Modernisation of the school D&T curriculum with special reference to disruptive technologies; a case study of trainee teachers' responses

Authors
David Barlex, Independent researcher, 40 Merton Court, The Strand, Brighton Marina, BN2 5XY UK
Tel: +44 1273 683723
david.barlex@btinternet.com

Nick Givens, University of Exeter, Graduate School of Education, St Luke's Campus, Heavitree Road, Exeter, EX1 2LU, UK.
Tel: +44 1392 724869
E: N.Givens@exeter.ac.uk

Alison Hardy, School of Education, Nottingham Trent University; Nottingham NG1 4BU, UK;
Tel: +44 115 848 2198;
E: Alison.hardy@ntu.ac.uk

Torben Steeg, Independent Consultant
Independent researcher, 3, Whitelow Rd, Chorlton, Manchester M21 9HQ UK,
Tel: +44 7801541690,
E: torben@steeg.co.uk

Key words
School design & technology curriculum, modernization, disruptive technology, teacher education, peer teaching

Abstract
New and emerging technologies are a feature of the design & technology National Curriculum (for pupils aged 5-13 years) in England and the proposed new GCSE design & technology course (for pupils aged 14-16 years). These features are part of the modernisation of design & technology that is taking place in England. This paper reports a small case study of an 'understanding new and emerging technologies' activity in which trainee design & technology teachers at a university in England were required to research particular disruptive technologies (Barlex, Givens & Steeg 2015), develop presentations about these technologies to the other trainees undertaking the activity who then had to summarise their understanding of each disruptive technology in a short piece of writing (around 600 words) dealing with both the nature of the technology and its potential to be disruptive. In addition they had to justify its inclusion and suggest how it might be taught. The paper will describe the responses of the trainees, consider the extent to which they found this work challenging and comment on the way in which an understanding of such technologies might be taught to secondary school pupils as part of a modernised design & technology curriculum which develops the essential 21st century skill of technological perspective.

Introduction
The National Curriculum in England (DfE 2013) and the new GCSE for design & technology which will be taught from September 2017 (DfE 2015) require the teaching of new and emerging technologies. This requirement to teach explicitly about new and emerging technologies is new for English teachers of D&T. The Disruptive Technologies Project (Barlex, Givens & Steeg 2015) argues that it makes sense to identify these technologies with those that are likely to be disruptive. The Project aims to provide teachers with information about a range of new technologies alongside support on how to teach about these technologies within D&T. The question driving this case study is "To what extent does an introduction to disruptive technologies enable trainee teachers to engage with the modernisation of the schools design & technology curriculum". This is an important question because curriculum development in school departments that are traditional in their approaches to design & technology often fall to new entrants to the profession

Questions emerging from the driving question are concerned with the impact of the information provided by the Disruptive Technologies Project and the extent to which a) it helped the trainee teachers learn about disruptive technologies, their applications and impact and b) whether the idea of disruption (as defined within the Project) is sufficient to enable the trainees to explore the disruptive potential of new technologies.

Disruptive Technologies

The McKinsey Global Institute (Manyika et al, 2013) has suggested some features that mark out a technology as having the potential to be disruptive.

- They upset the status quo, for example overturning existing hierarchies and offering the possibilities of both more and less democratic hierarchies.
- They alter the way people live and work, for example increasing or decreasing employment opportunities, changing the knowledge and skills required for certain kinds of employment, shifting the expectations of education systems and altering relationships
- They reorganise financial and social structures, for example by redistributing financial rewards towards those who are deploying these technologies.
- They lead to entirely new products and services.

Disruptive technologies in D&T education

Barlex, Givens and Steeg (2015) have identified nine technologies that meet the McKinsey criteria and are suitable for consideration within design & technology education. These are shown in Table 1.

