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Makers, Hackers and Fabbers: What is the future for D&T?

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Abstract

UK D&T curricula are largely predicated on developing in pupils designing and making skills and knowledge that are derived from industrial design (and, to some extent, engineering) practice; particular importance is given to the ideas of such things as designing for clients, a wide range of design communication skills and, particularly by GCSE (14-16 years), industrial practices such as designing for volume production, market awareness and protecting design ideas (through, for example, patents).

This paper examines the extent to which this 20th century model for D&T might be tested by changes in technology and social organisation that are already evident (often in nascent form) in the first years of the 21st century. Since these changes are likely to be subject to rapid acceleration in the next few decades, they are also likely to significantly challenge ideas of what a product is and how and by whom it might be created – and even owned.

Keirl (2007) has argued that there are five perspectives which should be used to examine the design of a D&T curriculum: The Global (how the curriculum relates to what is happening in the world), The would-be stakeholders (who the curriculum is serving), Society (the contribution of the curriculum to education for democracy), Students as fulfilled persons (what the curriculum does for pupils) and Curriculum dynamics (how our bit of the curriculum relates to the whole).

Keirl's perspectives are used to examine how approaching technological, legal and societal developments might not only be accommodated in a 21st century curriculum but also celebrated as a route to creating an 'ethically defensible' (ibid) curriculum that will allow D&T (or its immediate successor) to contribute meaningfully to a broad education for a technological literacy that supports education for democracy. Particular attention is given in the paper to the development of personal fabrication technologies, to the emerging use of web 2.0 technologies to support personal fabrication, to the growing international maker movement, to the contributions of

the hacker community, to the emergence of low cost embedded control technologies and the 'internet of things' and to the open-source and creative commons movements.

Key words

Introduction

Two future forces, one mostly social, one mostly technological, are intersecting to transform how goods, services, and experiences— the "stuff" of our world—will be designed, manufactured, and distributed over the next decade. An emerging do-it-yourself culture of "makers" is boldly voiding warranties to tweak, hack, and customize the products they buy. And what they can't purchase, they build from scratch. Meanwhile, flexible manufacturing technologies on the horizon will change fabrication from massive and centralized to lightweight and ad hoc. These trends sit atop a platform of grassroots economics—new market structures developing online that embody a shift from stores and sales to communities and connections.

(Institute for the Future, 2008)

The UK has a model for Design and Technology (D&T) education that is profoundly influenced by commercial design practice – especially from the practices of industrial design, product design, textiles design and engineering design (this paper has little explicit to say on the matter of food technology education, though food technology teachers may see associations that I cannot). Thus we find that particular importance is given to the ideas of such things as designing for clients, a wide range of design communication skills and industrial practices such as designing for volume production, market awareness and protecting design ideas (through, for example, patents). The following quotes from the latest version of the English National Curriculum for Key Stage 3 (11-14 years) exemplify this emphasis:

The Design and Technology Association Education & International Research Conference 2008

designing the curriculum – making it work
designing the curriculum – making it work
designing the curriculum – making it work
designing the curriculum – making it work

designing the curriculum – making it work

Under 'Key Concepts'
"Economic; this includes the patenting process"
(but not the open source or Creative Commons movements,
for example).

Under 'Key Processes'
"Reflect critically when evaluating and modifying their ideas and
 proposals: This includes: (...) anticipating the market (...)."

Under 'Curriculum Opportunities'
"Work with designers and makers where possible to develop
 an understanding of the product design process"
(implying that there is a single approach to product design).

(QCA[1], 2007)

By the time pupils reach their GCSE (14-16 years exam)
courses the emphasis on commercial practices is more deeply
embedded. For example the (currently draft) Electronic
Products specification from AQA[2] includes as things that pupils
should be taught:

Under 'Designing Skills'
 • design products to meet the needs of clients and
   consumers
 • design for manufacturing in quantity and to be aware of
   current commercial / industrial processes
 • understand the need to protect design ideas.

Under 'Making Skills'
 • manufacture products applying quality control procedures.

Under 'Commercial Manufacture'
 • describe one-off production of prototypes
 • describe batch production to produce small quantities of
   identical PCBs
 • describe the use of a high volume production line to
   manufacture large quantities of PCBs, or cases, to house
   electronic circuits.

