Educational Makerspaces: Disruptive, Educative or Neither?

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ABSTRACT

Makerspaces are now common in schools. Their advocates argue that they improve learning; that they foster future-focused learning; and that they are, potentially, a disruptive force for good in education. This article evaluates these claims. It looks at the origins of the makerspace concept and at its uptake by educationists. It argues that, in their current form, school makerspaces are unlikely to be 'educative', in the Deweyan sense. Nor are they especially 'future-focused' or 'disruptive'. The makerspace idea is, however, potentially useful in educational contexts. The article puts forward two rather different ways school makerspaces could be educative and/or disruptive.

INTRODUCTION

The past decade or so has seen the publication of hundreds of articles extolling the virtues of the 'maker' movement. This movement is variously seen as having the potential to scaffold new forms of democratised manufacturing; to produce a shift away from 'consuming' to 'creating'; and to re-ignite interest in the STEM professions. Makerspaces, FabLabs, and Hackerspaces are being set up in community spaces and public libraries; companies are providing them for their employees; and governments have established programmes to foster 'maker culture'.[1]

Ideas from 'maker culture' are becoming increasingly influential in educational contexts. New school builds now routinely include 'makerspaces' and many existing schools are re-purposing classrooms as makerspaces. Makerspaces are seen as having a range of educational benefits. For some advocates, they are 'future-focused', in that they foster '21st century skills', break down traditional subject silos, and/or 'disrupt' conventional pedagogies.

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[1] For example: the 'Nation of Makers' initiative in the US (see: https://obamawhitehouse.archives.gov/node/316486) or the Chinese 'Mass Makerspace' initiative (see: http://techculturematters.com/2015/11/06/mass-making-in-china).

For others, their strength lies in their capacity to engage more students in deeper learning, particularly in the STEM subjects.

This article explores these claims. It looks at the origins of the makerspace concept and then at how—and why—it was imported into education. It has two aims: to assess whether school makerspaces, in their current form, are 'educative', in the Deweyan sense, and to explore whether makerspaces are—or could be—a disruptive force in education.

WHAT ARE MAKERSPACES?

Makerspaces are collectives, active 'communities of practice' that allow people to work on projects of interest through sharing resources and knowledge (Fleming, 2015; Roslund & Rodgers, 2014). They can include elements from art/craft studios, sewing/textiles spaces, carpentry/engineering workshops, kitchens, multi-media spaces, or computer/science/robotics labs. What makes makerspaces different from all of these, however, is that their purpose is not to specialise or to learn discipline-specific skills but, rather, to foster collaboration, diversity, and 'cross-pollination' across different materials, techniques, and expertise (Cooper, 2013). Thus 'making' is distinguished from the usually solo activities of tinkering or inventing.

'Maker culture' has a set of core values. These include a commitment to sharing and collaborating with other makers with different interests and skills; a focus on creating, not consuming existing products; and an agenda for personal and social change (Hatch, 2014). Some makerspace advocates talk about the 'maker mindset' or 'identity', by which they mean a commitment to building knowledge together and, with others, turning it into action (Dougherty, 2013; Fleming, 2015).

The original makerspaces were deliberately informal, grassroots-level affinity groups interested in establishing semi-permanent spaces for resource-sharing to work on solo or collaborative projects (Schrock, 2014). Makerspaces were set up to be playgrounds for adults, places for experimentation, play, and collective innovation. These were seen as ends in themselves. Learning might occur, but it was not a focus (Kurti, S, Kurti, D & Fleming, 2014). 'Making' meant designing, prototyping, creating and, importantly, sharing manufactured works that could not have been created with the resources available to an individual working alone. Maker 'culture' is embedded in a wider socio-political movement, and the original makerspaces were explicitly intended to be quite unlike schools (Davis, 2014; Dougherty, 2016).

The makerspace idea's success has led to its uptake in other, more formal contexts. Makerspaces are now found in museums, public libraries and other community facilities; as adjuncts attached to not-for-profit organisations or commercial companies; and in schools and universities. One reason for this is that some educationists have identified synergies between the makerspace concept and some of the objectives of education.