Table 1 Disruptive technologies for the school design & technology curriculum

The technology	The description
Additive manufacturing (AM)	AM involves fabricating physical objects in successive thin horizontal layers, according to digital models derived from CAD designs, 3-D scans or video games. Such printing can takes place at different scales from nano structures to complete buildings and may involve a wide range of materials: human tissue, electronics, and food as well as traditional industrial product materials such as polymers, metals and ceramics.
Artificial intelligence (AI)	AI can be categorized at three different levels. First is 'narrow' AI that specializes in one area e.g. the AI that plays chess better than humans. The second and third levels are concerned with more general ability. 'General' AI can perform as well as a human across the board i.e. it is AI that can perform any intellectual task that a human can. Such AI is yet to be developed. Third is 'super intelligent' AI i.e. an AI that performs better than human brains in practically every field. This has yet to be developed but several prominent scientists and technologists (including Stephen Hawkin, Elon Musk, Bill Gates, The Observer 2015) have warned that this carries with in an existential threat for the human race.
Augmented reality (AR)	Augmented reality (AR) is a live, direct or indirect view of a physical real-world environment whose elements are augmented (or supplemented) by computer generated sensory input such as sound, video, graphics or GPS data.
Big data	Big data is data that exceeds the processing capacity of conventional database systems. The data is too big, moves too fast, or doesn't fit the strictures of standard database architectures. It is collected by large corporations and governments (and, increasingly, open data from 'citizen' scientists) and when interpreted using big data analytics it can be used to give insights into the behaviour of potential consumers and citizens. It is the ability to cross-reference large data sets and thus draw inferences that don't actually appear in any of the individual data sets that gives rise to concerns that the availability of such data and its analysis will invade people's privacy and lead to mass manipulation
Internet of things (IoT)	The Internet of Things (IoT) is the networking of physical objects i.e. things that have embedded within them electronics, software and sensors which

	are connected to one another over the Internet and can exchange data. This allows extensive communication between the physical and digital worlds, enables remote control of devices across the Internet and produces vast amounts of big data.
Neurotechnology	Neurotechnology is concerned with technologies that inform about and influence the behaviour of the brain and various aspects of consciousness. Current neurotechnologies include various means to image brain activity, stimulation of the brain by magnetism and electricity, measuring the electrical and magnetic brainwave activity, implant technology to monitor or regulate brain activity, pharmaceuticals to normalize erratic brain function, and stem cell therapy to repair damaged brain tissue. Recently measurements of brain activity have been used to control real world artefacts.
Programmable matter	Programmable matter, is matter which has the ability to change its physical properties (shape, density, elasticity, conductivity, optical properties, etc.) in a programmable fashion, based upon user input or autonomous sensing.
Robotics	A very basic definition of a robot is "a machine that automates a physical task". This is limited because it gives no indication as to the intelligence and autonomy of such a machine. A microwave cooker automates the task of heating food but is simply responding according to instructions selected from a menu of pre-programmed instructions. So a more appropriate definition is "a machine that carries out a physical task autonomously using a combination of embedded software and data provided by sensors". This definition embraces relatively simple robots such as the Roomba vacuum cleaner to extremely complex robots such as the google self-driving car.
Synthetic biology	Synthetic biology is the process of designing and creating artificial genes and implanting them in cells. In some cases all existing genes have been removed; in others the new genetic sequences are introduced into the DNA of existing cells. It is far more than simply borrowing existing genes from nature. Synthetic biology is the process by which completely new life forms, i.e. life forms that have never previously existed, are created. Proponents of synthetic biology, such as David Willets (2013) when he was UK Minister for Science, argue that the technology could "fuel us, heal us and feed us" but are concerned that there is the possibility of public rejection as was the case in the UK with GM food.

They justify the identification of new and emerging technologies with disruptive technologies on the grounds that it is important for young people to study those technologies that are likely to have a significant effect on their lives in the short and medium term. A website to support the consideration of these technologies in the secondary school design & technology curriculum went on line in March 2016, (Barlex, Givens & Steeg 2016) which includes a Teachers' Guide to disruptive technologies. This Guide elaborates five suggested ways in which teachers might approach teaching about disruptive technologies:

1. Through case studies
   These allow pupils to find out about how a disruptive technology works, what it is being used for and how it affects society, the environment and peoples' lives.
   As well as describing potential sources for case study material and advice on how to frame the structure of a case study, the Guide suggests ways in which pupils' interactions with case study materials can be made active.

