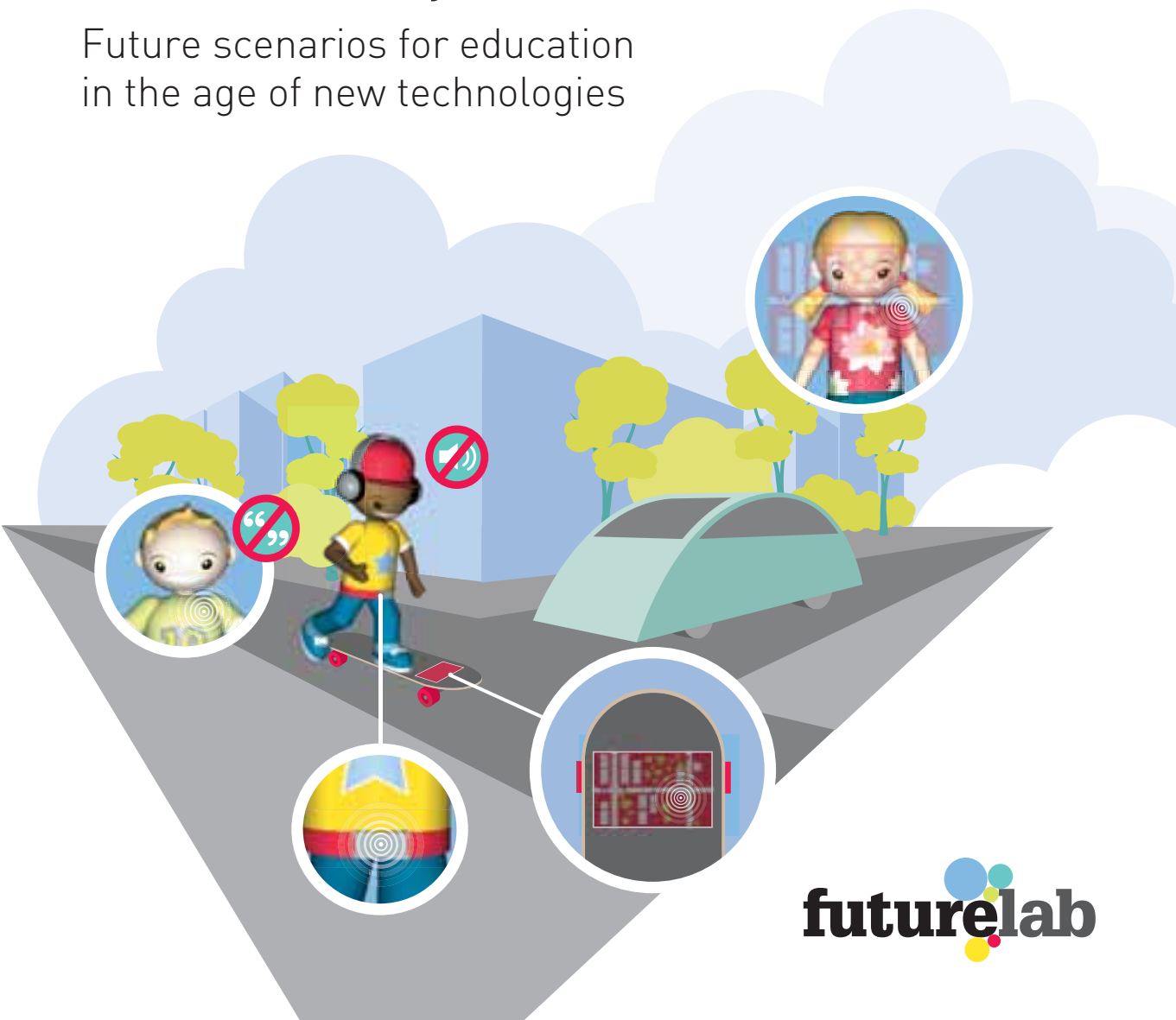


OPENING EDUCATION

2020 and beyond

Future scenarios for education
in the age of new technologies



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Hans Daanen and Keri Facer

Futurelab 2007

Foreword

What is the Opening Education series?

