Disruptive Technologies

Robotics Teacher Briefing

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This Teacher Briefing is organized as follows. Sections 1 and 2 discuss the disruptive technology in broad terms. Section 3 considers two particular examples in some detail. Section 4 discusses how the technology might be disruptive using the McKinsey criteria for disruption (McKinsey 2013). Section 5 considers trends in uptake and impact. Section 6 discusses contentious issues that might arise in relation to the deployment of the disruptive technology. Section 7 discusses briefly the interaction of the technology under consideration with other disruptive technologies. Section 8 lists useful web references that will allow the reader to keep up to date. This Briefing should be read in conjunction with the Teachers' Guide and the Robotics Teaching Guide.

1. What is a robot?

Developing an agreed definition of a robot that reflects current reality and possible future developments is an important first step in developing a robotics curriculum for use in the secondary school. Hawes (2014) provides a very basic definition of a robot as "a machine that automates a physical task". This is useful as it indicates that the machine will do something in the real as opposed to a virtual world but it makes no reference to the form that such a machine might take. A small case study (Barlex and Steeg 2014, Barlex 2015) indicates that pupils in Key Stage 3 tend to think about robots as 'metal men'. Hence this definition can move pupils away from the 'metal man' perception.

2. Where might we find robots?

Robots operate in a wide range of different fields and one way to challenge pupils' limited perspective is to consider robots in the home. If asked if a microwave oven was a robot most pupils would reply 'Definitely not!' Yet it meets Hawes' definition. It is a machine that automates the physical task of heating food for a specific length of time. It has to be programmed – time of operation and level of heating – using a simple instruction panel. Other domestic machines such as the washing machine and the tumble drier qualify as robots under this definition. The intuitive response that these machines aren't robots in the accepted sense reveals the limitations of this definition. The microwave simply responds to a set of pre programmed operations depending on the input to the control panel. Although responding to programmes the microwave has no autonomy in that it doesn't in any sense decide what to do for itself. Some washing machines might just qualify as a robot in that they decide how long a washing cycle is according to the weight of the load. Let us now consider the vacuum cleaner – essentially a suction device that a human operator moves around a room to suck up dirt, dust and litter on the floor but also from drapes, skirting boards and bannisters. It is easy to see how a pupil might imagine a metal man operating such a device but in fact robot vacuum cleaners, although not as versatile as human operated cleaners, have been available since 2002 in the form of the Roomba (and more recently from various other manufacturers). The Roomba can sense obstacles and navigate around them whilst cleaning a floor. It will behave differently according to the layout of obstacles in the room i.e. it has some autonomy. 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). So this can be seen as a growing market. 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. If domestic cleaners become robots then how long will it be before commercial cleaners and road sweepers become robots. An important trajectory to consider is how robots might radiate out from relatively contained situations – the car assembly line where there is little engagement with humans, the home

where the robots are very simple and directly under human control to situations where they are at large in the wider world and gaining in autonomy.
Nourbakhsh (2013) extends Hawes' definition that helps us consider the implications of this 'radiation' as follows:

> *In robots we have invented a new species that operates as a living glue between our physical world and the digital universe we have created. Robots can operate in the real world and at the same time can be fully connected to the digital world.*
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> Adapted from pages xiv & xv Robot Futures 2013

3. Exemplification

Considering robots and transport

The Pew Research Center is a non partisan think tank based in Washington D.C. that provides information on social issues, public opinion and demographic trends in the United States and the world (http://www.pewresearch.org/). One of its areas of interest is the use of the Internet. The Centre has published reports on AI, Robotics and the Future of Jobs and in one of these has canvassed the views of experts on the future of transportation and driving (Smith & Anderson 2014) The experts were in no doubt that 'driverless cars' would be with us soon as these extracts reveal.

Danah Boyd, a research scientist for Microsoft, responded, "There will be a lot more automation but much of it will be as invisible as it is now. So in that sense, yes, it will be part of the ordinary landscape. The biggest change will be to the movement of atoms—food, consumer goods, etc. The majority of the disruption will be at the blue-collar level, and I suspect that the biggest impact will be in warehouses."