MAKERSPACES IN SCHOOLS

Educational makerspace advocates argue that 'maker culture' could 'revolutionise' teaching and learning and 'disrupt' or 'transform' education, as

we know it (e.g. Dougherty, 2013, 2016; Kurti, S et al, 2014; Martinez & Stager, 2013; Moran, 2015). Some say that it builds 'future-focused' knowledge and dispositions, and that it breaks down the barriers between traditional subject 'silos' (e.g. Osborne, 2014; Wenmoth, 2015). Others make a case for seeing the school makerspace concept as both future-focused and able to foster deep learning, arguing that it:

> develops 21st Century Skills (particularly critical thinking, collaboration, creativity, and problem-solving) and provides students with opportunities to engage in deep/constructivist learning (Amos, 2014).

Thus, two broad claims are made. One, which I will call the 'better learning' claim, emphasises makerspace as a strategy for improving engagement in learning, or for supporting deeper learning. The other, which I will call the 'future-focused education' claim, emphasises makerspace as a strategy for supporting the re-development of education for the future, building '21st century skills' in students and/or creating opportunities for educators to re-think the purposes of education in the 21st century. These two claims are very different. It is, however, common to see them put together in ways that, as I argue later in this article, are detrimental to both maker culture and education.

The 'Better Learning' Argument

Citing Dewey, Piaget, Papert, and the Reggio Emilia philosophies, educational makerspace advocates argue that importing 'maker culture' into schools is a way of putting into practice key ideas from both progressivist education and constructivist theories of learning (e.g. Martinez & Stager, 2013). 'Maker culture' fits well with progressivist ideas in education. It involves 'learning by doing'. It is inherently 'active', 'authentic', learner-driven, inquiry-based, collaborative, and 'hands-on'. But, the advocates argue, maker culture can do far more than just support progressivist educational ideals: it can 're-animate' or 'power them up' (Stager, 2014). This is now possible through the ready availability of technologies that make digital fabrication affordable for schools (e.g. 3D printers, laser cutters, robotics, and tiny Internet-connectable microprocessors like Arduin or Raspberry Pi). It is now possible for students, even very young ones, to safely and cheaply design, prototype, build, and share their creations online (Blikstein, 2013; Eisenberg & Buechley, 2008). These technologies allow school students to genuinely participate in 'maker culture', outside the school classroom. For the educational makerspace advocates, this makes genuinely 'disruptive' innovation in education possible (Davis, 2014; Martinez & Stager, 2013).[2]

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[2] Disruptive innovation is a term used in business to mean a product or service that builds influence at the bottom of a market but moves upwards, eventually displacing long-established products. Its originator, Clayton Christensen, wrote a follow-up book on disruptive innovation in education (Christensen, Horn, & Johnson, 2008), and the term is now widely used by change proponents in education. Martinez & Stager (2013) draw on this idea when they characterise educational makerspace as a disruptive innovation.

School makerspace advocates also emphasise the capacity of makerspaces to improve learning. For Kurti, S et al (2014, p. 8), the point of a school makerspace is to "harness" the "intellectual playground concept" from maker culture for "inspiring deeper learning" in schools. Referencing early constructivist work, in particular work done in the 1970s by Seymour Papert, a key claim (e.g. Martinez & Stager, 2013) is that making *things* helps people *learn*: that is, people will use the experience of making a physical thing to help them make new personal knowledge. This claim re-purposes the original 'maker culture' values (some might say it subverts them). It also re-purposes some key educational ideas in ways that, it seems to me, detract from rather than support the educational makerspace case. Three examples are outlined below.

First is the fairly obvious point that constructing physical things is not the same as constructing mental structures, and these two activities do not map onto each other in any straightforward way. It is what happens *between* these two sets of processes that matters, educationally speaking. Piaget wrote about the 'child as builder' of their own intellectual structures (e.g. Piaget, 1929). Here 'building', in the sense of intellectual structures, is a metaphor. According to Piaget, the 'materials' children use for this 'building' come from the culture around them. Following Piaget, Papert (1980) points out that it is relatively easy for children to build the intellectual structures for some concepts, as the culture around them is replete with the necessary 'raw materials'. Other concepts are, however, much harder for children to 'build' because of, as he puts it, the "relative poverty of the culture in those materials that would make the concept simple and concrete" (Papert, 1980, p. 7).

Linking this to the makerspace argument, having children build physical things *could* foster the building of their internal intellectual structures, by providing them with 'raw materials'—that is, experiences—that are unlikely to be available to them in their everyday cultural context. But, for these experiences to be used to build intellectual structures, they have to be talked about and formed into ideas. Using the activity of building things to support the building of intellectual structures requires a focus on *ideas*, not things. These could be ideas about the nature of the things and/or how they work, or ideas that have to do with the social meaning of the things. As Papert (1980) puts it, for educational purposes, the built things are unimportant in themselves: their role is to be things to *think with*.