Opening Education is Futurelab's 'blue skies' publications series. As its name suggests, this series is intended to open up areas for debate; to provoke, to challenge, to stimulate new visions for education.

The ideas and arguments presented in these publications are generated in a variety of ways – through events and consultations with thinkers, practitioners and policy makers from a variety of sectors, through thought-experiments and visioning workshops, and as unexpected 'side effects' of the research and development activity that goes on at Futurelab on a day-to-day basis. The series complements our evidence-based publications by offering a space to propose new ideas that may not yet be ready for implementation or rigorous evaluation.

Why publish this series?

All the research into innovation in a range of sectors suggests that having a superfluity of ideas is essential for growth and development – education is no different. We need to have a surplus of potential ideas, visions and plans so that we have a range of strategies to draw on when we face the serious educational challenges that social, economic and technical change presents us with. Not all ideas will become a reality, not all ideas will survive in the form in which they were first presented, but what cannot be denied is that education, and educators, need to know that there is scope to dream; to think about new approaches and different ways of doing things; to know that the ways we do things now will not be always and forever the same.

It is in this spirit that we publish these ideas. They are experimental and exploratory, both in their arguments and in the forms in which we publish – they don't all look the same, feel the same, say the same thing. They all, however, attempt to open up a new area for debate and for action, and we look forward to hearing from you and working with you to determine their fate.

Keri Facer

Research Director

1. Introduction

At the present time the UK education system is witnessing a rash of crystal ball gazing. The Education 2020 report provides a vision for personalised learning for the next 13 years; the Building Schools for the Future programme is engendering debates about the institutions and structures of schooling for the next 50 years; and the 21st century curriculum reviews at QCA are generating discussions about the purpose and function of education for the next 100 years. These discussions are not restricted to the UK; since the late 1990s nation states around the world, and international organisations such as the OECD and UN, have been exploring the future of education in the 21st century.

This publication is intended to challenge and disturb some of the assumptions underlying these discussions by reviewing current predictions about the development in capacities of digital technologies between now and 2020.

In producing this brief paper, we want to ask the questions:

- To what extent are we prepared, as a society and as educators, for the massive changes in human capabilities that digital technologies are likely to enable in the next 13 years?
- To what extent are our future visions for education based upon assumptions about humanity, society and technology that are no longer valid?
- To what extent can we, as educators, help to shape the developments of technology in order to enhance human development?

Predicting the future, of course, is notoriously unreliable. We only have to look back to the 1970s to witness the prediction that only three computers would be required worldwide, for example; or to the 1960s to witness predictions that we would shortly be living on the moon in fetching silver jumpsuits. The pace of technological change is both more rapid than we can ever predict, and monumentally slower than we had thought possible. This is not only because it is sometimes harder to achieve the breakthroughs that we had intended, or indeed easier because developments in one field unexpectedly assist researchers in another (think of the implications for human genomics of the massive increase in computer processing power over the last ten years).

It is also because technologies enter into already existing social spaces – they are shaped by the existing social practices, human interactions and values that they encounter outside the laboratory. Again, we only have to look to the history of the record player to see how social practice can transform a technology – this device was originally intended as a personal recording machine rather than a replay tool which would spawn an entire industry and transform musical practices around the world.

Why, then, should educators consider some of the current predictions for developments in digital technologies?

If educators are to shape the future of education (and not have it shaped for them by external technical developments) it is crucial that we engage with developments in digital technologies at the earliest stages. We need to understand what may be emerging, explore its implications for education, and understand how best we might harness these changes. Without this early engagement we risk, as always, being the Cinderella sector of the technology world – constantly receiving the hand-me-downs from the business, defence and leisure industries and then trying to repurpose them for educational goals. Without this early engagement, we also risk designing educational practices and approaches that will be rendered obsolete and anachronistic in the context of new human-technological capabilities.

As Douglas Adams once observed, **“the best way to predict the future is to build it”**. We need to know the building blocks available to us as educators in the near future in order to know how we might use them and develop them for education.