Under 'Quality'
 • know why quality is important at all stages (quality
   assurance) of the designing and making process and how
   testing (quality control) can be applied to industrial
   products and candidates' own work.

Under 'Social, Cultural, Moral, Environmental and
Sustainability Issues'
 • automation and its implications on job opportunities;
 • the moral issues of products designed with planned
   product obsolescence and their impact on life style
 • extensive marketing of products which are labelled as
   fashion items and are targeted at the consumer
 • industrial applications of electronic systems.

Under 'Computer Aided Manufacture (CAM)'
 • show awareness of how CAD/CAM enables easier, faster
   and more flexible methods of manufacture, e.g. Computer
   Integrated Manufacture (CIM), developing product and
   design, stock control, high speed assembly, automatic
   production and quality control.

(AQA, 2008)

The limitations of space and reader attention mean that the
above is clearly just a sample from the whole specification
(which I believe to be a good one) and doesn't give the full
flavour; but it is typical not only of the requirements of all the
D&T specifications from this awarding body but of all of the
awarding bodies. Now, I'm not against pupils learning about
commercial practices in the world(s) of professional design; I
agree it is desirable for pupils to be taught the things listed
above. But should this be the only model for designing and
making they are presented with?

A significant challenge to this commercial model is that quietly,
but insistently, a number of disruptive developments is taking
place; these include developments in the ways things are
made, in how individuals are going about 'making' things (the
word 'making' seems hardly broad enough to cover all of the
activities described later) and in conceptions of intellectual
property rights.

**The future is already here; it's just not very evenly
distributed**

(Gibson, 1999)

The disruptive developments alluded to above are, as Gibson
(ibid) suggests, not always well known. However it seems clear
that, amongst its many aims, one role of education should be
to prepare children for the future they are likely to inhabit as
adults; education should be helping to redistribute the future.
The developments I'm particularly interested in include:
 • the development of personal fabrication technologies
 • the emergence of low cost embedded control

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[1] The English Qualifications and Curriculum Authority, legally responsible for curriculum content and examinations for 5-19 education.
[2] Assessment and Qualifications Alliance. One of the English awarding bodies who provide qualification specifications and assess pupils against them.

technologies and the 'internet of things'
- the emerging use of web 2.0 technologies to support personal fabrication, personal marketing and collaborative designing
- the growing international maker movement
- the contributions of the hacker community
- a growing concern about the environmental consequences of 'consumer society'
- the open-source and creative commons movements.

Fabbing

Computer-aided manufacture (CAM) is not new. But it has until recently been the preserve of institutions (industrial, research, increasingly schools) that could afford the equipment. So-called 'rapid prototyping' (RP) is a branch of CAM that allows 3-dimensional objects to be 'printed' relatively quickly by carefully depositing materials drop by drop or layer by layer, but, again, the costs have until recently been prohibitive even for schools. However, the prices of CAM and, particularly, RP equipment have been plummeting in recent years. At the same time computer-aided design (CAD) software, including 3D design software, has got cheaper (or even free in some cases (e.g. Google Sketchup, 2008)) and easier to use thanks to the increasing capabilities of personal computers. As a result many more people now have access to these fabrication (increasingly being called 'fabbing') technologies. Three examples of low cost fabbing technologies that are contemporaneous with the publication of this paper are:
- Desktop Factory (2008) ('It's a 3D world, print that way'). This is a low cost ($5000, £2500) desktop 3D printer designed for small business, school and even home use. By today's standards this is very cheap. It is likely that such technology will be similar in relative cost to the current costs of ink-jet printers within 10 years.
- Fab@Home (2008). This project from Cornell University (US) is "a project dedicated to making and using fabbers – machines that can make almost anything, right on your desktop" (ibid). Critically this is an open-source (see below) project with the design for the fabber(s) posted on the website; you can download the machine designs as CAD files and make them yourself, the electromechanical parts required are all listed and the required software is also free; the cost for parts is around £1200. A growing user community is creating a wide range of variants for different purposes.

- RepRap (2008). In a similar spirit to Fab@home, RepRap is a project from the University of Bath (UK) to create a self-replicating fabber; i.e. "RepRap makes a complete set of all the printed parts it needs to copy itself" (ibid). Inevitably (there is little point preventing people from using a machine to do what it was designed to do) the designs for RepRap are also free (under the GNU General Public Licence (2008)) with costs for parts being about £300. There is a quid pro quo involved here; "RepRap etiquette asks that you use your machine to make the parts for at least two more (...) for other people at cost" (ibid).

