, indeed, it occurs as part of grassroots making practices as they are understood nowadays. Technological connotation, in other words, looks and unfolds differently in different contexts while maintaining its cultural significance. In many cases, it leads to the proliferation of superficial or aesthetic features, at the expense of the structural properties of artefacts. The car, for example, has a number of structural properties and a very specific use value (transportation). This is what Baudrillard would call its denotation. When the car became entangled with the "system of signs" of modern capitalist society, it turned into a symbol of style, prestige, luxury, power, and so on. According to Baudrillard, these connotative features keep piling up, encroaching on the structural properties which gradually become inaccessible and invisible, buried under layer upon layer of cultural meanings. Eventually, excessively connotated objects undergo a process of "functional aberration" (p121), in which the structural properties become irrelevant, and objects become degraded versions of themselves: disposable gadgets and gizmos whose only value is as signs. Conversely, technological connotation can occur according to different rules and a different rhetoric, still very much aligned with the economic logic of capitalist production but manifested as grassroots technological ingenuity. For instance, aimless connotation was, for Baudrillard, at the heart of the movements of eager inventors and tinkerers that accompanied the industrial revolution in many Western societies – the forerunners of modern makers, hackspacers and moonlighting programmers. These like-minded science and technology enthusiasts, with their own gatherings and a lively subculture were, according to Baudrillard, complicit in encouraging the functional aberration of objects, obsessing over secondary functions and celebrating technological ornamentation and automation for their own sake, by creating artefacts that did not accomplish anything and yet "worked". The French Concours Lepine, one of the longest running competitions of small-time inventors, still held annually to this day, is described thus:

> The tinkering tradition of the Concours Lepine, where no true innovation can be seen, but by juggling stereotyped techniques objects are created that are once incredibly specific in their function and absolutely useless (…) The object answers no need other than the need to function. (Baudrillard, 1996: 122).

Figure 1. The historical roots of the Maker Movement: The Councours Lepine

While Baudrillard's critique was rooted in a fairly traditional view of capitalist production, it still helps us make sense of similar phenomena in the contemporary, post-industrial world of new media, where competing versions of technological connotation shape different notions of "making" – like those aptly championed by two of the main global entities in the digital economy: Apple and Google (see Ratto & Boler 2014). Famously, Apple adopts a "walled garden" approach where devices, content and users are bound to each other through a stringent framework of non-negotiable technical specifications, Application Programming Interfaces (APIs) and license agreements. This framework exists to ensure that every facet of the Apple universe, from the creation of new content and applications by independent developers to the end-user experience, is consistent with Apple's branding as a producer of exclusive, stylish and seamlessly functional devices. Google's approach, on the other hand, appears to be completely at odds in its championing of openness - not because of a genuine ideological stance against Apple's closed ecosystem – but because of a different business model where profits are generated through a parallel ecosystem, heavily reliant on advertising and data analytics and fundamentally "device-agnostic".

These two approaches translate in different visions of "digital making". Apple seems more inclined to constrain independent developers, while offering in exchange a streamlined environment and emphasising the curation of newly created content to support quality and innovation. On the other hand, Google advocates a form of grassroots development that emphasises the indeterminacy and "moddability" of open-source technologies, whose fundamental properties are not locked, inaccessible or buried under layers of over-designed functionalities and aesthetic features. As already mentioned, such a position ought not to be mistaken for a principled stance, as both openness and closure are in fact contained within the same sociotechnical dynamic, and their opposition must be problematized as part of a critical analysis of capitalist production in the digital economy, and the related forms of labour. As noted by Ratto and Boler (2014), digital making in the global, networked ecosystems of Google and Apple "will always incorporate not only 'do it yourself' but 'do it for them' " (p256) - especially for the vast majority of keen technology enthusiasts unwilling to explore "new opportunities present within new media and new technologies for novel and non-normative forms of cultural and political engagement" (ibid). In this sense, digital making should be conceptualised as a form of labour symbolically and materially interwoven with the world of corporate new media, and subsumed in a taken-for-granted, wholly neo-liberal rationality that emphasises self-entrepreneurship, self-improvement, continuous innovation and a pervasive and totalising work ethic (Appleby & Appleby 2011; Fuchs 2011; Harvey 2007; Rose 1989). In the context of education, this phenomenon should also be studied and understood against the background of changing notions of childhood and their impact on technological design.