2. The structure of the paper

This paper identifies five key areas where we believe there are likely to be developments in the field of digital technologies which are of potential interest to educators. These areas are:

- personal devices
- intelligent environments
- computing infrastructure
- security
- interfaces

In each of these areas we identify the overarching ‘big message’ offered by developments in the field; we offer imaginary scenarios of how these developments may translate into everyday experiences; and we then explore some of the implications of these developments for educational objectives, institutions and practices. In each section we also flag up the indicative R&D that is currently going on in universities and corporations which will feed into this field. Clearly, many of the scenarios we envisage could be recast as dystopias – and indeed, one of the intentions of this paper is to provoke discussion about what new values and rights we may want to develop in order to constrain or enable certain developments. The predictions in each of these areas are based on relative consensus amongst experts and organisations in the computing industry. They are not considered ‘way out’ by most commentators and would not be seen to be at the limits of credibility within a 13-year timescale (ie by 2020).

We also, however, wanted to explore a range of predictions at the fringes of certainty and which explore the interface between digital and biomedical developments. These are addressed in a separate section, entitled the ‘far future’, and should be treated with caution. The reason for including this section, however, is that these ‘visions’ represent the current imaginative (or dystopian) possibilities being explored by the computing and biomedical industries.

Finally, as we intend the paper to act as a prompt for discussion and action, we identify a series of recommendations and questions for educators, policy makers and developers.

3. Future scenarios

3.1 Personal devices

By 2020, digital technology is embedded and distributed in most objects. All personal artefacts – your keys, clothes, shoes, notebook, newspaper – have devices embedded within them which can communicate with each other. As a result, we will interact with these technologies in ways which are more seamlessly and invisibly integrated into normal activities.

As you walk down the street of a new city, directions in your ear give guidance on which route to take, a call from a friend is put on hold by the flick of a finger while you cross the street, and resumed as you reach the other side. The environmental noise of the city is suppressed while you talk and the directions to your destination are given now through pulses in your right and left sleeves. Your call finished, you extract from your pocket your paper-like visual display and summon up the notes you produced at home the day before to prepare for a presentation you will give the next day. Browsing through them your mind wanders and you remember the birthday present you'd intended to buy while in the city. You call up the map of the city and mark on it the time and place you want to be reminded to buy the present. Two hours later, as you are walking past a new department store, your alert goes off in your ear and directs you to the goods you had wanted to buy. Quietly you make your way home, your favourite book being read to you, your most recent music discovery humming in your ear. And as you do so, your sister at home watches your progress on her own map, tracking your movement through the city until you reach your front door where she waits to show you what she found today in the park. Pulling out her notepad she shows you the rare British house sparrow she found and filmed through her glasses, and the way in which she found out what it was by calling up the information on her audio feed.

By 2020 your mobile phone, your MP3 player, your PDA and Sat Nav are no more. No longer do you have discrete devices that you pick up, carry around with you and attempt to connect to each other. Visible gadgets have become invisible tools (unless designed for ornamental purposes like the interactive jewellery you wear). Invisibly integrated into your clothes and accessories, your digital devices work together to create an invisible set of connected tools and resources that allow you to interact with them in a range of different

ways. Audio communicators in your ear work together with visual displays in glasses and contact lenses, which connect with comms devices (embedded in your belt) and with the environmental sensors (picking up sound, movement, heat, pollution) embedded in your jacket or your car.



Questions for education

One of the longstanding debates in education has been the extent to which young people should be taught to resist or rely on new technologies. Since the dawn of formal education, there have been concerns about children's reliance upon slate, paper, pen and ink, ball-point pens, calculators and word processors (spellcheckers) in their learning. We have always, in these circumstances however, been able to clearly distinguish the artefact from the child.

As digital technologies become embedded in the very fabric of everyday life and integrated into commonplace materials, it will become almost impossible to consider what life is like without technological 'enhancement'. Instead, we may begin to conceive of concepts such as intelligence as a way of describing what someone is able to do with technologies and tools, not what they are able to do 'on their own'. 'Thinking' may be reconceived as a distributed activity – across the mind, body and digital resources that as a constellation make up the individual.