A second, related issue is that the focus on 'things' diverts attention away from Papert's main interest, which was children's *ideas* and how best to support their development. Papert's life's work involved developing learning environments that could allow children to construct 'powerful ideas'. For him, what matters is that children learn that "the most powerful idea of all is the *idea of powerful ideas*" (1980, p. 76). Here Papert is using the work of two influential early twentieth century philosophers. John Dewey and Alfred North Whitehead wrote extensively on the question of what constitutes an 'educative' experience. For Dewey, education means to scaffold intellectual adulthood. It is a slow and steady apprenticeship into adult-like ways of thinking and forms of knowledge. It involves learning to think for oneself, in increasingly abstract and complex ways. According to Dewey, an experience is "mis-educative" if it constrains intellectual development by "arresting or distorting the growth of further experience" (1938, p. 25). For him the educator's central role is to provide 'educative' experiences

that scaffold intellectual development by exposing people to, and allowing them to work with, increasingly complex or 'powerful' ideas.

Alfred North Whitehead, writing in the late 1920s, focuses explicitly on the role of ideas in education. For him, the purpose of education is to build 'activity of thought' by working with ideas. He argues that

> above all things we must beware of what I will call 'inert ideas' – that is to say, ideas that are merely received into the mind without being utilised, or tested, or thrown into fresh combinations (Whitehead, 1929, p.1).

Being educated, for Whitehead, involves using, playing with, and appreciating ideas, and, importantly, exploring the relationships ideas have with *other* ideas. Ideas are not inert, static entities to be passively acquired and stored away: they are complex, organic and malleable, always in process. According to Whitehead:

> What education has to impart is an intimate sense for the power of ideas, for the beauty of ideas, and for the structure of ideas.…[Education should develop an] eye for the whole chessboard, for the bearing of one set of ideas on another. (1929, p. 8).

> Education with inert ideas is not only useless, it is, above all things, harmful – Corruptio optimi, pessima. (1929, p. 1).

Accepting this means questioning the educative potential of makerspace, if the focus is on learning through making things, as opposed to learning through working with the *ideas* that give *meaning* to those things.

A third reason why the claim that building things supports learning is not helpful is that it treats 'learning' as an end-in-itself. It is not clear how, if at all, the making of physical objects supports the development of deeper conceptual understandings of the materials, processes and principles that allow the made object to 'work' – that is, Papert's "powerful ideas". Papert himself would not have argued that constructing things leads directly to learning. Nor would he have emphasised learning as an end-in-itself. His aims were rather different from that of many contemporary makerspace advocates. Papert was a mathematician who developed an interest in learning theory in order to find ways to help children have first-hand experience of powerful concepts, first from mathematics, and later science. In the 1970s he and his collaborators developed computer programmes (e.g. LOGO) designed to give children mathematical modelling experience as they designed games, composed music, or made movies (i.e. products they were interested in and which had personal meaning for them). Understanding *mathematics* was, however, the goal, not learning in general (Papert, 1980). Papert's aim was to provide contexts that could foster the learning of *particular* concepts that, he argued, are difficult to construct from the 'raw materials' readily available to children.

More recently, some educators have used this work to advocate using makerspaces as a strategy for engaging students in STEM learning (e.g. Baars,

n.d.; Thomas, 2012; Tucker-Raymond, 2016). If, however the makerspace experiences are to be 'educative" (in the sense discussed above), the focus should be, not on the things students produce, or learning in general, but fostering students' ability to work with the 'powerful ideas' of, in this context, mathematics and science. My point here is that bypassing the question of whether or not anything *in particular* should be learned is a strategic mistake. If the case for school makerspace rests on the 'improved learning' claim, but is silent on *what* is to be learned and/or how makerspace contributes to intellectual development, then, in the current educational climate, the case is likely to fail, and we can expect makerspace to join the many other 'disruptive' ideas that have been lost, marginalised, or assimilated.