1.3 Changing notions of childhood, labour and technology

In the book "Between Reason and Experience" (Feenberg 2010), the philosopher of technology Andrew Feenberg describes the debate over child labour in Victorian intellectual circles during the 19th century. His critique focuses in particular on the deterministic arguments that were made against any form of regulation. Influential and vocal sections of the Victorian establishment brandished economic and technological imperatives to justify the continued employment of children (and women). A common argument was that the very rational nature of industrial machines was such that many tasks were better accomplished by workers with short limbs and small hands. Any interference with this "objective" state of affairs was bound to have dire economic consequences, such as productivity slumps, bankruptcy, unemployment and ensuing social tragedies. Critically examining these claims, Feenberg notes that Victorian industrial machinery wasn't inevitably bound up with child labour by rational necessity. Rather, those machines had been often designed from the ground up to be operated by small people; in other words, there was nothing in the nature of industrial machinery that determined the condition of child labour, and technological development in that period was instead "overdetermined by both technical and social factors" (ibid: 13) .

The trajectory of child labour with its related technological infrastructure illustrates, for Feenberg, the limits of the deterministic argument in technological debates, that is, the idea that technologies are always the result of rational design and unavoidable imperatives. Although technologies are without doubt rational, i.e. they reflect an attempt to make sense of the world using laws, principles, mechanisms, algorithms and so forth, technological progress is *never* a straightforward matter of finding the most rational solution to a problem. Rather, it is based on finding or designing what seems to fit best with the values, expectations and assumptions which are dominant in a particular field at a particular moment in history. Technologies are therefore "underdetermined" by rationality.

The thesis of "underdetermination" holds that there is no one rational solution to technical problems, and this opens the technical sphere to these various influences. Technical development is not an arrow seeking its target, but a tree branching out in many directions" (Feenberg 2010: 135). Child labour was eventually abolished in most Western economies as new machines emerged which did not need children to be operated, and a social and ideological consensus coalesced around notions of childhood as a period of innocence, leisure and unproductive learning that requires a mix of moral safeguarding and compulsory instruction - a consensus which has endured for the large part of a century and has become interwoven with economic and educational considerations (see also Buckingham 2007).

> A vast historical process unfolded, partly stimulated by the ideological debate over how children should be raised and partly economic. It led eventually to the current situation in which nobody dreams of returning to cheap labour in order to cut costs, at least not in the developed countries". (p13) (…) today we see children as consumers, not as producers. Their function is to learn, insofar as they have any function at all, and not earn a living. This change in the definition of childhood is the essential advance brought about by the regulation of labour. (Feenberg 2010: 39).

Whilst this analysis is largely accurate, it does not account for the economic and political arguments that, since the early stages of modern education, have challenged universal notions of childhood as a safeguarded period of passive learning and nebulous "personal development".

Adopting once more a historical perspective, echoes of this debate can be found in the separation between vocational and elite education in Italy during the Fascist regime, documented by Antonio Gramsci in his prison notebooks (1971). Gramsci strongly criticised the artificial separation between academic instruction for the elite — the "free spirits" destined to become "masters of their own thinking" — and inferior forms of vocational training for the rest of the student population, aimed at developing practical and applicable work skills to the benefit of the emerging industrial economy. While Gramsci's view needs to be positioned in the context of a broader critique against the fascist regime, it goes to illustrate that notions of childhood in modernity have always been contested and shaped by ideological, economic and cultural factors, and that the relationship between children and the world of productive work has evolved historically. Our own contention is that the contemporary emphasis on making can be examined, to an extent, as the latest manifestation of this historical process. For instance, precursors of making, as it is understood nowadays, can also be observed in the trajectory of hobbyist cultures in industrial and post-industrial economies and, in particular, in the interface between leisure and work. In his study of hobbies in American culture from the mid-nineteenth century, Steven Gelber (2013) notes that the boom in leisure activities went hand in hand with the diffusion across all swaths of society of capitalist, self-driven work ethic:

> For a leisure activity to be a hobby it must, above all, be productive. Like work itself, hobbies generate a product and therefore hobbyists have something to show for their time, it has not been wasted. Even if they never even think of selling the products of their leisure, hobbyists know they have economic value, and that knowledge ties their free time to the ideals of the market economy. (Gelber 2013: 295)

The expansion of capitalism and its various crises after the Second World War once more called into question the idea of childhood as idle period of learning: a protected (and protracted) state of "moratorium" (Erikson 1956) during which children and young people could learn without being productive, and explore different identities before choosing a suitable path. On the one hand, this was accompanied by a growing dissatisfaction with traditional educational institutions and their ability to provide children with economically viable skills; on the other, it was underpinned by the "economisation" of leisure time for

adults and children alike, and to the rise of a hobbyist culture ideologically and materially tied to the world of technological innovation and entrepreneurship.
Gradually, childhood became a condition entirely contained within an economic worldview: the antechamber to work and productivity and a site of material and cultural consumption. Today's notion of the child as productive, self-motivated, digitally literate "maker" is obviously not comparable with that of the uneducated, impoverished and ill-treated Victorian child labourer, but the relationship between culture, economics and making as a socio-technical phenomenon can still be explained in terms of underdetermination. Not only is making the result of economic and cultural trends that challenged notions of childhood, education and productivity, but the very technologies that enable making among young people can be examined along these lines: as the result of design languages conceived from the ground up to be "child friendly", and as artefacts that can be operated, hacked into and modded effectively by inexperienced young users. Examples include simplified and visual programming languages like Scratch[4] and credit-card sized, single-board computers like the Raspberry Pi[5]. Along these lines, digital making can be understood as a hybrid phenomenon where educational aspects have become enmeshed with the language, values and practices of "digital labour" which were described in the previous section.
Up to this point, the report provided an analysis of making as a socio-historical phenomenon. A couple of key points can be summarised as follows:

a) In the first place, digital making can be understood as form of cultural connotation - the process through which culture and society alter what Baudrillard called the "technical structure" of artefacts. This alteration occurs not, or not only, through the post-hoc attribution of meanings, but through a socio-technical process in which design, material production and culturally mediated "modification" are indistinguishable: cultural meanings and material artefacts are created and negotiated simultaneously.
b) At the same time, and arguably following a similar logic, digital making as an educational phenomenon is "underdetermined" (i.e. not determined by a single force over the others) by the plurality of economic, cultural and technological changes that together altered the ways in which childhood is viewed in industrial and post-industrial societies.

Building on these points, the remainder of the report will describe the implementation of a small project in formal education, where making was viewed as a multifaceted process located in a specific sociocultural context: an urban, culturally diverse setting in the north of England.

2. The empirical study

2.1 Methodology

The fieldwork for this project took place from September 2015 to February 2016 in three data collection sites. The first site was the Leeds Hackspace, a community-run space where technology enthusiasts share equipment and expertise to collaborate on hacking, making and coding projects. The remaining two sites were two secondary schools in Leeds, both serving urban communities in Leeds and with higher than average proportion of students from disadvantaged backgrounds. In each school we worked with a mixed gender/mixed ability group of 15 students aged 12-13 (Year 8).The data includes verbal interactions and supporting photographic material collected during "making" sessions with students. The same template was adopted in both schools: students were encouraged to produce ideas and develop them through an iterative design process, starting from drawings and sketches and progressing to actual physical or digital prototypes. The activities were developed on the basis of interviews and observations carried out at the Hackspace, as well as the previous experience of one of

[4] https://scratch.mit.edu/
[5] https://www.raspberrypi.org/

the members of the research team. They involved a combination of programming using low-cost microcontrollers, a visual programming editor (Blockly[6]) and wearable technologies. We carried out four design sessions in both schools. Interviews were recorded using voice recorders, and then transcribed and analysed for recurring themes using a qualitative and interpretative approach (Denzin & Lincoln 2011). The main themes emerged from the analysis will be discussed in the next section, using representative quotes and photographic evidence from the making sessions with students. All names have been changed to pseudonyms.

