17 Developing work with disruptive technologies

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Introduction

We believe that the development of technological perspective is an important and much under-represented aspect of the design and technology curriculum in secondary schools. Acquiring technological perspective provides young people with the intellectual tools to decide for themselves how various technologies should be deployed in their society. Engaging young people with the nature of disruptive technologies and helping them to consider how these might play out in their future world is, to our minds, an important and effective way of developing technological perspective. There is the associated benefit that such an approach allows the curriculum to keep pace with the technological developments and innovations taking place in the world outside school. As yet the introduction of a consideration of disruptive technologies in the design and technology curriculum in school is at a very preliminary stage of development. We hope that this chapter will encourage you to introduce such considerations into your own teaching.

OBJECTIVES ✔

By the end of this chapter you should:

- ✔ understand the idea of disruptive technologies
- ✔ be able to describe examples of disruptive technologies from the past and the present
- ✔ be able to use a framework for exploring their disruptiveness
- ✔ be able to justify their inclusion in the secondary design and technology curriculum
- ✔ be aware of ways in which you could teach about disruptive technologies
- ✔ be able to consider future developments in such teaching.

What do we mean by disruptive technologies?

In this section we provide a series of definitions used in developing our thinking about teaching and learning concerning disruptive technologies. We define technology, disruption and disruptive technology and identify a set of disruptive technologies appropriate for consideration in secondary schools. Technology is not easy to define, as different philosophical positions lead to different definitions. We take the position adopted by John Naughton (1994) that rejects a simplistic applied-science view of technology and stresses that technology always involves 'ways of doing things ... a complex interaction between people and social structures on the one hand and machines on the other' (ibid.: 12). Naughton's description immediately, and in our view rightly, complicates the technology curriculum in that a consideration of machines, which some would see as a basis for a technology curriculum, becomes insufficient. Hence we believe that the following set of ideas is a useful and appropriate description of technology:

- Through technological activity people develop technologies and products to intervene in the natural and made worlds.
- Technology uses knowledge, skill and understanding from a wide range of sources especially, but not exclusively, science and mathematics.
- There are always many possible and valid solutions to technological and product development challenges, some of which will meet these challenges better than others.
- The worth of technologies and products developed by people is a matter of judgement.
- Technologies and products always have unintended consequences beyond intended benefit which cannot be fully predicted by those who develop them.

Task 17.1 Your experience of teaching disruptive technologies

Consider:

- In your own teaching experience, to what extent have you deliberately taught pupils about the nature of technology as outlined above?
- In your own teaching experience, to what extent have you seen other teachers deliberately teach pupils about the nature of technology as outlined above?

We suspect that your answers will be 'not at all' or 'very little'. Why do you think there is so little teaching about the nature of technology in the school curriculum?

The work of Clayton M. Christensen (2012) is widely referenced in discussions of disruption but he views disruptive innovation through the lens of business/commercial activity. We feel that this is limited for our purposes. We are particularly interested in the way certain technologies, as they emerge, have significant effects on the way individuals, groups and communities live their lives. These technologies emerge through commercial activity but it is the social impact of these technologies with which we are concerned. We think it is important in education to concentrate more on the social impact of technology.

Our purpose is focused on enabling pupils to develop a perspective on technology such that they can consider its impact on their lives and take part, from an informed position, in debates concerning whether and how technology should be deployed in the society in which they live. Inevitably social impact and economic impact are intertwined. This view is developed by McKinsey Global Institute (2013: 13):

> The relentless parade of new technologies is unfolding on many fronts. Almost every advance is billed as a breakthrough, and the list of 'next big things' grows ever longer. Not every emerging technology will alter the business or social landscape – but some truly do have the potential to disrupt the status quo, alter the way people live and work, and rearrange value pools and lead to entirely new products and services.

We can unpack the features of disruptive technologies as follows; such technologies will:

- disrupt the status quo, that is they will overturn existing hierarchies and may (or may not ...) lead to different and more democratic hierarchies
- alter the way people live and work, that is they may increase or decrease employment opportunities, change the knowledge and skill sets required for employment, impact on education and alter relationships
- rearrange value pools, that is they influence existing and new commercial activity in ways which redistribute financial gain, generally towards those who are deploying these technologies
- lead to entirely new products and services, that is they will provide types of products and services that have not previously existed.