The 'Future-Focused Education' Argument

'Future-focused education' is a term that now appears regularly in education policy documents and 'future focus' is one of the four key principles of *The New Zealand Curriculum* (Ministry of Education, 2007). The term is not easily defined, however. In policy and practitioner-oriented contexts, in New Zealand and internationally, it seems to be a gloss for a broad grouping of ideas, linked in various ways to change. At one end of this spectrum of ideas, 'future-focused' means 'working smarter' to raise achievement for the future while, at the other end, it signifies radical change, disruption, or paradigm shift. In between are a range of other ideas. These include the '21st century skills' idea, otherwise known as the '4Cs': critical thinking, collaboration, creativity and communication (e.g. P21 Partnership for 21st Century Learning, 2007). These skills, along with innovation and entrepreneurialism, are now widely advocated for schools (e.g. https://www.21cskillslab.com) and universities.[3] A second group of ideas, connected with the educational implications of various new technologies, appears under the 'future-focus' banner. This group includes the 'digital literacies' concept; coding; 'networked'/'connected' learning; BYOD; innovative/flexible learning environments; and so on. A third group of ideas focuses on the educational implications of the new forms of—and orientation to—knowledge that are a feature of the 'new times'.

The makerspace concept is commonly linked to the first two of these three groups of ideas: i.e. '21st century skills' and 'digital literacies'. For example, the New Zealand Ministry of Education, on its Te Kete Ipurangi website, locates its makerspace resources and information under the 'future-focused learning' tab, alongside material on coding, robotics, and game-based learning, and New Zealand's National Library, a strong advocate for school makerspaces, explicitly links them to 'future focused learning'.[4] I have, however, been unable to locate any work linking makerspace with the third, 'new orientations to knowledge' group of ideas. To me this is an important gap, in terms of the case for

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[3] See, for example, this article on 'C-skills' on the Auckland University of Technology's website: http://www.news.aut.ac.nz/news/2015/july/why-new-zealand-needs-more-c-students.
[4] See: http://elearning.tki.org.nz/Teaching/Future-focused-learning/Makerspaces and https://natlib.govt.nz/blog/posts/reconceptualising-the-school-library-as-collaborative-makerspace.

makerspace's links with future-focused education, but also in terms of its 'educative' potential.

The prevailing view of future-focused education as being primarily to do with 21st century skills, digital literacies, innovative learning environments, and so on is, I think, mis-educative, in the Deweyan sense, and misses the point of 'maker culture'. Adding the makerspace idea into this agenda squanders an important opportunity to think 'outside the box' as we head toward an uncertain future.

HOW COULD MAKERSPACE BE EDUCATIVE AND FUTURE-FOCUSED?

As outlined earlier, the purpose of education for Dewey and Whitehead, is intellectual development. For them, education aims to expand our collective capacity to actively work with—and improve—ideas, at increasing levels of complexity and abstraction. For Dewey, activities designed to support the 'taking in' of disciplinary knowledge, where this is seen as an end-in-itself, are mis-educative. So are activities designed to support the acquisition of specific skills, or making things, if these are seen as ends-in-themselves. As Whitehead, and later Papert, argued, however, these activities can be educative, if the making and/or the skill/knowledge acquisition are vehicles for supporting the capacity to work critically with ideas. I think the makerspace concept could be used productively to do this, and to support the development of 'future-focused' education.[5]

MAKERSPACE AND FUTURE-FOCUSED EDUCATION: TAKE ONE

Earlier, I argued that the claims made for the capacity of makerspace to improve learning are based on a less-than-adequate understanding of learning and education's purpose. In this section I briefly explore a strategy for using makerspace in schools in a way that I think is both educative and grounded in cognitive science. This strategy stays within the boundaries of current understandings of the purposes of education, but it also provides a foundation for more robust conceptions of 'future-focused' education.

In the discussion of 'future-focused education' above, I mentioned three groups of ideas: the '21st century skills' group, the 'digital literacies' group, and a third group, which I called the 'new approaches to knowledge' group. To me, this is the most significant of the three groups of ideas, yet, in policy- and practitioner-oriented discussions of future-focused education, it has a much lower profile.

Very briefly, in this set of ideas, there is a focus on the need for curriculum and pedagogical change in the light of, first, the ever-increasing growth in knowledge, and second, the change in what knowledge means that is a defining feature of the 'knowledge age' (Castells, 2000; Gilbert, 2005; Weinberger, 2011). In considering how education can support this new orientation to knowledge, some educators have made the case for reconfiguring classrooms as centres for knowledge construction, not knowledge transmission (e.g. Bereiter, 2002). From this, concepts such as 'just-in-time' knowledge, the

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[5] The 'gamification' of education idea has similar 'educative' *potential*.