2.2 Results

2.2.1 The maker movement in Leeds: passion, profit and community spirit

Consistent with the aim of analysing an instance of making in formal school settings as part of a broader sociocultural context, the initial phase of fieldwork focused on the maker movement in the urban environment of Leeds. Leeds is a large, growing city in the North of England where the service sector has almost completely replaced the traditional manufacturing activities that played a significant part in the historical development of the region, such as the textile industries. Leeds is now one of the main financial centres in England outside of London. Like in all major cities in the UK and around the world, a "hackspace" is present in Leeds. Hackspaces are part of an international network of community-oriented spaces where like-minded individuals with an interest in technology, craftsmanship and design can gather, socialise and collaborate. According to a recent survey[7], there are currently 97 Hackspaces in the UK, and they can be found in every region, although large cities like London and Manchester tend to dominate the landscape in terms of size, quality of equipment and range of activities allowed. Manchester and London, for instance, are the only cities where hackspaces are equipped with "biolabs" to experiment with molecular biology and microbiology. Men tend to be prevalent by a large margin in these settings, with membership predominantly male in 80 per cent of the spaces, compared to 18 per cent which have 50 per cent or more female members.

Our observations and interviews in the Leeds hackspace took place during an "open evening", when the workshop can be accessed by non-members who are free to ask questions and experiment with the equipment, under the supervision of more experienced makers. During the course of the evening, we focused our questions on the relationship with the national and international network of hackspaces and with educational institutions (schools and universities) in the region. The main two themes to emerge from the interviews and observations were one of "distinction" in relation with larger hackspaces and other commercial realities, and one of incompatibility between the maker movement and the world of formal education. The more senior members of the Hackspace were indeed keen to emphasise the charitable and community-based nature of the activities and initiatives – something that sets them apart from the more recent developments in the maker movement, branded as "commercial" in nature. Here is a representative extract:

> ***Mark***: Yeah I think the worry is that you end up with sort of commercial maker spaces, which do exist, and there are sort of varying levels in between as well. We're about as uncommercial as you can get really. Occasionally members will take on projects for other people, but that's about as far as it goes. But you get some places where they're deliberately set up as say a co-working space and they happen to have a workshop as well, and you get others where you're sort of to the Fablab kind of end of the market, where it's purely commercial. But, I don't know, there's probably room for all of those models.

Some of the younger members were more open to such commercial model, and a few were actively exploring the possibility of setting up parallel spaces or "offshoot" initiatives as

[6] https://developers.google.com/blockly/

[7] http://www.nesta.org.uk/sites/default/files/open_dataset_of_uk_makerspaces_users_guide.pdf

business ventures, even though they were conscious of the challenges and, in particular, of the fact that Leeds could not achieve the same level of sponsorship and "critical mass" that seemed to be commonplace in larger and more affluent contexts, London above all:

> ***James:*** So literally the company I'm trying to get running, the only reason I'm going down that route is literally because this model can't support the very thing I do want to do with it, like, having a bio-hacking lab where you really can do the proper end of it rather than just going, 'Oh yes, I've got to play around with the microscopes a bit', that's fun, but it's not actually modifying stuff. If you want to do that you need proper controlled conditions. You need to be responsible for it. And you can't do that without sufficient lab space which is not going to happen here because, as lovely as all these guys are, not everyone is interested in doing this sort of things, and we certainly don't all have a few thousand grand lying around to just go and chuck in for the random offshoot that may or may not work out for people.
> ….London is the classic example, they are licensed (…) They're actually licensed for bio-hacking, and basically because I want to do that sort of thing but as far as I can tell, we don't have anything nearing that amount, because London is that critical mass (…) literally a case of anything could go on there…I mean London is a whole other organism in itself, I don't think you can ever compare that to everything else in the country.

Alongside this notion of a "provincial identity" and a concern for the economic and cultural limitations of the Leeds context, we also noted a certain reluctance to engage with formal education. On the one hand, the Leeds Hackspace is actively involved in the local cultural life, with a presence during events, festivals and other community-based activities. There are also links with libraries and other charities and groups, in particular those working with young people. On the other hand, involvement with schools is minimal or non-existent. Interestingly, the educational side of making was viewed by members as unequivocally commercial and business-oriented, rather than a natural extension of the charitable, communitarian approach that otherwise inspired, according to them, the broader movement and the Leeds experience in particular. The overall consensus was that schools are generally not worth the effort, and that the best opportunities for a non-compromised version of "educational making" were in fact in the private sector – possibly in the shape of small enterprises (such as FabLabs[8]) providing a service to communities or parents willing to pay for out-of-school experiences, thus circumventing the safety regulations and curricular constrains of state-funded education.