Task 17.2 The features of disruptive technologies

If pupils are to use the four features of disruptiveness to interrogate new and emerging technologies it will be important for them to understand the meaning of each feature. The features above are written for teachers; write a simplified version of each feature that will be accessible to pupils yet still retain its essential nature.

It is possible that a new and emerging technology might meet only some of these criteria. In such cases the technology would be, probably, less disruptive than one that met all the criteria. In identifying disruptive technologies for consideration in the school curriculum we have attempted to identify new and emerging technologies that meet all the criteria.

The McKinsey Global Institute (2013) have identified 12 technologies that have significant potential to alter the business or social landscape:

- mobile internet
- automation of knowledge work
- Internet of things
- cloud technology

- advanced robotics
- autonomous or near autonomous vehicles
- next generation genomics
- energy storage
- three-dimensional (3D) printing
- advanced materials
- advanced oil and gas exploration and recovery
- renewable energy.

This list is to some extent mirrored by David Willets (2013) in *Eight Great Technologies*:

- the Big Data revolution and energy-efficient computing
- satellites and commercial applications of space
- robotics and autonomous systems
- life science, genomics and synthetic biology
- regenerative medicine
- agri-science
- advanced materials and nanotechnology
- energy and its storage.

The following list of potentially disruptive technologies, which we think are relevant and potentially engaging to pupils, was drawn up independently of these reports:

- additive manufacturing
- artificial intelligence
- augmented reality
- Big Data
- intelligent matter
- Internet of Things
- neurotechnology
- robotics
- synthetic biology.

Whilst there is not complete one-to-one correspondence with the technologies identified by McKinsey or Willets there are sufficient similarities to give us confidence that our list is robust in terms of new and emerging technologies likely to have significant social as well as economic impact.

Task 17.3 Your experience of disruptive technologies

Comment briefly on the extent to which you have encountered outside school the technologies we suggest pupils should consider.

In the next section we consider the place of disruptive technologies in official curriculum documentation and possible justifications for their teaching.

Disruptive technologies in design and technology curricula

The official documentation that describes curriculum content provides guidance on what schools should teach but, as with all such documentation, it requires interpretation. No curricula documents that we are aware of specifically mention disruptive technologies but the official documents of several countries, England included, incorporate the study of new and emerging technologies and their impact. Some of these are shown in Table 17.1.

Given that there is this concern about teaching the impacts of technology, we find ourselves asking what does it mean to consider the impacts of technology? The features of disruptive technologies identified in the previous section give a framework by which impact may be judged. Such a framework gives pupils a yardstick by which to measure the impact of technologies. Initially these may be those technologies which we as educators think are likely to be disruptive, but ultimately we would want young people to be able to use such a framework to consider the possible impact of any new and emerging technology. This is just one reason that can be used to justify teaching aspects of disruptive technologies in design and technology. Further reasons which suggest benefits include:

Table 17.1 National curricula references to new and emerging technologies

England	National Curriculum design and technology programmes of study: Key Stage 3, section on 'evaluation' (Department for Education 2013) • Investigate new and emerging technologies. • Understand developments in design and technology, its impact on individuals, society and the environment, and the responsibilities of designers, engineers and technologists.
Scotland	Curriculum for excellence: technologies experiences and outcomes Technological developments in society, Fourth Level (Education Scotland undated) • I can debate the possible future impact of new and emerging technologies on economic prosperity and the environment.
New Zealand	Technology curriculum achievement objectives Nature of technology, Level 7 and Level 8 (Ministry of Education 2010) • Understand the implications of ongoing contestation and competing priorities for complex and innovative decision making in technological development. • Understand the implications of technology as intervention by design and how interventions have consequences, known and unknown, intended and unintended.
USA	Next Generation Science Standards High School Engineering Design Influence of Science, Engineering, and Technology on Society and the Natural World (Next Generation Science Standards 2013) • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

For teachers:

- to provide a way of keeping the curriculum they teach up to date and relevant
- to develop understanding of what the critiquing of disruptive technologies offers to design and technology education.