The questions these embedded and ubiquitous devices raise for education are potentially profound: Who or what should be tested in exams? The person, the person plus tools or the person's use of tools? What skills should education develop? Skills of interpretation of complex and ongoing dataflows, or skills of finding silence and reflection in the midst of constant information? Who is the subject of education? The child or the tools which need to learn to support the child? What are educational basics in an age when interaction with information and knowledge is as likely to come through auditory and image-based media as through written text? What does a fair education system look like, if intelligence is enhanced and developed through tools that can be purchased?

Indicative R&D

Almost every technical research lab in academia and industry has projects on aspects of wearable computing. IBM has an overview of its research in this area here - www.research.ibm.com/cross_disciplines/p_systems.shtml. The Equator project (www.equator.ac.uk) has developed various examples of devices that are integrated and wearable.

3.2 Intelligent environments

Digital technology is everywhere; it is embedded in everything around you from city streets, to buildings, to flagpoles and bus stops. These technologies can talk to each other and to the technologies and sensors you have embedded in your own clothes. As a result, your environment can adapt to you and connect with you and know everything about you – where you are, how you feel, what you’ve done, what you might want to do.

You’re too hot, the temperature has been up in the top 30s again for the third time this week, and you’ve had enough. Walking in from the heat to your local learning centre the building senses this – imperceptibly it alters the temperature and the air conditioning in the areas you walk into until it picks up from your biosensors that you have cooled down. As you enter the building, it also lets you know that the person you’ve been wanting to talk to about a project you’re working on has indicated that she’s got free space in her calendar for a chat and that she’s on the third floor. As you make your way up the stairs, the doors unlock and allow you through – they know who you are and where in the building you are allowed to go. You and your friend sit down together around a table and call up the confidential documents you wanted to work on. As someone from another project team enters the room, however, the documents cloud over and restrict access and you decide to move to a more private space to talk through the issues that have come up.

As you make your way home, you decide to link back into a game you’ve been playing throughout the city for a while now. Instantly, a jungle is overlaid on your vision of the city streets and buildings. Other players of the game are highlighted in your vision and you can decide to talk to them, work together with them or avoid them, depending on the information that flashes up on your screen – they may be allies or enemies, advisors or decoys. Around you, hotspots visible only to you and other players glow on the walls of buildings

and on the pavement beneath your feet, on the buses and trams that go past and in the lights that line the streets. As you walk up to these they register your presence and reveal information and clues for the game you are playing, based on your location and on the materials you have already collected. Your journey through the city takes you out of yourself and at the same time, connects you with strangers and places that you would never otherwise have found.



Questions for education

The institutions in which we educate, in which we organise teaching and learning, have embedded within them what Torin Monahan has called a 'built pedagogy'. They make some sorts of interactions easier than others, make some more likely and others unpleasant and difficult. The development of intelligent environments renders this relationship between space and human behaviour infinitely more complex and raises a number of opportunities, challenges and questions for educators.

If environments are intelligent, they offer the opportunity of responding to the specific needs, preferences and difficulties of individuals. At the same time, they potentially offer increased flexibility in that there is the capacity to reshape educational environments in multiple ways at different times to meet the needs of different occupants of the space. Different information can be displayed on walls; different levels of stimulus can be made visible; temperature, air pressure and light levels can be transformed to serve different purposes. The institution can be seen as a constantly changing and evolving environment, rather than a fixed resource with only limited properties and adaptability. At the same time, schools have historically been places which have been defined by exclusion – limiting access to non-teaching adults for example, as a result of security concerns. If institutions know who and who isn't allowed access then open door policies and greater interactions with other people and places may become possible.

Indicative R&D

The UbiCompGC is one of the UKCRC Grand Challenges in Computing (www.dse.doc.ic.ac.uk/Projects/UbiNet/GC/index.html) that gives direction to research in this area and looks at all the aspects involved. The Research Consortium in Speckled Computing (www.specknet.org) and the Berkeley Smart Dust project (robotics.eecs.berkeley.edu/~pister/SmartDust) do research in making computing devices that are small enough to be sprinkled around like dust and can form sensor networks anywhere.