> ***Mike:*** they (schools) will turn the whole thing into an educational activity, completely denying the social and creative aspects – simply put, it won't work like that and it will fail.
> ***John:*** I worry about bringing schools into it – with their regulations, safety and control – as opposed to run this as a private entity where you can do what you want … schools bring their own set of instructions and protocols that make the idea unfeasible.

2.2.2 Making in schools: disappointments, enthusiasm and the negotiation of identities

The interviews with the experienced makers provided us with valuable contextual information, as well as specific ideas and suggestions for the making sessions in the two schools. During these sessions we observed interactions among students and between students and devices, collecting verbal and visual evidence. The sessions were organised to replicate a simplified design process from idea to final prototype. Students were first introduced to the process through generative activities, such as drawing a basic circuit using conductive ink and the opportunity to manipulate playfully the equipment. Following the introduction, they were encouraged to work collaboratively sketching out ideas for a "digitally enhanced" artefact using only paper and pencils.

[8] http://fablabsuk.co.uk/

What became clear from the outset was the support required to produce feasible designs, coupled with the effort to manage the mildly disruptive behaviours, while keeping imagination and creativity constantly stimulated and fending off the boredom caused by the inevitable wearing off of the initial enthusiasm. As the design activities progressed from one session to the next, a few students became more involved than others in negotiating designs. On a couple of occasions, these discussions developed into heated debates about the direction of the design process, with students trying to convince each other (and the researchers) that their idea was the one to be taken forward into production. In one case, two students spent a considerable amount of time debating two different implementations of the same idea about wearable technology; one involving the ability to recognise clothing items for shopping purposes, and a more specific design sketch, which eventually succeeded, about a “smart” cat-flap and cat-collar combination (see Fig.2).

> ***Ikana:*** Basically, you know how like there’s sometimes you see other people, they’re wearing something and you wanna know where they got it from but you don’t want to ask, you don’t want to sound like an idiot, so obviously, you’ve got like clothing recognition, where you take the picture of the actual item, it analyses it and then it tells you where it’s from and you can go buy it from the shop without asking where it’s from (…) What about…you know you said about the cat one…
> ***Sam:*** so, my idea, I’m working in group but Ikana came up with the actual idea, and it’s this cat flap that’s connected to your phone and you can change whether the cat flap lets your own cat in, out or both ways or no way, like, locked. It’s also…the cat’s also wearing a collar that it tells the cat flap whether it’s in…the cat is in or out or not. You can…and you can…it also stops any cat that’s not your cat getting in, so like a cat, even with the same brand, it’s got a different serial number or high like frequency so that it doesn’t let anyone else’s cat in, even if it’s with the same brand. I just came up with this idea.
> ***Ikana:*** What if you saw a cat, and thought, ‘Oh, I wonder if that’s the same cat that’s on this poster?’, and maybe you could have something so that you take a picture of the cat and it registers…
> ***Sam:*** That’s what I said…

Figure 2. the "smart cat collar"

When the smart cat-flap + collar design sketch was taken forward into “production” alongside other ideas, it became soon clear that it would have been too demanding and complex to develop actual artefacts, given the many constraints in which the project was operating in terms of time and resources – not to mention that we lacked access to a real cat in order to test prototypes. Therefore, the process continued by exploring individual technological functions associated with the original design ideas, eventually focusing on an implementation which, although basic, was realistic and achievable given the available equipment and the level of technical expertise in both groups of students. This involved the creation of personalised messages and loops using the LED lights integrated into programmable microcontrollers (Fig. 4)[9] which, in turn, could be sewn onto clothing items and, in theory, even a cat collar.

Figure 3. A Code Bug - one of the micro-controllers used in the project.