2. Through designing without making
   Building on the Young Foresight Project (Barlex 2012) and incorporated into England's National Strategies for design & technology (Department for Education and Skills 2004), designing without making is now a fairly well-established approach to helping pupils envisage the sorts of products and services that might derive from the deployment of a particular (in this case, disruptive) technology – especially those that for reasons of cost, safety, accessibility etc. are not easy to bring into a school environment.

3. Through designing and making
   Noting that, at present, the disruptive technologies most amenable to this kind of approach, given the kinds of tools that schools currently have access to, are additive manufacturing, robotics, the Internet of Things and augmented reality.

4. Through making without designing
   Activities in which pupils make artefacts that someone else has designed allow pupils to develop particular making skills without the distraction of design activity or the problems that might be caused by trying to make something they have designed but that is too demanding with regard to their current level of making skill. Some disruptive technologies can be used for making without designing. Printing an item designed by the teacher in order to learn how to use the 3D printer for example. Or building a simple robot from a kit of parts following instructions provided by the supplier.

5. Through considering consequences
   The Guide suggests four approaches to considering consequences:
   a) Considering winners and losers
      Examining consequences by asking “Who wins?” and “Who loses?” when a particular technology is deployed. This approach is amenable to pupils at the start of secondary education and useful as it immediately enables the technology to be scrutinised from the perspectives of different stakeholders and reveals to students that the way technology and society interacts is not straightforward.
   b) Using the Mckinsey criteria
      These are noted earlier and provide a set of lenses through which to view the technologies so that they can adopt a constructively critical perspective.
   c) Exploring the life cycle of a technology
      Technology teachers are well versed in helping young people consider the so called ‘life cycle’ of products and have used such teaching to engage students in the environmental impact of not only the manufacture of products but also their use and disposal as a critique of consumerism and the need to move from a linear to a circular economy (McArthur 2015). Exploring the emergence of a technology, its adoption and impact on society is less familiar territory and we introduce the the Gartner ‘Hype’ Cycle (Gartner 2015) as an attempt to chart the life of a technology. It provides a graphic representation of the maturity and adoption of technologies and applications, and how they are potentially relevant to solving real business problems and exploiting new opportunities.
   d) Exploring and building scenarios
      A general approach often used to present or build scenarios is to identify two sets of so called ‘critical or significant uncertainties’ and to use these as axes to create four quadrants such that located in each quadrant there is a particular scenario (see Figure 1). Each of these can be fleshed out into a human story which can be explored from various perspectives.