For pupils:

- to develop engagement in speculative thinking about the future within design and technology
- to develop understanding of the ways in which technology leads to change
- to provide preparation for a world in which many technologies are rapidly becoming more democratised and more available to the masses
- to start to unpick how new affordances will redistribute social, moral, environmental, and financial, responsibilities.

Task 17.4 Benefits to pupils of teaching about disruptive technologies

In your own teaching experience, to what extent have you had the opportunity to teach lessons that meet some of the benefits for pupils identified above?

We suspect that your answer will be 'not at all' or 'very little'. Why do you think there is so little teaching about these aspects of technology in the school curriculum?

If pupils do become engaged with critiquing disruptive technologies, how might this impact on other aspects of their learning in design and technology?

Disruptive technologies – examples from the past

In this section we take two technologies from the past and discuss them in terms of our criteria for disruption to show how they were disruptive.

The story of Kodak

At the end of the nineteenth century photography was pursued by those with expert knowledge, sophisticated equipment, financial resources and time. George Eastman, founder of the Eastman Company, changed that. His company developed a camera that was very simple to operate, used a roll of film and, the main feature leading to disruption, a service that took the exposed film and produced a set of negatives and black and white prints. The result was an extremely rapid growth in the use of photography by the general populace (Snyder 2013). This can be considered in terms of the features of disruption as follows.

The company, known by its trademark Kodak, democratised access to photography hence it disrupted the status quo. It altered the way people worked in providing employment for darkroom technicians who processed the film and the way people lived in providing a popular hobby. It rearranged value pools in that it enabled the Eastman Company to be financially very successful in a market that had not previously existed. Ironically the company later developed the digital camera and the burgeoning popularity of digital photography led to the demise of Kodak's film photography business. Here we see another disruption involving a shift in the way people live and work – increased use of photography facilitated by digital cameras and loss of employment for darkroom technicians, rearrangement of value pools – away from the film-based photography industry to industries supporting digital photography. In terms of disrupting the status quo the role of digital photography coupled with communication technologies has led to significant global disruption.

The story of Henry Ford

The way in which transport was mechanised by the application of the internal combustion engine to horse drawn vehicles was a revolutionary technological innovation. But it was not, at its inception, disruptive because early automobiles were expensive luxury items that did not disrupt the market for horse drawn vehicles. The market for transportation essentially remained intact until the debut of the lower priced Ford Model T in 1908. Henry Ford (1922: 73) indicated his intention to be disruptive as follows:

> I will build a car for the great multitude. It will be large enough for the family, but small enough for the individual to run and care for. It will be constructed of the best materials, by the best men to be hired, after the simplest designs that modern engineering can devise. But it will be so low in price that no man making a good salary will be unable to own one – and enjoy with his family the blessing of hours of pleasure in God's great open spaces.

The automobile, by itself, was not disruptive. It was the development of the mass production system that enabled the profitable manufacture of large numbers of vehicles that were affordable both in terms of purchase price and running costs that was disruptive. To show Ford's mass production system as disruptive we can use the criteria for disruption:

- Did the mass production system disrupt the status quo?
  Learning to drive and acquiring a motor car have become a rite of passage for most young adults, male and female, in many countries. The opportunity to move from your place of birth to new and different places, to gain employment, to meet new people, to form friendships and relationships was facilitated by the motor car. This physical and social mobility had a deleterious effect on small, localised communities. Clearly the status quo was disrupted by the affordable availability of the motor car.
- Did the mass production system alter the way people live and work?
  The availability of the motor car and other motor vehicles provided new employment opportunities for large numbers of people in manufacture, use and maintenance. The skill sets needed for this employment became features of education for employment.

Peoples' lives at work and leisure were changed by the availability of both public and personal transport.

- Did the mass production system rearrange value pools?
  Considerable new commercial activity arose through the availability of the motor car: in selling, leasing and maintaining motorised vehicles, in providing new infrastructure needed by the vehicles, in providing financial services for those using motorised vehicles.
- Did the mass production system lead to entirely new products and services?
  Although the motor car can be seen as an alternative to a horse-drawn vehicle its development into a wide range of vehicles for the transportation of individuals, families, groups of people and goods indicates new products and associated services. The parallel development of large networks of roads and motorways and associated services again indicates new products and services.