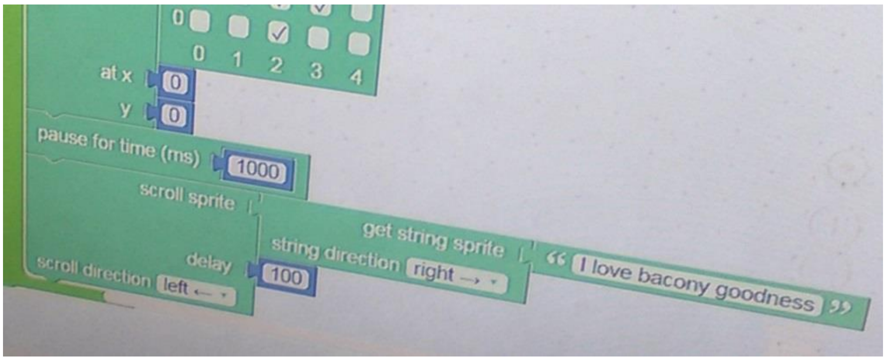

Figure 4. Lines of code in Blockly

[9] http://www.codebug.org.uk/

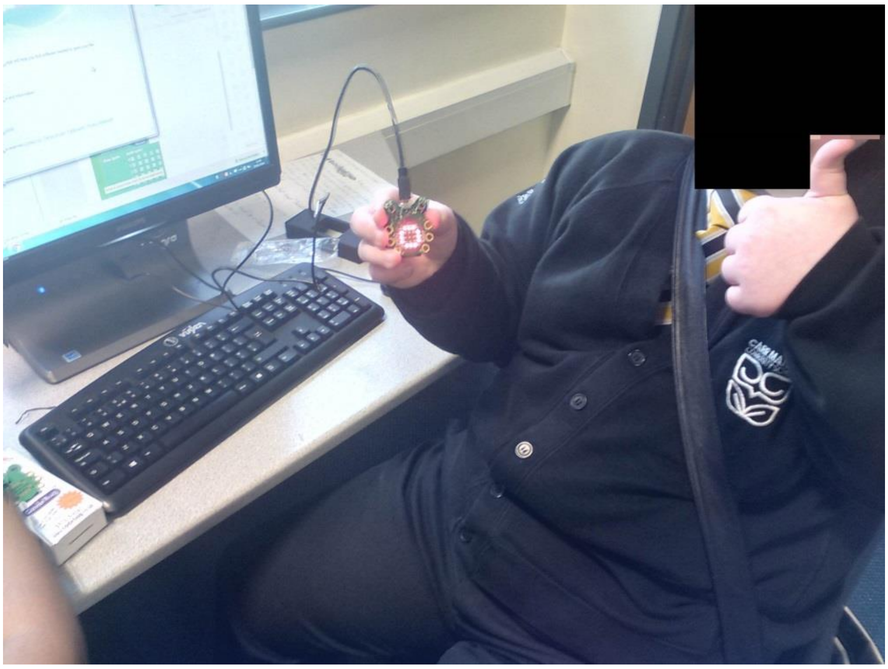

Figure 5. "Eureka" moment as the device worked as intended.

Despite the frustrations and the compromises, the process continued with students growing visibly more proficient and developing an awareness of the complexities of technological design and software coding. Towards the end, we began to observe signs of positive identities and roles emerging from the interactions - identities which were associated with specific academic and professional trajectories. One of these was the stereotypical "geek" identity, here explored as part of a positive, socially acceptable mode of engagement with technology, and positioned in contrast to the less appealing but equally stereotypical "nerd" identity.

> ***Sam*****:** The best part, I think, was when you actually saw it all like coming together. The hardest part for me was when…I was accidentally failing on one part of the entire thing, and then would have to change it all the entire thing wouldn't work if just one part of it was broken or something (…) And I like doing this, like making stuff, and I do like Science so I probably will do more stuff like this in the future.
>
> ***Callum:*** Yeah, I quite like the idea of being able to like express yourself through technology. And being able to, you know, create new stuff. And, you know, just give that a try.
>
> ***Jasmine***: I think the word 'geek' is like…a geek is someone… they've got a social life yeah, and they can like go out and like be with friends, but they've got skills and like science-y type stuff and like computer and all that sort of stuff and loads of people like get geeks and nerds mixed up. Because stereotypically geeks are the ones who like to go out and they can do stuff with their friends, but they can also come in and do techy stuff, and nerds are just lonely, and just sit at a computer all day, just like this far away from the screens like.