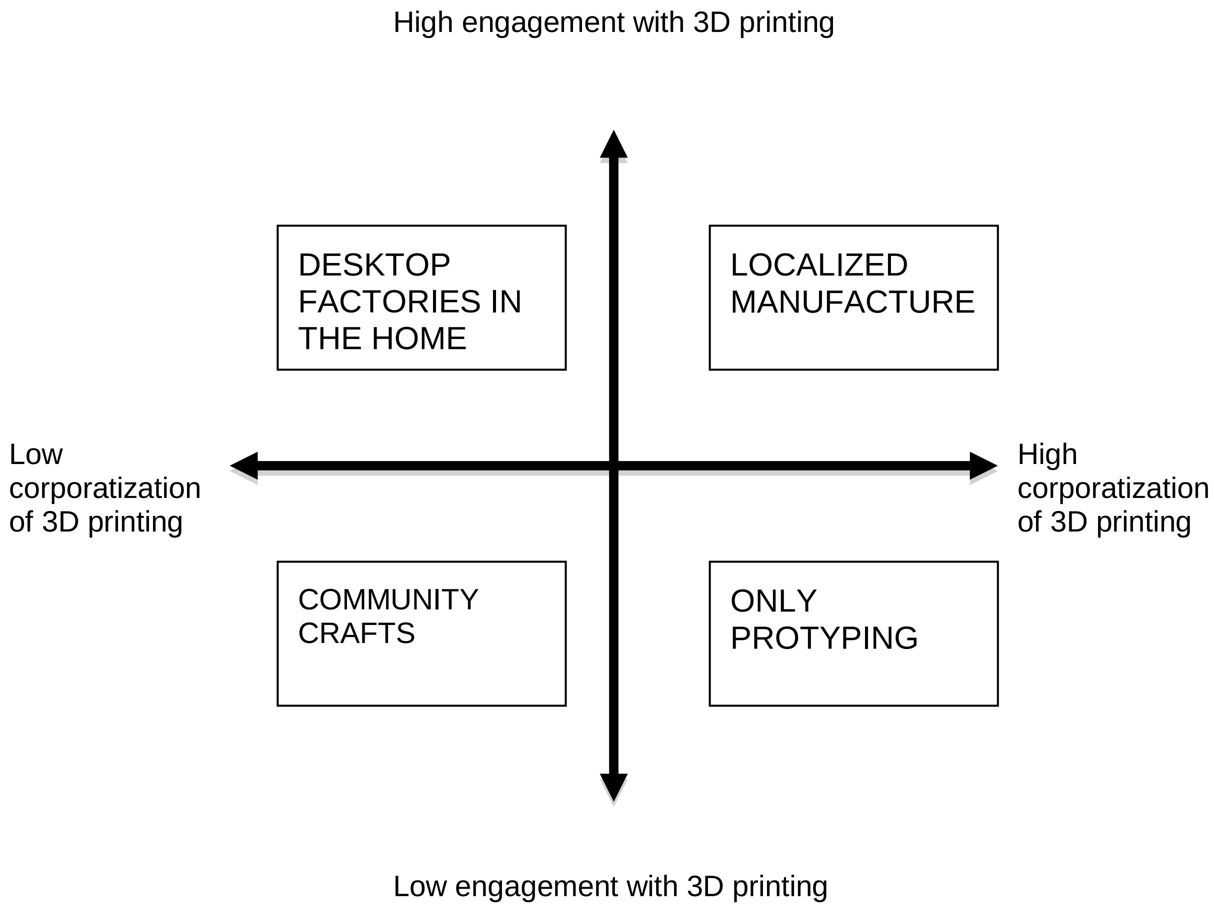

Figure 1: Four scenarios based on axes of uncertainty concerning 'Engagement with 3D printing' and 'Corporatization of 3D printing' (from Birtchell et al 2012)

In order to prepare undergraduate trainee teachers[1] for teaching in this area a university in England required that trainees consider a disruptive technology as part of the programme of study and justified this in terms of a) the need for the design & technology curriculum to modernise, b) the inclusion of new and emerging technologies as part of this modernisation and c) that it makes sense to use potentially disruptive technologies as the example of new and emerging technologies. Each trainee was assigned at random one of the disruptive technologies identified by Barlex et al (ibid) and required to present a seminar to the other trainees in the group about his/her assigned disruptive technology. Every trainee was required to attend all seminars. The trainees were then required to produce an extended piece of writing about their assigned disruptive technology (1000 words) plus a shorter summary piece (600 words) on the other disruptive technologies. In addition, each trainee had to suggest how they could teach their disruptive technology topic in a design and technology lesson, which would provide opportunities for embedding thinking skills, creativity and problem solving skills (1500 words) with regard to his/her assigned disruptive technology.
This paper will limit itself to a consideration of the extended pieces of writing that six trainees undertook about their assigned disruptive technologies.

Data collection and analysis
The six selected trainees considered the following disruptive technologies:
- Additive Manufacture

[1] In England the term 'trainee teacher' is used interchangeably with 'student teacher', both terms having a similar meaning to 'preservice teacher'.

- Artificial Intelligence
- Big Data
- Neurotechnology
- Programmable Matter
- Synthetic Biology

Each trainee gave permission for their response to the assignment to be scrutinised for the purposes of this paper. Each response was scrutinised with regard to the following questions.

1. Did the response indicate that the trainee understood the nature of the disruptive technology?
2. Did the response indicate that the trainee appreciated the breadth of application of the disruptive technology?
3. Did the response indicate that the trainee has identified arenas of activity in which the technology was likely to be disruptive?
4. Did the response indicate that the trainee has identified the nature of the disruption created by the technology?