Already some schools in the UK own 3D printers, but it seems likely that these will soon be as common – and cheap – as 2D printers. In the meantime there seems considerable scope for having pupils make their own using one of the low-cost open-source designs described above; this could be a project, initially at least, for an after-school club, but there are also possibilities for use with, for example, an Engineering Diploma group, where pupils first build and then use the fabber.

The Internet of Things

Under the names, variously, of ubiquitous computing (ubi-comp), pervasive computing, ambient intelligence, physical computing, haptic computing or everyware a range of commentators (e.g. Gershenfeld, 1999, Brockman 2002, Mitchell, 2003, Mau, 2004, Morville, 2005, Sterling, 2005, Greenfield, 2006) have suggested that the exponential (Broderick, 2001, Kurzweil, 2005) trends in reducing size and cost of electronics means that we will find reasons for embedding electronics in the humblest of items as well as, densely, in our various environments. Sterling (2005) suggests that the combination of GPS[3] , RFID[4]   and low cost communications will mean that any object will know what it is, where it is and be able to communicate that information; he calls these objects spimes – objects that know where they are in space and time. You will be able to Google your lost glasses. Sterling also suggests that objects will exist, primarily, as digital data, being instantiated when they are needed and then returned, sustainably, to the material stream when no longer needed.

Foo Gershenfeld (2006) has created an internet protocol (Trivial Hypertext Transfer Protocol (THTP) or Internet 0) designed specifically for the low level needs of everyday objects (for example light bulbs) that are to be internet enabled.

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[3] Global Positioning System. A satellite system allowing objects to know reasonably precisely where they are on the Earth's surface.
[4] Radio Frequency Identification. Very cheap electronic devices can provide an object with a unique identification that can be 'read', without any contact, using radio waves.

In England microcontrollers[5] , in the form of PICs, are of growing importance in electronics education (Steeg & Martin, 2007, Steeg & Barlex, 2007) as the heart of circuits whose function is defined by how they are programmed, though they are not yet in universal use or even dominant over more traditional hard-wired approaches to designing circuits. Yet even this 'modern' programmable approach is based on a family of microcontrollers that are, by 21st century standards, rather low powered. Already emerging are approaches to electronic product design that will allow pupils to engage, in a straightforward way, with designing into objects the kinds of electronic capability that they take for granted in the products they own; a range of communication capabilities, RFID, GPS, accelerometers, digital cameras, MP3, video, internet capabilities etc.

Gershenfeld (2005) explores the consequences of providing fabbing and embedded control technologies, in the form of 'Fab Labs', to both students at MIT and to various communities around the world and describes an extraordinary range of personally desired products that 'ordinary' people are prompted to create when the opportunity to "Make (Almost) Anything" is presented. He notes that working like this with students created a demand for a rather different pedagogy where students found what they needed to know to support designing and making as they needed to know it, using a wide range of sources for this information. He characterises this as 'just in time' learning and contrasts this with the dominant engineering pedagogy of 'just in case' learning. This would certainly be a very different approach to that commonly found in English D&T workshops (though one possibly familiar to teachers who were working in the 1970s and 1980s).
It is noteworthy that most secondary schools in England already have the facilities required to create a 'Fab Lab' (both for pupils and their local community) – they just aren't conceptualised like that.

Web 2.0

While Gershenfeld was creating Internet 0, many others were talking about Web 2.0, a term first coined by Tim O'Reilly in 2004 (O'Reilly, 2005) which, while contested (Anderson, 2006), is generally used to describe trends in web use and design focussed on enhancing information sharing and collaboration – often characterised as 'social networking'. Two examples of Web 2.0 approaches are relevant to this discussion;

• Collaborative designing supported by wiki-type[6] environments (as exemplified by Fab@Home and RepRap, described above).
• Ponoko (2008). This website allows users to post CAD files for products designed to be manufactured using a laser cutter (though, in principle, design files for ant manufacturing technology could be shared). These can be downloaded by others, either for free or a small charge and the new owners can, with the right Creative Commons Licence (see below) then modify these files before making them – or even selling the new plans themselves. More than this though, Ponoko will make and ship any of the products from the website on demand. And, even better, they are setting up a network of partners around the world who will act as local manufacturing agents, thus minimising transport costs (and carbon footprints).