A good overview of the research in pervasive computing can be found in Wikipedia (en.wikipedia.org/wiki/Ubiquitous_computing). The number of places that do research in this area is very large. Wikipedia has a list of academic research centres (en.wikipedia.org/wiki/List_of_ubiquitous_computing_research_centers).

3.3 Computing infrastructure

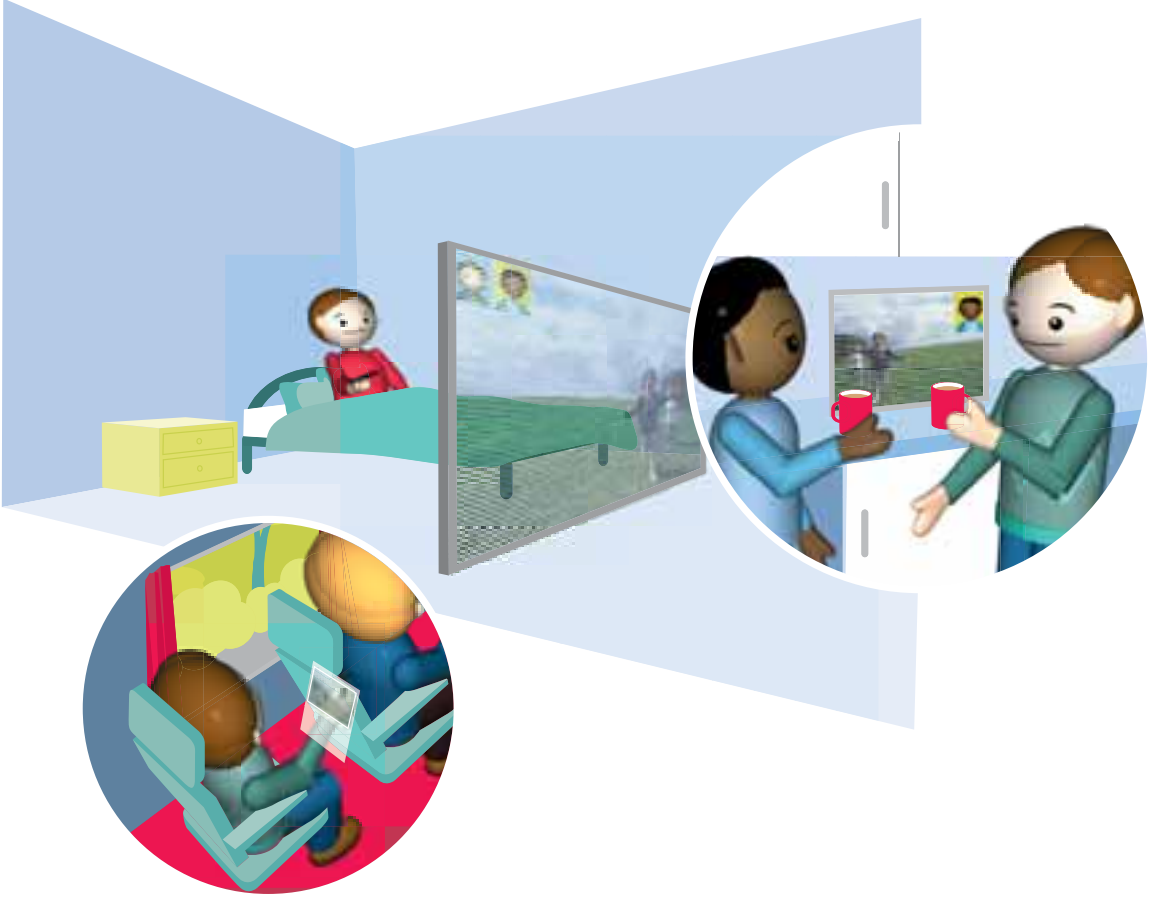
3.3.1 The network

Everything is connected to everything through THE network. There is no longer any such thing as 'the internet', 'telephone', 'TV' and so forth; instead there is blanket wireless connectivity to the network which allows (in rich countries) access to all communications channels even in remote areas.