The results of the scrutiny are shown in Table 2

Table 2 Analysis of trainee's assignments

	Understanding the nature of the technology	Appreciating the breadth of application	Identifying arenas of activity	Identifying the nature of the disruption
Additive Manufacture	A clear understanding is shown	Some appreciation of breadth is shown although the printing of function as opposed to structure is not considered	There is some identification of disruption	There is little consideration of the nature of disruption
Artificial Intelligence	A clear understanding is shown	A clear appreciation is shown	Clear identification of arenas of activity	The nature of disruption considered existential threat
Big Data	A clear understanding is shown	A clear appreciation is shown	Clear identification of arenas of activity	This is considered in moderate detail
Neuro-technology	A clear understanding is shown	A clear appreciation is shown	Two main arenas of activity were identified but not discussed in terms of disruption as such	This was not considered
Programmable Matter	A clear understanding is shown	A clear appreciation is shown	Clear identification of arenas of activity	This is considered only to a limited extent
Synthetic Biology	A clear understanding is shown	A clear appreciation is shown	Clear identification of arenas of activity	This is considered only to a

				limited extent

Discussion

To what extent does an introduction to disruptive technologies help the trainee teachers learn about disruptive technologies, their applications and impact?. It must be acknowledged that the task set to the trainees is demanding, requiring them to acquire knowledge and understanding of topics that were new to them and to view these from the perspective of disruption which was again a new topic as far as they were concerned. It must also be acknowledged that the imposed word limit does constrain the trainees' ability to be expansive in showing their grasp on the topics they were given. The trainees were given their topic at the start of the module, each was timetabled to present their work starting four weeks later. Between this and the first trainee-led presentation other lecturers gave seminars about other new technologies, not necessarily disruptive, modelling how they could present their topic. Planning and delivering a seminar that lasted between 30 and 45 minutes, on an unfamiliar topic for presentation to their peers presented several challenges for the trainees. Additionally, the concept of disruptive technologies as a component of the design & technology curriculum challenged their preconceptions. Their prior experiences involved handling materials and components, and designing and making solutions, none of which was a possibility with most of the disruptive technologies; possible exceptions including additive manufacturing, robotics and the Internet of Things. In the light of this, it is encouraging to see that all the trainees were able to find out about the technologies they researched, both in respect of the nature of the technology and its main applications.

Whether the idea of disruption (as defined within the Project) is sufficient to enable the trainees to explore the disruptive potential of new technologies? Most trainees were able to identify at least some areas where the technology might be disruptive but they were less successful in considering the extent to which a technology might be disruptive. None of the trainees explicitly used the McKinsey criteria for disruption (Manyika et al 2013) in considering the impact of the technology on society or used scenario building to explore possible futures involving the technology. However, they all discussed ethical issues with regard to the deployment of the technologies. This is not surprising as we might expect design & technology trainee teachers to be adept in understanding technologies and their applications, but the ideas surrounding 'disruption' in the sense that we have used the word, leaning heavily on the McKinsey 'features of disruption' (Manyika et al 2013), are probably novel and will take some time to absorb. A useful follow-up to this study would be to track the trainees through their in-school placements and in the first years of full time teaching to find out if they are teaching about disruptive technologies and if so how and with what success. It would also be useful to undertake parallel research with serving teachers to establish whether they, like the trainees, have little difficulty in grasping the nature of the disruptive technologies and possible applications, but need more support in dealing with the ideas surrounding disruption.

This brings us to an interesting point with regard to the place of such technologies in the school curriculum. The centrality of values to designing and the potential of school design & technology as a context for teaching pupils about values is a recurring theme in the literature (e.g. Layton 1995, Middleton 2005, Barlex 2007, McLaren 2015). In teaching young people about the technologies and their impact on society, it is likely that they will develop a value position with regard to that impact. They may even come to school with value positions already in place that design & technology lessons may either reinforce or challenge. For example, does the technology under consideration lead to benefits and if so for whom? Does it lead to others being disadvantaged? And, more profoundly, whatever the winners versus losers situations that arise, should we be deploying these technologies at all given that, in the case of at least some of these technologies (for example Artificial Intelligence and Synthetic Biology), some argue that humans are 'messing with nature' and going beyond our remit as stewards of the world (see Macnaghten et al 2010 with respect to cultural narratives influencing views on technology). Stevens (in press) writing about the teaching of bioethics raises the interesting question of assessing students' responses to value positions suggesting that they should not be judged by comparison with a given, and perhaps preferred value position of the assessor, but whether the position is well supported or not by the arguments provided by the students.