The consequence of this is that anyone can sell a design to anyone else (there is no mass market barrier to cross before your design can be made) and the buyer can either make the design themselves (possibly modifying it first) or ask a local producer to do so. Suddenly the whole world is a market to every school pupil doing D&T – and there is an opportunity for schools to make money by becoming local Ponoko manufacturing partners. This is a classic example of long tail selling (Anderson, 2007). It is not difficult to imagine this idea extended to 3D designs for a range of fabbers.

If you can't open it, you don't own it

(Mister Jalopy, 2005)

People have always made things for themselves and, until the last quarter of the 20th century, at least, it was customary for people to maintain and fix the products they owned. Increasingly, however, products come with labels saying they contain 'no user serviceable parts' or stickers over casing screws warning that if the sticker is removed the warranty will be voided. In a reaction to this trend there is a growing maker/hacker[7] movement, represented by printed publications (e.g. Berger & Hawthorne, 2006, Craft Magazine (Craft, 2008) Make Magazine (Make, 2008), ReadyMade Magazine (ReadyMade, 2008)) but more richly facilitated by Web 2.0 technologies (e.g. Craft, 2008, Evil Mad Scientist Laboratories, 2008, Hack a Day, 2008, Instructables, 2008, Make, 2008, ReadyMade, 2008). These are rich sites built on user-

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[5] A microcontroller is a computer, albeit a low-powered one, on a cheap (less than £1) integrated circuit 'chip' that is designed for control purposes. PICs are a particular family of microcontrollers.

[6] "A wiki is a collection of web pages designed to enable anyone who accesses it to contribute or modify content, using a simplified markup language. Wikis are often used to create collaborative websites and to power community websites." Wikidepia,2008

[7] The term 'hacker' originally referred to programmers who used unorthodox tricks to optimise computer code. It has since evolved in two opposite directions: Firstly (by confusion with the term 'cracker') to describe someone who performs some kind of computer sabotage, secondly to describe someone who uses unorthodox methods to modify and improve any hardware or software. The second sense is used in this paper.

generated content that provide guidance on making, modifying, customizing, reusing, repurposing and hacking products. Between them these sites cover a wide range of technologies and materials. They also allow new technologies and materials to become widely known rapidly. To take just one example, there is a great deal of interest in new conductive materials and threads that can be used to create flexible circuits suitable for integration into clothes and other fabric-based products and a community of users has sprung up around just one instantiation of this, the LilyPad Arduino "a set of sewable electronic components that let you build your own soft, interactive fashion" (Buechley, 2008). Key to the success of this has been basing it on an open system (the Arduino, 2008) and popularising the information on how to use the LilyPad on many of the websites mentioned above. A group of English educators is currently working on a version of this based on PIC microcontroller technology for use in D&T education.

The spirit of the maker movement described above is that people should be enabled to make what they want in the way that they want, using whatever materials are appropriate. This does lead to some rather odd, if harmless, tributaries such as a faction obsessed with making Cylon replicas (from the TV series Battlestar Galactica (2008)) and the Steampunk (2008) movement in which modern technology is redesigned as though it were from the Victorian era. But is also leading to a resurgence of people making things themselves, often for themselves or family and friends, challenging standard consumer products and production and, often, thinking hard about sustainability; it is not clear that current D&T education practices always does these things well.

Sustainability

Education for Sustainable Development (ESD) has a high profile in both schools and D&T departments and there is a wide range of materials to support ESD work in D&T education – notably those from Practical Action (e.g. Capewell, 2008). Outside education, support for those who wish to design sustainability is also growing (e.g. Fuad-Luke, 2004, Steffen, 2006). Yet at the same time we are encouraging pupils to view their designing and making through the lens of designing products for mass consumption in the consumer market. There is a clear contradiction here. There is at least the suggestion that elements of the personalised and shared approach to designing and making outlined above might provide greater scope for pupils engaging in designing and making that has sustainability embedded within it. For example, a unit of work in which the focus is on pupils bringing in objects to be repurposed or repaired, would be rather novel. If the results of this work were then appropriately shared through a site such

as Instructables or Ponoko, the pupils would have an experience of the potential for social networking to create change that would be rather different from the social bonding purposes of sites such as Myspace (2008) and Facebook (2008) that they are likely to be more used to.