Task 17.5 Planning to teach about disruptive technologies

Plan a lesson introduction for lower secondary pupils that uses one of the examples of disruptive technology described above to help them learn something about the features of disruption.

If possible, teach the introduction and evaluate pupil responses and pupil learning.

Disruptive technologies – three recent examples

Here we consider three technologies, from our list of nine disruptive technologies, that we think are relevant and potentially engaging to pupils. These technologies are:

- additive manufacturing
- augmented reality
- robotics.

In each case we refer to related science fiction sources as we believe such writing and films can provide insight into possible future scenarios involving technology and its impact on society.

Additive manufacturing

Additive manufacturing (AM) involves fabricating physical objects in successive thin horizontal layers, according to digital models derived from computer-aided designs (CAD), 3D scans or video games (Lipson and Kurman 2013). A number of AM processes are currently in use:

- fused deposition, in which a thermoplastic filament is melted, cooling and hardening as it is incrementally deposited

- 3D inkjet printing, which deposits a liquid binder onto thin layers of powder (sand, plaster, ceramics or polymers) (Fused deposition and 3D inkjet processes can also be used with some foodstuffs.)
- laser metal deposition, which uses a laser beam to create a melt pool on a metallic base, into which metal powder is fed
- stereolithography, which uses laser beams to selectively harden liquid photopolymers
- powder bed processes, which use a laser beam to selectively melt or 'sinter' successive layers of thermoplastic or metal powder.

AM was initially conceived and developed for rapid prototyping. Its use for production of finished components and products is expected to vastly outstrip prototyping. Current and emerging applications include:

- products which consumers print at home, or have printed by 3D print-on-demand providers, to their own designs or to open source or commercially available online designs
- bespoke dental and medical implants and other prosthetics, adapted to individual patients by data from medical scans to inform exact dimensions
- aerospace and motor racing components, where there is a premium on the weight saving that can be achieved by combining AM with topology optimisation (Hague 2013).

Current research seeks several prizes: integral printing of structural and functional, for example electronic or optical, materials; 'zero waste' of feedstock; parts consolidation enabling an assembly to be made as a single component; AM using multiple materials (Hague 2013; Hague and Reeves 2013; Wohlers Associates 2012; Wohlers and Caffrey 2013).

How might this technology disrupt the status quo?

As design tools become more accessible, some democratisation and deskilling of design and manufacture is likely. There may be widespread public participation in 3D printing relatively simple designs at home, and a smaller but significant body of AM hobbyists who design and make with some sophistication. This pattern could be replicated in the small business sector, for example widespread and highly localised retail provision of on-demand 3D printing of off-the-shelf designs for simple products, complemented by a smaller number of AM specialist services capable of manufacturing domestic and commercial clients' own designs, and of providing franchised just-in-time manufacture of industrially designed products and replacement parts for national or multinational companies.

Cory Doctorow (2009), in his science fiction novel *Makers*, describes a not too distant future in which thousands of garage inventors are linked with the funding and communications infrastructure from large companies and, using 3D printers, are able to take part in the revitalising of the American economy.

As 3D scanning becomes more sophisticated and more available it will be possible to pirate patented domestic and industrial products. Will intellectual property ownership have to carry responsibilities as well as rights? Who *is* liable when a component based on an open source design fails catastrophically in service? Will possession of a 3D file be taken as intent to manufacture for illegal purposes?

How might this technology alter the way people live and work?

Certain design and manufacturing occupations are likely to be deskilled or eliminated and a smaller number of new occupations will emerge. For example, workforce reductions – and often relocations – will result wherever a sequence of existing processes, for example casting–milling–drilling, is replaced by a single AM operation.

The affordances (Norman 1988: 9) of AM will require professional designers to 'un-learn' some design skills (Wohlers Associates 2012) and may change the attributes required in new designers. Some occupations will be deskilled, others replaced, eliminated or relocated (see below).

How might this technology rearrange value pools?

Where AM reduces cost, improves quality, facilitates flexible manufacturing, enables personalisation of designs, for example in medical and dental prosthetics, or offers 'just-in-time' benefits, some manufacturing will move from industrial to post-industrial scales, sometimes bringing relocation from the 'global east' to the 'global west'. Reduced demand for transport and warehousing of finished products will not be fully offset by growth in logistics relating to AM feedstock and AM equipment. Reduced demand for traditional manufacturing materials may, however, be balanced by growth in demand for existing and new materials developed specifically for AM.