Summary

This paper has set the scene for a consideration of disruptive technologies to be investigated in the secondary school design & technology curriculum. It has described the responses of trainee teachers to tasks requiring them to learn about such technologies and comment on their impact on society. The responses indicated that the trainees had grasped some essentials of the technologies, could identify some ethical concerns with regard to their deployment but were less secure in considering their disruptive nature. The discussion considered the professional development teachers in post might need and identified the issue of assessing school students' value positions with regard to the deployment of disruptive technologies.

References

Barlex, D. (2007) Justifying design & technology. In Barlex, D. (Ed.), *Design & technology for the next generation* Whitchurch, England: Cliffeco

Barlex, D. (2012). The Young Foresight Project A UK Initiative in design creativity involving mentors from industry. In B. France & V. Compton (Eds.), *Bringing communities together: Connecting learners with scientists or technologists* (pp. 113-126). Rotterdam, The Netherlands: Sense

Barlex, D., Givens, N. & Steeg, T. (2015). Thinking about disruptive technologies. In Gwyneth Owen-Jackson (Ed.), *Learning to Teach Design and Technology in the Secondary School* (pp.303-322). 3rd edition Oxford, England: Routledge

Barlex, D., Givens, N. & Steeg, T. (2016) The Disruptive Technologies Project available at https://dandtfordandt.wordpress.com/projects/disruptive-technologies/

Birtchell, T., Urry, J., Cook, C. & Curry A. (2013) Freight Miles Impacts of 3D Printing on Transport and Society ESRC Project ES/J007455/1. Retrieved June 11 2016 from http://eprints.lancs.ac.uk/66198/1/Freight__Miles_Report.pdf

Department for Education (2013) *Design and technology programmes of study: key stage 3*. London, England: Department for Education

Department for Education (2015*) Design and technology GCSE subject Content*. London, England: Department for Education

Department for Education and Skills (2004) *Key Stage 3 National Strategy Foundation Subjects Design & Technology: Framework and training materials,* London, England: DfES

Gartner (2015) Gartner Hype Cycle. Retrieved June 11 2016 from http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp

Layton, D. (1995) 'Constructing and Re-constructing School technology in England and Wales' *International Journal of technology and Design Education* 5:89-118

Macnaghten, P., Davies, S. & Kearnes, M. (2010) Narrative and Public Engagement: Some findings from the DEEPEN project. In René von Schomberg and Sarah Davies (Eds) *Understanding Public Debates on Nanotechnologies Options for Framing Public Policy* Luxemberg: European Union

Manyika, J. et al (2013) *Disruptive technologies: Advances that will transform life, business, and the global economy* McKinsey Global Institute. Retrieved June 11 2016 from http://www.mckinsey.com/insights/business_technology/disruptive_technologies

McArthur, E. (2015) Resources developed by the Ellen McArthur Foundation can be found at http://www.ellenmacarthurfoundation.org/schools

McLaren S. V. (2015). Developing Values. In Gwyneth Owen-Jackson (Ed.), *Learning to teach design and technology in the secondary school* (pp. 287-302). 3rd edition Oxford, England: Routledge

Middleton, H. (2005) 'Creative Thinking, Values and Design and Technology Education' *International Journal of Technology and Design Education 15:61–71*

Observer (2015) Retrieved June, 11 2016 from http://observer.com/2015/08/stephen-hawking-elon-musk-and-bill-gates-warn-about-artificial-intelligence/ but also http://www.bbc.com/news/technology-35082344 for a more positive view

Stephens, D. (in press) Teaching Bioethics: The intersection of values and the applications that advances in technology make possible. In Barlex, D. & Williams, P. John (Eds.), *Enhancing technology education Helping teachers develop research-informed practice*. Singapore: Springer

Willets, D. (2013) *Eight Great Technologies*, London, England: Policy Exchange