Reformulating intellectual property protection

Much of the work described above has been successful not only because of the use of social networking to spread and grow ideas rapidly, but also because the originators of ideas have placed them, in one form or another, in the public domain. That is to say, instead of trying to 'protect' their ideas through some form of intellectual property (IP) limitation such as copyright, they have deliberately encouraged others to use and build on their work. There are various approaches to placing work in the public domain including simply giving it away (sometimes with the sole restriction that it can't be sold). The term 'open source' generally means that a product's designs are made available; software generally follows either the rules of the Open Source Initiative (2008) the Free Software Foundation (2008) or other related initiatives (Futurelab, 2006, provides a good discussion of this area). For example RepRap (2008) is released under the GNU General Public License (2008).

A more structured approach is offered by Creative Commons (2008) licences which ensure originators of work maintain their copyright but "allow people to copy and distribute your work provided they give you credit -- and only on the conditions you specify here" (ibid). Users of Creative Commons can specify whether others may modify their work, how they can use it commercially and how they can distribute it. Concern has been expressed about the relationship between Creative Commons licences and the legal frameworks surrounding IP, but "it is heartening to see the vibrancy that Creative Commons has evoked in civil society" (O'Sullivan, 2008).

Perhaps at least some of the work that pupils engage in could be recognised by posting it on an appropriate social networking website with a Creative Commons Licence.

How to respond?

Underlying what I have described above as 'disruptive developments' is the likelihood that change will continue to happen at an ever faster rate (e.g. McCarthy, 2003).

"...the twentieth century was gradually speeding up to today's rate of progress; its achievements, therefore, were equivalent to about twenty years of progress at the rate in 2000. We'll make another twenty years of progress in just

fourteen years (by 2014), and then do the same again in only seven years. To express this another way, we won't experience one hundred years of technological advance in the twenty-first century; we will witness on the order of twenty thousand years of progress (again when measured at today's rate of progress), or about one thousand times greater than we achieved in the twentieth century."

(Kurzweil, 2005, p11)

The developments described above are the results of and responses to this accelerating change as well as the harbingers of it; the question is, how might D&T education shift to be better placed to accommodate (embrace, even) this change? This does beg the further question of whether such change should be accommodated; the extent to which the content of D&T education should be driven by changes in the technologies available to support designing and making is considered briefly in the concluding comments of this paper. A more fundamental question underlies those above; what is the purpose of a D&T curriculum? Keirl (2007) has argued that there are five perspectives which should be used to examine the design of a D&T curriculum:

- The Global (how the curriculum relates to what is happening in the world),
- The would-be stakeholders (who the curriculum is serving),
- Society (the contribution of the curriculum to education for democracy),
- Students as fulfilled persons (what the curriculum does for pupils),
- Curriculum dynamics (how our bit of the curriculum relates to the whole).

It is instructive to use these perspectives as a framework for examining the relevance of the developments described above.

The Global

The disruptive trends discussed, with the exception of sustainability, do not figure significantly in the current D&T National Curriculum, exam specifications or most practice in schools. However not only are these things happening in the world, they are linked to growth trends that mean they are likely to be available in pupils' homes in the near future. If we want the D&T curriculum to relate to what is happening in the world then there should be much greater scope for pupils to engage in designing and making that makes appropriate use of social networks and the best of modern technologies as well as having personal meaning and community significance.

The Would-be Stakeholders

The debate about who a curriculum serves has the potential to be lengthy (Barlex & Steeg, in press). However the list will include pupils, their community and society more broadly, including the wide range of workplace settings. The introductory part of this paper argued that there is currently considerable focus in the curriculum on the (current) practices of professional design and engineering. If there truly is likely to be a shift toward personal and personalised designing and making, then we will better serve pupils, their communities and society (as well as the product design and engineering professions) by ensuring the curriculum reflects this shift and provides greater scope for pupils to engage in making of personal and community significance using current designing and manufacturing technologies.