Will this technology lead to new products and services?

While AM will reveal and exploit opportunities for new products, its initial impact may be seen in enabling new and better designs for exiting products – some of which would be un-makeable through existing processes (Hague and Reeves 2013). 'Better' may mean more personalised, lower in weight, stronger, requiring less feedstock material, or more aesthetically innovative.

Augmented reality

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 Global Positioning System (GPS) data. A recent manifestation of this technology is 'Google Glass' – a wearable computer in the form of spectacles which displays information and can interact with the internet by natural language commands (Future Apps 2013). An example of the use of Google Glass is in the Irvine School of Medicine (2014) in the training of doctors and surgeons.

How might this technology disrupt the status quo?

When people wear such AR devices for much of their waking lives, their experiences of the world will be quite different from those who reject or do not have access to this technology. And this experience will be manipulated by those who control the sensory input into the AR devices. Who might control the input? Commercial concerns like Google, Amazon or Facebook, or perhaps governments? A dystopic view of this situation is described by David Brin (2013) in his *Insistence of Vision* short story. All people wear the glasses and the state controls what you can see such that convicted criminals are ostracised because their glasses 'augment' their perceived reality by making other citizens appear 'blurred', unrecognisable and unavailable for interaction. When only some have access to AR and when the augmentation provided varies according to status or AR provision, it is almost certain that disruption of the status quo will follow, with different groups having more or less power depending on the extent of their access to AR and what they use this access for.

How might this technology alter the way people live and work?

It is easy to imagine workplaces such as factories, distribution centres and offices where information provided by AR devices is used by workers in carrying out their day-to-day work. The science fiction novel *Rule 34* (Stross 2011) describes AR glasses worn by police that have access to face-recognition software and can provide criminal record information on those the police meet with during investigations. The provision of AR during leisure activities is easy to envisage. Spectator sports could easily be augmented, as could theatre and TV. At social gatherings people could choose to display AR information about themselves visible only to those wearing the appropriate reader. It is easy to envisage AR tourism.

How might this technology rearrange value pools?

Those who provide AR services will do it as a commercial venture. Much of the money they make will come from advertising. Imagine if you are looking at items in a shop window that have been tagged to be recognised by your glasses. It would be easy for the glasses to overlay access to new products and services related to the item you are looking at, put you in touch with people you know who have bought such products and services, and so on. And of course the way in which people respond to their AR experience will generate massive amounts of data about them as potential consumers. Many companies will pay for such information as it provides significant market intelligence.

Will this technology lead to new products and services?

The provision of AR through wearable technology is itself a new product/service but clearly there is considerable potential for providers of AR to develop a wide range of new services for those who adopt their initial services. Exactly what these services might be is a matter of speculation but an intriguing possibility is somehow capitalising on users' responses to AR and adding a new layer of services concerned with sharing responses.

Robotics

Illah Nourbakhsh (2013) has noted that robots can operate in the real world and at the same time can be fully connected to the digital world. There is already concern as to the effects of robots on society as exemplified by the EU-backed €1.5 million (£1.3 million) RoboLaw Project (see www.robolaw.eu/) which brings together a team of roboticists, lawyers and philosophers to develop proposals for the laws and regulations necessary to manage emerging robotics technologies. Noel Sharkey takes a broad view of the project (Piesing 2013: 2):

> This is a very important project to help us to pre-emptively deal with the emerging robot technologies. The biggest issue is not beyond the remit of the project: the rapid rise in robotics for military and broader national security purposes. Other important civil issues are raised by the use of robots for childcare and care of the elderly; currently the law is inadequate to control this use.