Robert Bell of IntelligentCommunity.org responded, "Technology will continue to make things better, faster, cheaper and safer: the impact of self-driving cars alone will be immense in terms of reduced traffic congestion, lower costs for insurance and transport, and driver safety."

Tom Standage, digital editor for The Economist, wrote, "Self-driving vehicles promise to upend existing approaches to car ownership, car design, car sales and insurance, urban planning, logistics, deliveries, taxi services, etc.

Howard Rheingold, a pioneering Internet sociologist expressed his belief that this can only be for the best: "I, for one, welcome our self-driving automobile overlords. How could they possibly do a worse job than the selfish, drugged, drunk, and distracted humans who have turned our roads into bloodbaths for decades?"

And as these briefing notes are being written driverless cars are being piloted in Milton Keynes, Coventry, Greenwich and Bristol (See http://www.theguardian.com/technology/2015/feb/11/driverless-cars-roll-out-trials-uk-roads) and negotiations are taking place regarding London (http://www.bbc.co.uk/news/uk-england-london-35511980) In the US, the National Highway Traffic Safety Administration has recently declared that the computers controlling a self-driving car can be regarded as equivalent to a human driver in terms of compliance with various safety regulations. http://www.nytimes.com/2016/02/11/technology/nhtsa-blurs-the-line-between-human-and-computer-drivers.html)

Considering robots and care

Noel and Amanda Sharkey have written a very useful article "The Rights and Wrongs of Robot Care" (Sharkey and Sharkey 2012). They note that care by robots is now no longer science fiction and that already there are significant developments in the use of robots to

care for the very young and the elderly. They acknowledge the potential benefits. For the elderly assistive care with robot technology has the potential to allow for greater independence for those with dementia or other aging brain symptoms enabling the elderly to stay out of institutional care for longer. Robots can help children with special needs. The engaging nature of robots motivates young people towards STEM careers and may facilitate social interaction with the elderly. The Sharkeys are however very concerned about the impact of such care on personal liberty and privacy. In some situations the behaviour required of a care robot to infringe on personal liberty is clear – preventing a child or elderly person stepping out in front of heavy traffic for example. Other situations require more nuanced interpretations. A robot should prevent a child getting a sharp knife from a kitchen draw but not an elderly adult who is engaged in cooking unless it was known that the person had suicidal tendencies for example. Whilst it would be permissible for a robot carer to watch a young child sitting on the toilet and cleaning its bottom and recording this to share with the child's parents it would be completely inappropriate for this procedure to be applied to an elderly person and those responsible for their care. They also note that completely replacing as opposed to complementing human companionship with robot companionship carries significant risks. Relationships developed in a child's early life are crucial to their development and it is unlikely that a 'robot nanny' if providing most if not all of a child's care could provide a sufficiently human relationship. The author of these Briefing Notes knows from personal experience that the carer who visited his elderly mother provided considerable and much valued companionship in addition to her 'defined' care duties. A robot carer capable of such companionship seems unlikely in the near future.

4. In what ways are robots being or likely to be disruptive?

- 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 i.e. 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 decision 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 reprogramme them? Will this lead to cleaning being a hi tech job for those with significant 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 trillion – $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) 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.*
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5. Trends in uptake and impact

The 2014 report of the Robotics and Autonomous Systems Special Interest Group (RAS 2020) provides a usual overview of trends and impacts of robotics. The report is clear as to the considerable impact of robots and autonomous systems on our lives.