Society

The degree to which design (generally) currently serves democracy is open to question (Baynes, 2005). For example the trends in manufacturing towards low-cost, short-life products supported by a mass-market and constrained by the ever-increasing scope of IP laws have a number of anti-democratic consequences. To take just two instances; the lifestyle of Northern/Western consumers is based on employment and manufacturing practices in Southern countries that would be illegal in the consumers' own countries, and consumers are increasingly finding that they don't own products that have bought, but simply a limited licence to use them.

D&T curricula do little to either make pupils aware of these consequences or suggest that alternative approaches might be possible. Aspects of the maker/hacker ethos could be powerful in demonstrating to pupils that other approaches to personal designing and making are available and that the mass-produced products they own can be re-conceptualised in interesting ways. The use of product-oriented social networking could be used to both personalise and democratise the way that products are created, allowing designers and users to talk directly to each other and share in the designing process. Encouraging pupils to share their designing work widely, while retaining ownership through a system such as Creative Commons could be a powerful context for exploring the democratisation of designing and making.

Students as Fulfilled Persons

Despite the continuing popularity of D&T, there are suggestions that many pupils find the subject unsatisfying (Nicholl et al 2008) and that this dissatisfaction revolves around issues of lack of autonomy, challenge and scope for personal creativity.

The tools for personal fabrication described here certainly have scope to allow greater autonomy and creativity. Opening up the curriculum to allow more opportunity for making of personal significance also seems likely to enhance the experience for pupils. Barlex (2005) has argued that the ability of pupils to make design decisions is central to good work in D&T education and the trends described here, by personalising designing and making, have the potential to open up the range of design decisions that pupils are able to make.

Curriculum dynamics

Current education politics suggest that the 'appropriate' curriculum setting for D&T is within STEM (Science, Technology, Engineering and Maths). The developments described above indicate that it could be at least as natural to locate D&T as linked with Art & Design, Citizenship, ICT (or, even better, Computer Science) or the social sciences. Given that D&T could (should?) be about the whole of the made world, this would be much more natural than limiting our links to 'STEM'. Nevertheless, D&T will and should remain central to the STEM initiative's aim to improve the quality of education in these technical areas. A D&T curriculum focussed on pupils designing products of personal significance that include embedded computational power, are manufactured using low-cost but advanced CAD/CAM, perhaps supported through social networking and focussed on sustainable design for a democratic purpose ought to provide plenty of scope for interdisciplinary work with science, mathematics and engineering colleagues (Kipperman & Sanders, 2007).

Concluding thoughts

This paper has argued that a range of technological, legal and social developments in the ways that products are designed and made present a challenge to the current ways we approach D&T education. This argument has not, however, tackled various thorny questions such as:

- If change is accelerating in the way some authors claim (e.g. Broderick, 2001, Kurzweil, 2005) how might the community of D&T educators manage the impact of this?
- Is, in fact, change accelerating at all (Sandford & Facer, 2008)?
- To what extent, anyway, should the D&T curriculum be driven by technological change?
- What are the (or, are there) timeless central components of a D&T curriculum that will remain unchanged in a changing world?
- How is it that we, both as the community of D&T educators and as society generally, should go about deciding the answers to such questions?

Our current model of curriculum change appears to be that from time to time some teachers and/or manufacturers introduce evolutionary or radical new technologies or approaches into teaching. If these are successful they spread from school to school until some kind of critical mass is reached at which point they are adopted by QCA and the awarding bodies. The introduction of microcontrollers (PICs) into D&T education over the last 10 or so years is a good example of this process.

It seems unlikely this will remain a satisfactory approach (if it ever was) in a time of accelerating change. It is also worth noting here that his paper has not included consideration of two technologies that have the potential to be even more disruptive than those that have been included; nanotechnology and genetic engineering. These are clearly in the 'STEM' family and potentially could be a part of D&T education – imagine pupils designing objects at the atomic or genetic level. There is the potential for serious challenge to the D&T education community's implicit theories of the subject (Dow, 2007). Whatever the right ways to approach change are, this paper has argued that the technological, legal and social developments outlined above can be accommodated in a 21st century curriculum. More, they should be celebrated as a route to creating an 'ethically defensible' (Keirl, 2007) curriculum that will allow D&T (or its immediate successor) to contribute meaningfully to a broad education for a technological literacy that supports education for democracy.

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