It's Sunday morning and when you wake up you decide to lounge around in bed for a while watching a film. You get about halfway through when your friends call and invite you over to their place. Having paused the film when you left the house, you call it up again on the tram on the way and watch it on your notebook. You watch the last bit at your friend's house on their kitchen screen while you get yourself a drink and talk to them.

As you and your friends sit around talking, a phone call comes in from another friend on the other side of the country. You're all going to a birthday celebration in a couple of weeks and she wants to know whether the outfit she's just bought seems right. Her video call comes through on the lounge 'TV' and while she's on screen you decide to meet her in the virtual clothes shop you both often visit. You borrow video glasses from your friend and all of you meet up online, where you see your friend's avatar wearing the outfit she's chosen. You are able to call up the clothes you've selected and you can compare these with your friend's.

On your way home, your grandmother calls – she's having trouble identifying a plant she's just found in her garden. While you're talking to her, she sends the photo of the plant through to your notepad and you can check on your own database whether it's going to need clay or sand soil. You promise to come round to help her plant it in the next week – at which point she sends a jokey reminder to you to do just that which pops up in your ear at regular intervals – something you're not entirely pleased about.



Questions for education

Integrated networks combined with intelligent environments raise a number of questions for educators – not least of which is the question ‘where do schools need to be?’

Where in the past schools, universities and other institutions grew around the fixed resources of libraries and laboratories – if information can be accessed anywhere, if simulations and experiments can be run anywhere, if ‘human’ interactions can be achieved virtually in any location, where does learning need to take place? What sorts of new practices, institutional arrangements and human interactions can be developed to best support learning when we are not reliant upon a centrally organised location for people and material resources, but instead can enable ‘near presence’ interactions between learners, experts, advisors and mentors wherever they might be?

Indicative R&D

The European Ambient Networks project has a video of what this might look in five years (www.ambient-networks.org). The Wireless World Initiative (www.wireless-world-initiative.org) is another European project coordinating the research in several labs in this area. The MIT Communication Futures Program (cfp.mit.edu/index.html) looks both at the technical and the economic aspects of the evolution of the network.

3.3.2 Processing

It will be possible for individuals to have access to many increased processing resource because processing will not be located at the level of the individual device but centralised, and because rapid increases in processing power will continue. You will be able to do much more complicated and resource intensive things on any of your personal devices than at present.

It’s a wet Wednesday afternoon. In a bedroom in a small village, five children are playing with toys. The toys are moved around, stories emerge, characters develop and as the fantasy gets more complex the children ‘film’ parts of it. As they record more and more, they decide to make an animation of a half-hour story. The next day they share this animation with their friends. Everyone likes it so much that they decide to render it in broadcast quality using their

local data centre. It only takes five minutes so they can change bits that they hadn't modelled particularly well and they submit it to the animation channel for public release.

Over the road from the amateur animators (who two weeks later were surprised to start getting royalty payments from their show which had turned out to be an unlikely success) you are trying to figure out how the Moon really relates to the Sun and the solar system and everything else. Your friend was asking for an explanation and he couldn't understand why the sun didn't go round the Earth – after all, he said, it looks like it does. You are able to pull up a massively complex immersive simulation of the solar system projected on your bedroom wall, and to walk around it and in it, over it and under it, until you understand the dynamic relationships. Next time your friend comes round, you show him the simulation, and the two of you are able to move forward and backwards in time, walking through space, until it all makes sense.

Next door to you, Peter is obsessed with developments in aeronautics and he's determined to make his own glider. He's been scouring examples of wing shapes and sketching possible ideas in his CAD programme. The programme takes his rough sketches and refines them, making suggestions for improvements based on its massive database of existing wing designs. Connecting to the data centre, Peter is able to experiment, revise and create complex new ideas rapidly and repeatedly – refining plans and seeing the results of adaptations within minutes.



Questions for education

The massive processing power of technologies by 2020 allows relationships to develop between users and software which may offer new approaches to teaching and learning. Where complex simulations and experiments were once the property only of those with significant training and access to expensive machinery, now it is possible for anyone to input ideas, sketches, draft notes and, working with the computer, explore the implications of these ideas as simulations. Trial and error, rapid experimentation and evolution of ideas become possible. The challenge for education is to understand how best to harness this increased capacity, how to share ideas and information generated, how to engage with young people's capacity potentially to act as experimenters, designers and creators.