> *In the future, we will increasingly use robots and autonomous systems to enhance almost every aspect of our lives. They will be part of our response to national challenges: an ageing population, safer transport, efficient healthcare, productive manufacturing, and secure energy. Robots and autonomous systems technologies will be truly transformational for the whole of society, part of the 'Embodied Internet' that will be at the heart of our future smart cities, smart homes and smart industries. Acting as the arms and legs of 'Big Data', connected in 'The Internet of Things', robots and autonomous systems is a ubiquitous and underpinning technology that can fuel the UK's Industrial Strategy. There are clearly identifiable hot spots where robots and autonomous systems capability can impact on vertical sectors including aerospace, agriculture, automotive, energy, health, manufacturing, marine, nuclear and transport. These can be used to inform public and private investment decisions.*
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The report presents Robots and Autonomous Systems in Action case studies in the following areas:

Aerospace The impact of unmanned aircraft systems will be considerable involving the routine performance of tasks that are dull, dirty and/or dangerous, delivery of small parcels to customers, providing connectivity to parts of the world currently without reliable communications infrastructure plus the development of collision detection and avoidance systems

Offshore Energy Autonomous marine robots will inspect, survey and maintain subsea infrastructure

Nuclear robotics Decommissioning current and future nuclear facilities will require the significant use of *robots and autonomous systems*

Intelligent mobility The driverless car is seen as a key feature in combating the ever growing congestion on UK roads

Farms of the Future *Robots and autonomous systems* have the potential to provide more effective energy use, radical reductions in treatment with fertiliser and pesticide, more effective use of land, reduced environmental impact and enhanced cropping systems, with attendant beneficial economic impact upon yields and quality through reducing the time from field to supermarket shelf.

Space The space industry already depends and will continue to depend on *robots and autonomous systems* that operates in extreme environments using minimum power. This technology can spill over' into terrestrial situations – the water industry, nuclear power, mining and agriculture.

Smart Cities *Robots and autonomous systems* will provide inspection and maintenance of infrastructure and historic buildings without scaffolding, integrated personal transport that enables better traffic flow, and a supportive community through assistive living

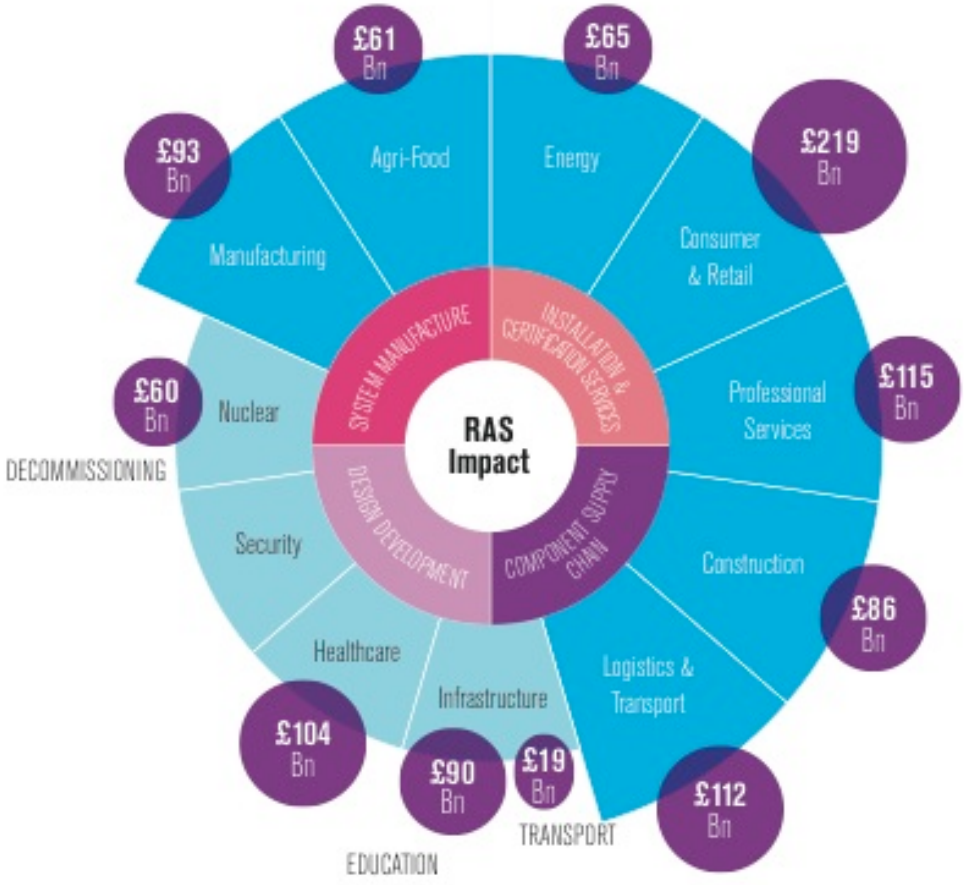
Deep Mining This will become more important as surface mining sources become depleted so the use of robot teams will become essential for future deep mines with innovations in this field being applicable to emergency services (particularly search & rescue and fire-fighting), nuclear decommissioning, waste management and space exploration.