'knowledge-creating school' and a view of students as the 'co-constructors' or 'producers' of knowledge have emerged (e.g. Bigum, 2003; Hargreaves, 1999). These terms now appear frequently in policy- and practice-oriented discussions, often in unhelpful ways, from the perspective of the present discussion. In particular, personal knowledge and disciplinary knowledge are often conflated, as are the different processes through which each of these is built. This muddying of the waters, while not a new issue (see: McPhail, 2017), makes it very difficult to properly consider the role of knowledge in future-focused education. In terms of the present discussion, however, untangling this issue is critical if school makerspaces are to be future-focused and/or educative. Fortunately, there is an existing body of work to be built on here: the 'knowledge-building' concept, developed and tested in classrooms in four decades of work by the Canadian researchers Carl Bereiter, Marlene Scardamalia and their various associates. This concept is briefly outlined below.[6] Picking up on Papert's focus on 'powerful ideas', my point here is to argue that linking makerspace with knowledge-building is one possible way for makerspace to be future-focused and educative.

Knowledge, Knowledge-Building and Learning

Learning is usually thought of as an internal, individual mental process that produces changes in an individual's personal store of knowledge and the way they make sense of it (Bransford, Brown & Cocking, 2000; Claxton, 2002; Perkins, 2009). For most people, education and learning are tightly linked, almost synonymous concepts. Bereiter and Scardamalia's 'knowledge-building' concept is an attempt to break this deadlock. For Bereiter and Scardamalia, 'knowledge-building' is not learning, and this is its point. For them, 'knowledge-building' is sustained, intentional, working with others to *improve ideas* (Scardamalia & Bereiter, 2006). These improvements are made available for modifying and extending by others, with the aim of eventually making some sort of contribution to public knowledge (i.e. something that extends beyond the individuals involved). Like learning, knowledge-building involves cognitive activity, but the point of it is to focus is on collective idea improvement, not individual cognitive processes (Scardamalia & Bereiter, 2006). Bereiter and Scardamalia liken educational knowledge-building to the experience of working in a research team: participants may learn something, but this is not the central point of the activity (Bereiter, 2002; Scardamalia & Bereiter, 2006). Bereiter argues that all classroom activities should be reconfigured to resemble what he calls 'real research', as opposed to inquiry, collaboration, project-based learning and so on, which, he says, militate against knowledge-building (Bereiter, 2002).[7] For him, knowledge-building in 'real research' contexts, not learning, is an appropriate basis for developing the capacities, understandings and

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[6] For more detailed accounts of knowledge-building, see the original sources cited in the text, especially Scardamalia & Bereiter (2006); Bereiter & Scardamalia (2014), Knowledge Building New Zealand's website https://sites.google.com/netnz.org/kbnz/home; Skillen, 2015.

[7] Claxton (2015) makes a similar case for the educational benefits of students carrying out community-based consultancies and research. See also: Claxton (2014).

dispositions needed for life and work in the 'knowledge age' (see also: Scardamalia & Bereiter, 1999).

Bereiter and Scardamalia's knowledge-building idea has a great deal in common with the makerspace concept, as expressed in maker culture. Both focus on collective idea improvement, and on sharing the improved ideas for further development by others, for the collective good. Putting these two ideas together could be a useful strategy for supporting the development of the 'future-focused' orientations to knowledge referred to earlier. But, for this to be productive, educationally speaking, it is important to be clear about the very different meanings of knowledge embedded in the knowledge-building concept. Bereiter and Scardamalia (2014) distinguish Knowledge (with a capital K) from Knowledge-in-Development. For them Knowledge is disciplinary knowledge: the validated, agreed-on, codified and published set of concepts that form the basis of a given discipline at any point in time. Knowledge-in-Development, on the other hand, describes the processes by which new knowledge in a given discipline is developed over time: that is, the experimentation, collaboration, argumentation, negotiation, and debate that takes place between the people who are the field's experts, as they 'construct' new knowledge, using the procedures and protocols of that discipline, with each other - i.e. socially. Successful Knowledge-in-Development requires skills and dispositions over and above mastery of the discipline's key concepts, skills and dispositions. These skills and dispositions usually develop informally, *alongside* conceptual knowledge, as individuals are inducted into a particular 'expert' context.