At the same time, as increased processing power enables digital technologies to become 'more intelligent' and to offer bespoke and specific information and recommendations in the development of ideas, these technologies come to act more as collaborators than 'tools'. As such, new concepts of creativity and originality are required and new approaches to the assessment of learning with these tools become necessary.

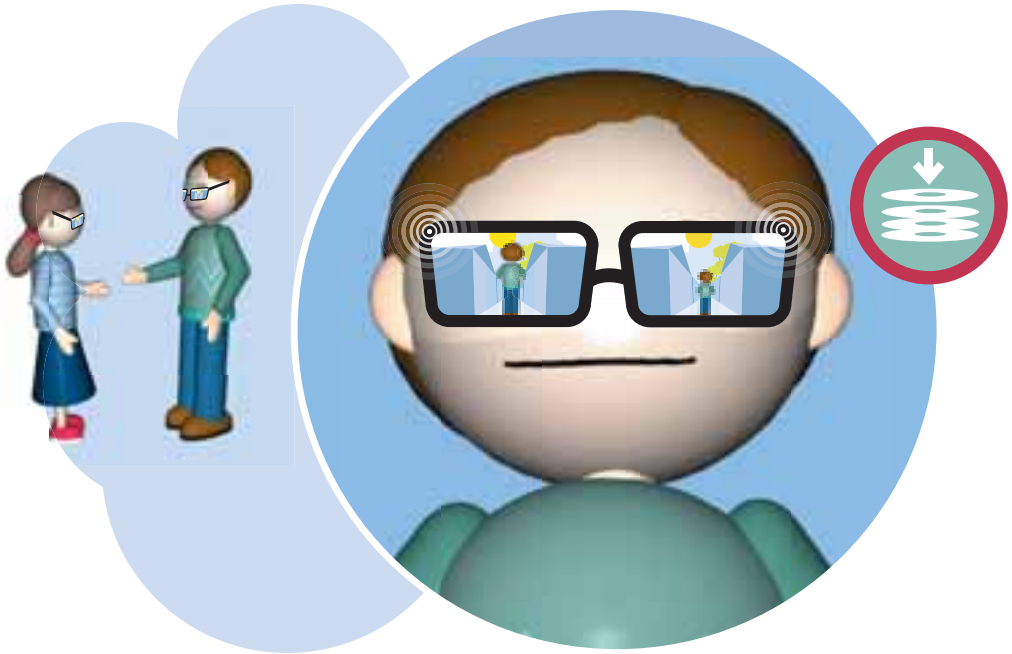
Indicative R&D

This is an area where the industrial research labs play a big role. As to be expected Intel does research in every aspect of this field (www.intel.com/research). IBM has been doing research in this area for years and dedicated a special issue of its Systems Journal on this topic in 2004 (www.research.ibm.com/journal/sj43-1.html) Hewlett-Packard has a lab dedicated to this area (www.hpl.hp.com/research/issl/projects/index.html), and Cambridge University has the XenoServers project (www.xenoservers.net).

3.3.3 Storage

Storage will become so cheap and capacity so big that you can record your whole life in DVD quality. The storage is available on the network rather than your personal device, so worries about backups and disk crashes have become a thing of the past.

The life recorder is embedded into the frame of your glasses, allowing you to capture an audio-visual record of every second of your life and recall it through visual, audio and text searches wherever you are. This allows you to recall the names of acquaintances, find the article you were reading which you can only remember from a rough date and a position on the page, and pull up the location of your lost keys. The life recorder is your external memory.



Questions for education

The concept of limitless storage of data raises profound questions about the competencies and skills we will need to learn in future. Will recall of facts and events become obsolete as a socially valued skill? Will the ability to synthesise information become the primary goal of education? Will the development of complex searching and archiving techniques become a 'new basic' in education? The ability to record and retrieve all experiences requires a debate on the purpose and function of education: what is its goal when all information – from facts, to skills advice – is constantly accessible?