Surgical Procedures Already well established for some procedures, advances in robotic surgery will widen the scope of application and reduce costs, decrease time spent in hospital, and reduce the side effects of surgery

Manufacturing *Robots and autonomous systems* can contribute significantly to CADCAM approaches to manufacturing especially for SMEs and support the return of manufacture from the Far East to the UK

Health and Social Care High staff turnover and low wages in the health and social care sector have led to growing concern about poor standards of care that impact the dignity of the most vulnerable. It is important to note that the introduction of robots in healthcare should occur with sensitivity towards public concerns about the possible dehumanisation of care.

The report presents the following infographic that indicates the various sectors affected or disrupted by the introduction of new robots and autonomous products and services



The larger sectors in blue represent those market sectors where RAS will have an impact, whereas the smaller sectors in turquoise represent areas where government expenditure will be impacted by RAS.

6. Contentious Robotics

One question that we must ask with regard to robots in general and autonomous vehicles in particular is how might they respond to ethical dilemmas? Imagine a situation in which you are being driven in a self-driving car and another car pulled out in front without warning. Further imagine that if the self-driving car takes avoiding action it, with you in it, will go off road and fall into a ravine in which case you will surely be killed. But if the self-driving car does not take avoiding action and crashes into the car then it is highly likely that the car, which includes children among its passengers, will be pushed into the ravine but you will survive with little more than whip lash. What should the self-driving car do? Protect you, its occupant or sacrifice you so that those in the other car are saved? It is in the light of such dilemmas that google's self driving cars travel at low speeds and have in fact been 'pulled over' by law enforcement officers for driving dangerously slowly (see http://www.bbc.co.uk/programmes/p037mx8q)

In the past new technologies have always led to the waning of the enterprises they displaced but invariable many more new opportunities for employment arose as people were employed in industries that adopted or responded to the new technologies. One major concern with the deployment of robotics is that they will make many people unemployed. Some have gone so far as to predict the 'end of work' as we know it. Turney (2014) has speculated about a not too distant future in which robots take care of agricultural and industrial production and work is no longer needed.

If we abolish work, we abolish exploitation, but also the reward of exercising skill and ingenuity to contribute to the human community. … can we dispense with one without sacrificing the other?

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However there is a school of thought that sees the deployment of robotics as having much greater implications than shifts in employment patterns. This is concern about the nature of our relationships with robots. This problem is explored in science fiction films. In the film West World (Crichton 1973) people can visit an amusement park and act out fantasies in different times – the American West, Medieval Europe or Ancient Rome – at the expense of robots which take on different roles and are expendable. In the film Robot and Frank (Schreier 2012) the character Frank, a grumpy elderly man with dementia is bought a care robot. Initially Frank is highly suspicious but as the film unfolds he develops a strong bond with the robot, actually describing the robot as "his friend" and is aghast when he has to 'turn off' the robot thus destroying all its memories of the relationship with Frank. Just how should we treat and behave towards robots?