Robots are already operating in a wide range of arenas, including the following:

- Military operations – the increasing use of robots for military and/or law enforcement purposes has been the subject of two recent science fiction films: the 2014 remake of *RoboCop* and *Elysium*. In each scenario robots are autonomous, making decisions for themselves as to what to do when confronted with humans behaving in ways they interpret as being enemies or contravening the law. Currently the military uses robots that are under human control. These include bomb disposal units (see MOD site) and drones (see ga-asi site). It is not unlikely that developments in robotics will lead to robots that could operate autonomously in warfare.
- Surgery – robot surgery is now well established having a dedicated journal since 2007 (see Springer website). The main advantages of such surgery are its minimally invasive nature and the fine motor control that can be achieved by robots operating under human surgeon guidance.
- Manufacturing – the use of robots in manufacturing has been increasing steadily over the past 20 years from 55,000 units shipped annually in 1994 to 160,000 in 2012 (International Federation of Robotics 2013). Until recently these have been highly expensive items used in large scale manufacturing. But the development of the Baxter robot at MIT (Rethink Robotics 2013) may change this. It is small, inexpensive and requires human instruction to perform simple operations.
- Social care – Japan is investing heavily in developing robots that might care for the elderly (BBC 2013a). The film *Robot and Frank* (2013) makes a poignant case for such human–robot relations. Research into the views of health care providers has indicated that they are quite open to the idea of receiving assistance for certain tasks (Rogers et al. 2013).
- Transport – the Foresight Vehicle Technology Roadmap developed in 2004 accurately predicted most of the developments that have taken place in the past 10 years including the emergence of the self-driving car (Foresight 2004). The UK government

is supporting the introduction of driverless cars and these are being tested in Milton Keynes (BBC 2013b). Unmanned trains are becoming common in places where they are built from scratch, although reservations have been expressed when they are required to operate in old infrastructure (Evening Standard 2014). There is significant interest in unmanned aircraft systems as evidenced by the Unmanned Aircraft Systems (UAS) road map developed by the Federal Aviation Administration (2013) in the USA.

- Domestic services – in 2013 earnings before tax on sales of the Roomba, a basic robotic cleaner, were \$62.2 million, an increase from \$52.5 million the previous year (irobot 2013). Recently James Dyson has announced his intention to support research into robotics at Imperial College (BBC 2014) with a view to developing a robotic domestic cleaner. Hence there is clearly a growing market here.

In terms of our criteria for disruptive technologies:

How might this technology disrupt the status quo?

A significant question asked in the 2014 remake of the film *RoboCop* was the extent to which robots should be able to make decisions that were formerly made by humans, that is could robots be relied upon to make judgements that were driven by the same value systems as would be applied by humans in that situation? There is no doubt that robots already make all sorts of decisions according to their programming. At a very basic level the Roomba makes decisions that allow it to circumnavigate furniture. But as robots become more sophisticated and move into arenas where human and humane decision making is required, there is the distinct possibility that they will be asked to make decisions once made by humans and this will almost certainly disrupt the status quo.

How might this technology alter the way people live and work?

Some argue that robots will replace human workers (Rotman 2013) whilst others (Knight 2012) suggest that robots will become co-workers, releasing humans for tasks more suited to human as opposed robot knowledge and skill. Will the domestic robots developed by Dyson increase or decrease opportunities for human cleaner employment? Will being a cleaner involve being in charge of robot workers and being able to maintain, repair and reprogram them? Will this lead to cleaning being a hi-tech job for those with significant science, technology, engineering and mathematics (STEM) qualifications? If so where does that leave those who are cleaners today?

How might this technology rearrange value pools?

The McKinsey Global Institute report (2013) suggested that by 2025 applications in robotics will have a total direct economic impact of \$1.7–4.5 trillion. But the report warns that public resistance to job losses and lack of workers educated in mathematics, science and technology are possible barriers to such development. Those companies that successfully enter this new and emerging market are likely to make significant profits but they will need to make large initial investments to do so. Companies with large financial resources such as Amazon (Rotman 2013) and Google (IEEE Spectrum 2013) are acquiring robotic expertise and capacity.

Will this technology lead to new products and services?

Illah Nourbakhsh (2013) has written a series of very engaging short stories about the use of robots in the future. They are all edifying with regard to the impact beyond intended benefit of robots in our society. This has led Nourbakhsh (ibid.: 119) to argue for an approach to robotics that isn't driven solely by elites in their search for financial gain and power.