For Bereiter and Scardamalia, school activities should be an apprenticeship in Knowledge-in-Development. They should give students opportunities to experience, in simplified form, all aspects of the process. This could scaffold the '4C' skills referred to earlier, and it could also scaffold deeper conceptual understanding of whatever disciplinary Knowledge is involved. But, and this is important, in the knowledge-building context, none of this is the point. The point is to develop the capacity to actively and intentionally work with ideas, in increasingly complex ways, and to improve these ideas for the collective good. This is what makes knowledge-building *educative*.

Bereiter and Scardamalia are very clear that Knowledge and Knowledge-in-Development in professional contexts are not the same as knowledge and knowledge-in-development in schools (Bereiter & Scardamalia, 2014). They use knowledge (lower case k) to refer *not* to disciplinary Knowledge, but to the collective 'constructs' made by a group of students as they work together to improve ideas, while (lower case) knowledge-in-development denotes the processes students experience together as they do this work. Individual learning and/or the acquiring of (capital K) Knowledge may occur, but they are not central.

Bereiter and Scardamalia are *not* arguing that schools should be creating new disciplinary Knowledge. Rather, their point is that schools should scaffold the *capacity* for Knowledge-in-Development. This is an important point in terms of the confusion, referred to earlier, between personal knowledge and learning on the one hand, and disciplinary knowledge and the processes by which it is constructed, on the other. It is also an important point to reflect on when considering the implications for education of the 'maker revolution', one of which is the possibility that young 'makers' *could* actually contribute to the

development of new, capital K Knowledge. This possibility is explored in the next section.

MAKERSPACE AND FUTURE-FOCUSED EDUCATION: TAKE TWO

The prevailing view of future-focused education as being about 21st century skills, digital literacies, and/or innovative learning environments is, in my view, woefully inadequate. Space constraints here preclude a detailed discussion of why I think this view is inadequate (and I have made these arguments elsewhere: see Gilbert, 2005; 2016; 2017; Gilbert & Bull, 2013), but briefly, it seems to me that future-focused education, as currently represented in policy and practitioner contexts, is basically 'business as usual' education, with a few added features. These 'add-ons', while they might make things look slightly different, have not challenged twentieth century ideas about the purpose of education and/or the nature of its relationship to the wider social, economic, or political context. As we move into a new and very different age, in my view, we need to re-engage with, and possibly re-work, some of our past assumptions about what education is for.

Outside education, a large and very diverse literature has been documenting the disruption of the foundations of twentieth century thinking by a variety of developments, including, the 'digital revolution' (Brynjolfsson & McAfee, 2011; Dobbs, Manyika & Woetzel, 2015; Kelly, 2016; Ross, 2016; Watson, 2016); the growth of new, 'networked 'forms of knowledge (Castells, 2000; Weinberger, 2011); the advent of the Anthropocene and the need for new low-emissions economies (Dator, 2009; McNeil & Engelke, 2014; Slaughter, 2012); and recent shifts in the global economic and political landscape (Mason, 2015; Sardar, 2010). Some commentators predict that these developments are about to come together in the form of a 'singularity' that is likely to trigger abrupt, exponential and unimaginable change in human civilisation (Kurzweil, 2005).These developments have enormous implications for education, on many levels, which will not be addressed by the current focus on '21st century skills' and 'digital literacies'.

Some commentators make the case for including the 'maker revolution' in this list of key 'disruptors.' (e.g. Anderson, 2012; Hatch, 2014). As we have seen, ideas taken from 'maker culture' have been picked up in educational contexts. This has occurred in ways that do not reflect the wider—and some would say defining—features of maker culture, however. In this last section I look at the maker revolution in terms of its capacity to disrupt education, possibly fatally. My point is to suggest that, because makerspace ideas are familiar to many educationists, elaborating them could be a useful starting point for the difficult discussions about the future of education that we need to have. Instead of appropriating aspects of maker culture to prop up the existing system, we need to take a bigger view, to pay attention to the maker revolution's implications for education's future. Doing this makes it clear, I think, that the current focus on 21st century skills and digital literacies is not only inadequate, but actively contributing to the decline of public education. Unlike some commentators (e.g. Blacker, 2013; Labaree, 2010; Marsh, 2011), I do not think this decline is inevitable, but we do need to stop forcing new ideas to fit into a system that was built for an earlier age.