The final set of remarks in this section relates to the broader impact that the project had on the curriculum in both schools. Indeed, digital making ignited thoughts on the role of meaningful technological engagement and its place in formal education. Through formal timetabling or extra-curricular groups and projects, such place was often determined by constraints on the curriculum and leadership decisions which were constantly negotiated between us researchers and the schools. During the course of the project, whether making "creative" or "art" circuits, playful electronics or incorporating physical computing into projects, some teachers voiced concerns about planning for the unexpected and others radically changed their learning spaces to facilitate a whole new peer to peer learning approach. The amount of time taken to plan alongside extending teachers' knowledge and skills to effectively facilitate was indeed problematic for some teachers. Nonetheless, what became apparent with our cohort of students and their teachers was the intrigue, interest and inventive opportunities associated with building a wearable tech project. Whilst facilitation was intensive, remarks from the students point towards a learning environment which is free from the usual constraints of their "usual" curriculum and takes time to adapt to.

3. Conclusion and next steps

In this report we described the main findings from a from a small research project involving two schools in Leeds. A reflection upon the overall process and an analysis of the implications will begin in this conclusive section, and will continue in future planned publications, which include at least one peer-reviewed article. The main points can be summarised as follows:

- The maker movement, and its influence on formal education, can be productively examined as topics of sociological and cultural interest, in order to better understand the pedagogic implications and the applicability of specific instructional interventions. Making, in other words, is not a brand new educational innovation, nor does it signal the emergence of radically different educational approaches. It should instead be viewed as part of historical and cultural trends that include changes in the nature of industrial production in the 20th century, the increase in, and sophistication of, "productive" leisure time among the middle classes, changes in notions of childhood and shifts in the perceptions about the economic and social purpose of education.
- During the design sessions, the process of working with students from a vague design idea to an output of some description was as much based on a playful engagement with tools and hackable devices, as on the constant need to generate interest and secure localised forms of "micro-sponsorship", whilst maintaining high levels of engagement and motivation. This process was distributed and multidirectional in nature. On the one hand, we encouraged students to inject personal motivations and interests in their designs; we asked them to convince us and their peers that their ideas were interesting and worth pursuing; and we invited them to go online to seek validation and advice from various online communities of makers. On the other hand, we were doing something very similar in our own relations with teachers and school leaders. Laboriously rekindling interest among actors while trying to secure sponsorship for the project and convincing our interlocutors that this was a worthwhile effort which would generate impact. It was precisely at the juncture points of all these networked relations that the "creative" process was taking place.
- It is also undeniable that some of the creative outcomes that emerged from this process were more successful than others - by "success" we mean the coming together of individual, technical and social factors that allowed some ideas to eventually "become real", even though in a compromised form, leaving behind the nebulous stage of sketching and "messing about" (often accompanied by playful banter and mild forms disruption) and acquiring tangible connotations. Whenever this happened, it led to those "eureka" moments which were as uplifting for students as they were for us, as we were all equally implicated and invested in this miniature innovation process.
- The findings are consistent with insights from sociomaterial studies in education (Fenwick et al., 2011), which suggest that teachers, students and artefacts can become involved in "micro innovation processes" revolving around material connections and artefacts. Similar notions from Actor-Network theory can be drawn upon to make sense of the findings, such as Bruno Latour's work on "technological love" (1996). According to Latour, innovation processes cannot be sustained without full, uninterrupted attention and a great deal of propping up, encouragement and cheerleading. Rather than being the work of "invention", technological design at all levels (even among young people) requires a tireless commitment to mobilise opinions and generate interest. These ideas represent, altogether, an original

contribution to our understanding of the social process that underpin and, in the right circumstances, may enable making in formal education.

Dissemination activities so far:
Perrotta, C. and Garside, C. (2016). Technological love revisited: the materiality and sociality of "digital making" in education. Paper presented at British Educational Research Association (BERA) Annual Conference, University of Leeds, 13-15 September 2016.

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