> Robotics is becoming a potent force, but, like much of technology, it has no innate moral compass. It is destined to influence society, and I believe the early adopters are already apparent: corporations, militaries, governments, and a privileged band of technically savvy individuals. What is missing from this list is the interests of citizens and local communities, motivated neither by power nor by economic value, hoping to contribute to a sustainable quality of life. Our challenge and opportunity lies in becoming the vanguards of ever-better robot futures, and this means we must bend the lines of influence that robotics will forge.

Task 17.6 Disruptive technologies in lower secondary school

Based on the above, identify three key points about the implications of each of the above disruptive technologies that you would want lower secondary pupils to understand:

- additive manufacturing
- augmented reality
- robotics.

In the next section we consider how you might teach about disruptive technologies within design and technology.

Approaches to teaching disruptive technologies

Here we consider three ways of teaching pupils: case studies enabling critique, designing without making enabling speculation as to future uses, and designing and making in which pupils utilise disruptive technologies and the role of local research and development centres in supporting such teaching.

Case studies

Case studies are true stories about design and technology in the world outside school. Through case studies pupils can find out about how a disruptive technology works, what it is being used for and how it affects society, the environment and people's lives. It is important for pupils to make sense of any case study and this can be achieved by embedding three types of task into the study. These are:

- Pause for thought – which helps pupils to think about what they have just read so that the following text will be easier to understand. There is no need for them to write a response.
- Questions – which ask the pupil to stop reading and to tackle the questions. The range of possible answers is wide. The pupil may need to write down an answer, make a drawing or a model, discuss the study with other pupils or make a short presentation to the class.
- Research – which asks the pupils to find out more and report about what they have found out. It may involve using other information sources or talking to an expert. It may take quite a lot of time so pupils probably need to do it as homework. The report may be in the form of writing but other responses are possible, for example a short PowerPoint presentation, an audio or video recording, or a Pinterest board.

Producing case studies about disruptive technologies need not be a time-consuming task. For example, the BBC news website has many articles in the Science/Environment and Technology sections that are the basis for interesting case studies concerning disruptive technologies. One of the authors, David, regularly tweets about such articles. It is relatively straightforward to direct pupils to a particular item and suggest where they might 'pause for thought', answer a particular 'question' or do some follow up 'research'. In some cases you might wish to print out the website page and ask the pupils to use DART techniques, Directed Activities Related to Text. This might involve underlining important words, making notes in the margin, cutting out pictures, sticking them onto a large sheet of paper and adding notes, colour coding words or phrases to do with a particular issue. By structuring pupils' engagement with the case study you can enable them to critique a particular disruptive technology. As pupils gain experience in using case studies that you have written they can move on to producing case studies of their own.

Designing without making

In this approach pupils design, but do *not* make, products and services for the future using a disruptive technology in their design proposals. They write their own design briefs. They work in groups and have to present their proposals to their peers and teachers. Removal of the requirement to make what has been designed allows the pupil to conceive ideas for products that are not limited by their personal making skills and the tools, materials and equipment available in the school. It also enables them to consider applications of disruptive technologies that are unlikely to be accessible to schools. However, the pupils should be required to justify their design proposal in terms of four features: technical feasibility, being acceptable to the society in which the product will be used, meeting clearly identifiable needs and wants and the nature of the market into which the product will be sold (Barlex 2012). If any one of the considerations is omitted it is likely that the resulting design concept will be flawed. The detail with which the pupils describe and justify their proposals indicates that they are products of worth and capable of production, albeit not by the pupils. This opportunity to be creative reflects the creativity of the designer in the world outside school where the designer is seldom required to manufacture her design proposal although she has to ensure that it can be manufactured. Preceding or accompanying this sort of activity with case study work provides the pupils with the necessary background information about the disruptive technology to tackle the required design task with some confidence.