This concern has not remained the province of speculative fiction. As an extension of care robots for the elderly or infirm TC Systems and True Companion have developed a female sex robot (See http://www.bbc.com/news/business-23637225). David Levy (2007) predicted the existence of such robots suggesting that with probable advances in artificial intelligence and robotics it would be possible for a person to fall in love with a robot companion by 2050. Levy (2015) is a great advocate of robot prostitutes. He believes …

That the availability of sexual robot partners will be of significant social and psychological benefit for society, but accepts that there are important ethical issues to be considered relating to robot prostitutes.

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Others are much less sanguine with regard to robot sex workers. The Campaign Against Sex Robots (https://campaignagainstsexrobots.wordpress.com/) argues that these kinds of robots are potentially harmful and will contribute to inequalities in society. They contend that being able to exploit a robot for sexual pleasure will demean the human participant and is likely to encourage him or her to behave badly towards other humans.

Lurking beneath our interaction with robots is the extent to which they are conscious. Some argue that robotic consciousness will approach that of humans and that robots should be given rights on par with human rights. (see https://en.wikipedia.org/wiki/Ethics_of_artificial_intelligence). Others argue quite the opposite suggesting that it is impossible for machines to have the consciousness of humans but, and it is a very big BUT, it is perfectly possible to engineer a robot such that it behaves as though it has full consciousness when in fact it has none. Such robots are called 'philosophical zombies'. (See Elkus 2015) Coming full circle in our discussion of contentious issues regarding robots where does that leave us in the way we might treat a robot co-worker which although to all intents and purposes appears and behaves as a human would but has no consciousness or feelings whatever? Would this be some sort of emotional uncanny valley that we would find repulsive or would it make no difference at all and we'd just accept it for the way it behaves?

Although we may regard them as machines the way we react to and treat robots will say much about what it means to be human and how humans should treat each other.

7. Interaction with other disruptive technologies

There is a clear and strong interaction between robotics, artificial intelligence and the Internet of Things. Developments in artificial intelligence, sometimes called machine learning, will significantly increase the capabilities of robots. Such intelligence will enable robots to be part of the Internet of Things. There is also the possibility of an interaction with Big Data as such data will be available to robots if they are part of the Internet of Things. And as robots can gather data they will be able to contribute to Big Data. The use of robots in the oceans to gather environmental data is a good example (BBC 2007). The deployment of robots in tandem with or as part of additive manufacture indicates a further possible interaction. And of course additive manufacture can currently be used to produce the mechanical parts of robots and in the not too distant future electromechanical and electronic parts as well.

8. Useful websites

Imperial College Robotics
The Main Website
http://www3.imperial.ac.uk/robot
Imperial College Robotics Society
http://icrobotics.co.uk/wiki/index.php/Main_Page

University of Oxford *Robotics Research Group*
http://www.robots.ox.ac.uk/
Website of Michael Osborne
http://www.robots.ox.ac.uk/~mosb/
The Oxford Martin Programme on Technology and Employment
http://www.oxfordmartin.ox.ac.uk/research/programmes/tech-employment

Sheffield University Robotics
http://www.sheffieldrobotics.ac.uk/
The website of Noel Sharkey
http://staffwww.dcs.shef.ac.uk/people/N.Sharkey/

Southampton University Robotics
Autonomous Robotic Systems
https://blog.soton.ac.uk/robotics/
Maritime Robotics
http://www.southampton.ac.uk/engineering/research/themes/maritime_robotics_laboratory.page

Robotics Groups at MIT
The interactive Robotics Group
https://interactive.mit.edu/
The Personal Robotics Group
http://robotic.media.mit.edu/
The Biomimetics Lab
http://biomimetics.mit.edu/
Field and Space Robotics Laboratory
http://robots.mit.edu/index.htm

The Robotics Institute Carnegie Mellon University
http://www.ri.cmu.edu/
The website of Illah Nourbakhsh
http://www.ri.cmu.edu/person.html?person_id=216

DARPA Robotics Challenge
http://www.theroboticschallenge.org/

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see https://dandtfordandt.wordpress.com/projects/disruptive-technologies/