The 'Maker Revolution'

Inserting maker culture into schools is problematic because the two contexts have different premises. The makerspace concept could disrupt education, or it could be assimilated into it, depending on how educators choose to react to it. Currently the latter looks more likely. According to Halverson and Sheridan (2014, p. 500), citing Dougherty (2012),

> the greatest fear…of those deeply invested in the maker movement is that attempts to institutionalise making—through schools, after-school programmes, etc—will quash the emergence, creativity, innovation, and entrepreneurial spirit that are hallmarks of the 'maker revolution'.

Halverson and Sheridan go on to argue that it is the extent to which another core value of maker culture, its 'democratising potential', is taken up that will determine whether "institutionalisation will kill the essence of the maker movement" (2014, p. 500). For Halverson and Sheridan,

> the great promise of the maker movement in education is to democratize access to the discourses of power that accompany becoming a producer of artifacts, especially when those artifacts use twenty-first century technologies (2014, p. 500).

Put another way, school makerspaces could be 'educative', if they make it possible for *anyone* to work with the 'powerful ideas' involved in creating new things. As argued above, this is, however, unlikely where the focus is on making things or on learning, as ends-in-themselves, especially where these activities are largely teacher-directed. Educationally speaking, the 'democratising potential' of makerspace is its greatest asset. Among other things, it could link the past purposes of education with its future purposes., but because it could make schools redundant, it is also a threat, however.

The term 'maker revolution' appears to have been coined by Chris Anderson to denote the maker movement's role in a new industrial revolution, defined by what Anderson calls the 'democratisation' of manufacturing (Anderson, 2012). According to Anderson, just as the digital revolution 'democratised' publishing, broadcasting and communications, in that now anyone can publish anything, something similar is happening with manufacturing. Making physical things, formerly the province of large companies and specialised professionals, has 'gone digital'. The capacity to use digital 'bits' to manipulate physical atoms has given us the Internet of Things, but it has also made possible what Anderson calls "networked digital DIY" (2012, p. 21). According to Anderson, "we are all makers now" (2012, p. 13): *anyone* can manufacture *anything* (see also Dougherty, 2012).

For Anderson, 'maker culture' is a revolutionary social movement. This movement has arisen from the coming together of people sharing particular values and political goals with the affordances of recent technological innovations. According to Anderson, maker culture is collaborative "making in public" (2012, p. 21), but it has aims that go far deeper than simply making and/or improving things as ends in themselves. For him it has three key features, all of which are transformative:

1. People using digital desktop tools to create designs for new products and prototype them ('digital DIY').
2. A cultural norm to share those designs and collaborate with others in online communities.
3. The use of common design file standards that allow anyone, if they desire, to send their designs to commercial manufacturing services to be produced in any number, just as easily as they can fabricate them on their desktop. This radically foreshortens the path from idea to entrepreneurship, just as the Web did in software, information and content (Anderson, 2012).

Thus, for Anderson, maker culture is very different from tinkering and/or inventing, which take place on a small scale, one-off basis, rarely going beyond the inventor's garage or spare room. Maker culture's networking/sharing ethos allows anyone to be an entrepreneur and/or a manufacturer, if they want to. Minimal set-up capital is needed, economies of scale are not important, and innovation is easier. Because products do not need to be mass-produced on a one-size-fits-all basis, space is created for niche and/or 'artisan' goods. Small businesses can stay small: they can be small and global, artisanal and innovative, high-tech and low-cost.

All this, Anderson points out, means that the maker revolution, like earlier industrial revolutions, has major implications for manufacturing. Anderson remarked that Cory Doctorow's 2009 sci-fi book, *Makers*, imagined a world in which "[t]he days of companies with names like General Electric, General Mills, and General Motors are over" (2012, p. 16), adding that Karl Marx's ideal—that the means of production be controlled by the masses—could be a reality (2012). And, as was the case with the earlier industrial revolutions, these changes also have major implications for the social and economic structures that evolved alongside the mass-production way of doing things, including education.