Designing and making

Although the majority of disruptive technologies will not be available to schools, some will. Three come immediately to mind – additive manufacturing, robotics (and with this artificial intelligence) and the Internet of Things. Increasingly schools are acquiring 3D printers. Hence pupils will be able to design complex components and artefacts on screen and manufacture them with little if any conventional hand tool or machine tool use. Such work might be difficult to assess under current assessment requirements and can be seen as disrupting the conventional school design and technology experience. Additive manufacturing may disrupt global supply chains by enabling local manufacture (Birtchell et al. 2013). Hence it is possible that as pupils engage with a technology that disrupts their experience of school design and technology, that same technology is also disrupting what happens in the world outside school. Of course the extent to which pupils are aware of this wider disruption will be dependent on the use of case study work concerning additive manufacturing. In England, the 2014 National Curriculum for design and technology requires lower secondary schools' pupils to develop products with embedded intelligence (Department for Education 2013). The PICAXE microcontroller makes this feasible in lower secondary school and provides progression to more sophisticated work in upper secondary school. Other available microcontroller systems include the Arduino and mbed systems. Supporting such work with case studies concerning the impact of robotics, artificial intelligence and the Internet of Things will enable pupils to put the simple applications they develop into the wider context of considering impact in the world outside school.

The role of local research and development centres

Most universities have research and development centres and some of these are working on disruptive technologies. Each of the authors of this chapter has been able to find such centres in their locality: The Centre for Additive Layer Manufacturing at Exeter University, Manchester Institute of Biotechnology at the University of Manchester, and Centre for Robotics Research at King's College in London. Such centres, if approached correctly, can have a useful role in supporting pupils' understanding of disruptive technologies. You, as the teacher responsible for introducing the subject, would need to make contact with a researcher active in the new technology; not necessarily a high ranking academic. There should be an initial meeting to identify some key features of the technology that could be used to engage pupils and you would aim to leave with a pile of reading links. You would ask your contact to make a technical review of the drafted curriculum materials you produce to ensure that these are accurate and reflect the field. If possible you would organise for the researcher to visit the school to talk briefly to pupils about their work with the disruptive technology. There is benefit for the university in gaining a higher profile with pupils which will support the widening participation programme in higher education.

Task 17.7 Exploring local research and development centres

Using the websites of the universities closest to your school, or to where you live, explore their research institutes to see if any relate to the nine areas of disruptive technology discussed above.

If possible, find a contact willing to work with you in supporting your curriculum development in this area. (You could also simply search for a 'widening participation' contact.)

Possible future developments

In this chapter we justify the inclusion of disruptive technologies in the secondary school design and technology curriculum with a focus on technological perspective as an underlying educational rationale. We have considered the nature of such technologies and given examples from both the past and the present. And we have looked at how such disruptive technologies might be taught.

To some extent future developments rest in your hands. If you think disruptive technologies should be part of the design and technology curriculum there are several ways to develop this as a feature of your teaching. You can use disruptive technologies as part of design and technology extra-curricular activities. This provides a relatively risk-free way of finding out how to engage pupils. If this proves successful then a next step would be to introduce it as part of the lower school curriculum under the auspices of investigating new and emerging technologies. Assuming that design and technology examination specifications build on national curriculum requirements, there should be opportunities to extend this work into the upper secondary school.

A particularly important feature of work still to be carried out is developing approaches to understanding the features of disruption that are accessible to a wide range of pupils. We believe it is important that the ability to critique as an aspect of design and technology education is made as widely available as possible. It is of course preferable to carry out such development in collaboration with other teachers, both in your own school or with teachers from other schools. Setting up a small development group involving teachers from different schools would make the exercise more manageable. It would mirror the view that teachers should have the opportunity to develop new professional knowledge (Hargeaves 2001). If you or any of your co-developers are involved in supporting teacher training, then there will be opportunities to involve new entrants to the profession. However you move forward in this development it will be important to convince various stakeholders that it is an activity of worth. First and foremost you must convince the pupils, but it will also be important to secure support from your senior leadership team. This will certainly be necessary if you wish to involve input from those working in local research and development centres. And of course it will be important to involve pupils' parents and carers with this aspect of the design and technology curriculum so that they understand some of the wider educational intentions for the subject.

We are excited by the potential of disruptive technologies to engage pupils in thinking about the technological future(s) before them; we hope you are also and we'd be delighted to hear about work that you do with pupils.

Further reading

Useful starting points for further reading are Brin (2013), Lipson and Kurman (2013) and Nourbakhsh (2013) in the references.

Websites

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www.ga-asi.com/products/aircraft/predator.php – ga-asi website
www.robolaw.eu/ – RoboLaw Project website
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