The 'Maker Revolution' and Education

Our education system—and the ideas that drive it—was forged in first industrial age thinking (Beare, 2001; Bolstad & Gilbert, 2012; Gilbert, 2005; Leadbeater, 2011; Robinson, 2011). First industrial age economies are based on extracting resources from nature and mass producing them into standardised goods, on a huge scale, in factories owned by large companies. The way our education system is structured is deeply embedded in this thinking. We still use large-scale production lines to turn out standardised products. Technicians trained to focus on different zones of the production line 'bolt on'

pre-set knowledge and dispositions that (we think) young people will need for their future work in large-scale enterprises organised as factories or bureaucracies. The response of education to the 'digital revolution' has, so far, been limited to adding digital devices into the mix of existing structures and systems, basically as nice-to-have 'extras'. While it has produced major social and economic change in other areas, the 'digital revolution' has not seriously disrupted education at its roots (Dumont, Istance & Benavides, 2010). Rather, a selection of its products has been appropriated, and, like square pegs in round holes, made to serve first industrial age purposes. Our education system is a long way from being ready for the third and fourth industrial revolutions, now well under way, described by Anderson and others (e.g. Rifkin, 2011; Schwab, 2016). If Anderson is right, much of what currently happens in schools is already redundant. The first industrial age focus on preparing people for known forms of work in large-scale enterprises, to respect authority, follow standardised rules, and turn up on time, is not necessarily appropriate. Nor is the focus on delivering existing disciplinary knowledge in pre-set sequences of bite-sized pieces to age-related cohorts of students.

If the shift Anderson anticipates occurs, large-scale manufacturing processes will be mainly carried out by robots, but many products will be created on a much smaller scale, for niche markets, by agile groups of makers. This, as other commentators have pointed out, has already produced deep changes in capitalism, which have outmoded the need for mass labour, disciplined to work—and think—in particular ways (e.g. Avent, 2017; Blacker, 2013; Bregman, 2017; Dunlop, 2016; Harari, 2015; Kurzweil, 2005; Mason, 2015). This in turn outmodes the first industrial age justification for public education designed to equip each and every citizen with productive capacity. New—or other—justifications are now needed.

But, looking at this from another angle, the maker revolution makes it possible for individuals or small groups to do many things previously only possible in large organisations. Because the new makers will not need these organisations, they will not need the entry requirements to them, currently provided by schools. This de-coupling between schooling and this kind of work is a threat to education, as most people currently think of it.[8] It is, however, also an opportunity to seriously consider some new—or not so new—purposes for education.

This is where the 'democratizing potential' of the maker revolution could be important. In one scenario, it could make education redundant. But in another, if it was used to provide everyone with access to powerful ideas, it could pave the way for renewing education. Participating in the informal, agile, and ideas-rich environments of maker cultures could democratise entrepreneurialism, but it could also prepare people to survive and thrive in a world without formal paid work. Or both.

The 'maker revolution' work of Anderson and Hatch has been criticised for its neglect of the likely response of capitalism to the scenarios suggested (e.g.

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[8] I am not arguing that the purpose of education is to prepare people for employment (as I hope is clear from the content of this article), but, in many contexts, inside and outside education, this purpose is assumed.

Morosov, 2014),[9] in particular the assumption that, as the 'maker revolution' disrupts manufacturing, its key values (collaboration, sharing, equal opportunity, and so on) will persist. This has implications for educational thinking about makerspace. Celebrating the makerspace idea without a clear theory of the purpose of education is, I think, dangerous (and likely to contribute to further inequalities). But, if school makerspaces can be used to democratise access, not (necessarily) to the means of physical production, but to the means of *intellectual* production, then there is a clear educational justification. This is the main point of this article. I have argued that maker culture *could* be productive, educationally speaking, if the focus is on *ideas*—expressing them, playing with them, testing them, trying them out in different combinations—for all. This focus is critical, not just for education, but for the planet.

I suggest the ultimate '21st century skill' to be fostered in students is the capacity to work with ideas in ways that can address the 'wicked problems' we now face —the very complex problems that are difficult or impossible to solve with first industrial age thinking (Conklin, 2006; Frame, 2008; Rittel & Webber, 1973). The current emphasis on learning and/or acquiring existing knowledge, as an end in itself, is unlikely to foster this capacity.

In this article, I have argued that claims that school makerspaces can improve learning and/or contribute to future-focused education are, in their present form, flawed. The makerspace idea does, however, have educational potential. Put together with an ideas-oriented pedagogy like knowledge-building, it could be both future-focused and educative. Alternatively, it could serve as a kind of 'canary in the coalmine' for education, a warning that continuing with 'business as usual' education is likely to kill it.

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[9] Morozov (2014) also points out that Anderson and Hatch have business interests in products linked with maker culture.

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