Indicative R&D

The Petascale data storage institute is a US initiative to do research in large-scale data storage (www.pdsi-scidac.org). The UKCRC Grand Challenge 'Memories for Life' is an EPSRC-sponsored project that focuses the research in the implications of this development for individuals (www.memoriesforlife.org). Microsoft Research builds a prototype of a life recorder in its SenseCam project (research.microsoft.com/sendev/projects/sensecam). Carnegie Mellon's Data Storage System Centre (www.dssc.ece.cmu.edu) researches a wide variety of subjects in this area and draws on a vast knowledge network in the US.

3.4 Security

In 2020, digital security will feel much more open than today and there will seem to be fewer barriers around different sites. In fact it will be much more secure. Systems will know what and who can be trusted and who can't without users needing to specify access for each individual. Identity will be more closely tied to the person and biometrics.

Security is an area that concerns everybody using networked computers. At the moment the response to system security is building big bastions of firewalls. The result of this is that collaboration becomes quite difficult and it is often impossible to access remote data or mail, and you have to have a large number of user-IDs and passwords to get access to all the applications you use on a day-to-day basis (how many have you got for various websites?). The vision that people working in this area are pursuing is a much more integrated approach that is easy to use and is built into systems from the start, rather than added afterwards. It will have to be tied to your physical being in a way that makes it very difficult to create or assume fake identities (and so bypassing and undermining the security system – as is currently the case with a username and password). Trust in the security system by end-users and ease of use will determine how quickly they will lower the walls that we currently find on the internet and its connected networks.

To illustrate the effects of this vision on everyday life with a scenario is difficult as it is characterised by an absence of visibility. Even so developments in this area will transform the way we can share information and collaborate with others.

Access to all of your personal embedded devices, interactions with intelligent environments, and connections with the network are all infinitely more complex and distributed in 2020 than your 2007 interactions with computers. And yet, the interactions seem more straightforward. You don't need to know 15 different passwords and 20 different ways to connect to information only to find out that the network you are connected to doesn't allow you to read your e-mail through a secure connection (as happens today). Instead, your access to files, data and services is facilitated by the system knowing who you are, knowing your history and knowing your permissions, and it knows this not

because you enter information, or because anyone is regularly monitoring and specifying permissions, but because you are identified by biometric data unique to you. At the same time, you can access information and work wherever you wish because your own personal devices will scan the network at whatever point you connect and ensure that it is safe and uncompromised for use. You won't stumble on images that you don't want to see.

Collaboration and cooperation may also be easier – as network systems will easily enable collaborators to work together without security restrictions, while placing significant walls against those who would wish to breach these restrictions. Those who believe in separate spaces for children and adults will also be satisfied with increased movement of children on the web, as biometric data will identify the ages of people children may interact with and ensure the creation of children's only spaces.



Questions for education

Security issues are often presented as reasons for not being able to do things in education. Lack of security places constraints upon assessment practices – the possibility of accessing early versions of tests for example. Lack of security places limits on children’s use of information resources – we can’t risk them using social software in case they come across the wrong people. Enhanced security potentially offers peace of mind for educators and yet it also raises questions. If it is possible to wholly protect children’s online interactions within a child-only space, when will they develop ‘digital social skills’? If it is possible to manage children’s access to information through biometric data, what ownership and control do we need to offer children over that data? As with all questions of identity and security, the education community will need to take a number of profound ethical decisions in the coming 13 years.

Indicative R&D

An indication of the direction computer manufacturers are going in is the Trusted Computing Group (www.trustedcomputinggroup.org), although its work is not uncontended as you can read in this article on Wikipedia: en.wikipedia.org/wiki/Trusted_Computing_Group. IBM Research has a department looking at this area (domino.research.ibm.com/comm/research_teams.nsf/pages/secure_systems_department.index.html), and HP Labs has a lab dedicated to security (www.hpl.hp.com/research/ssrc/security).

3.5 Interfaces

Input to and feedback from digital technologies have become much more ‘natural’ by 2020, and we feel as though we are interacting with things and with people, not machines, screens and keyboards.

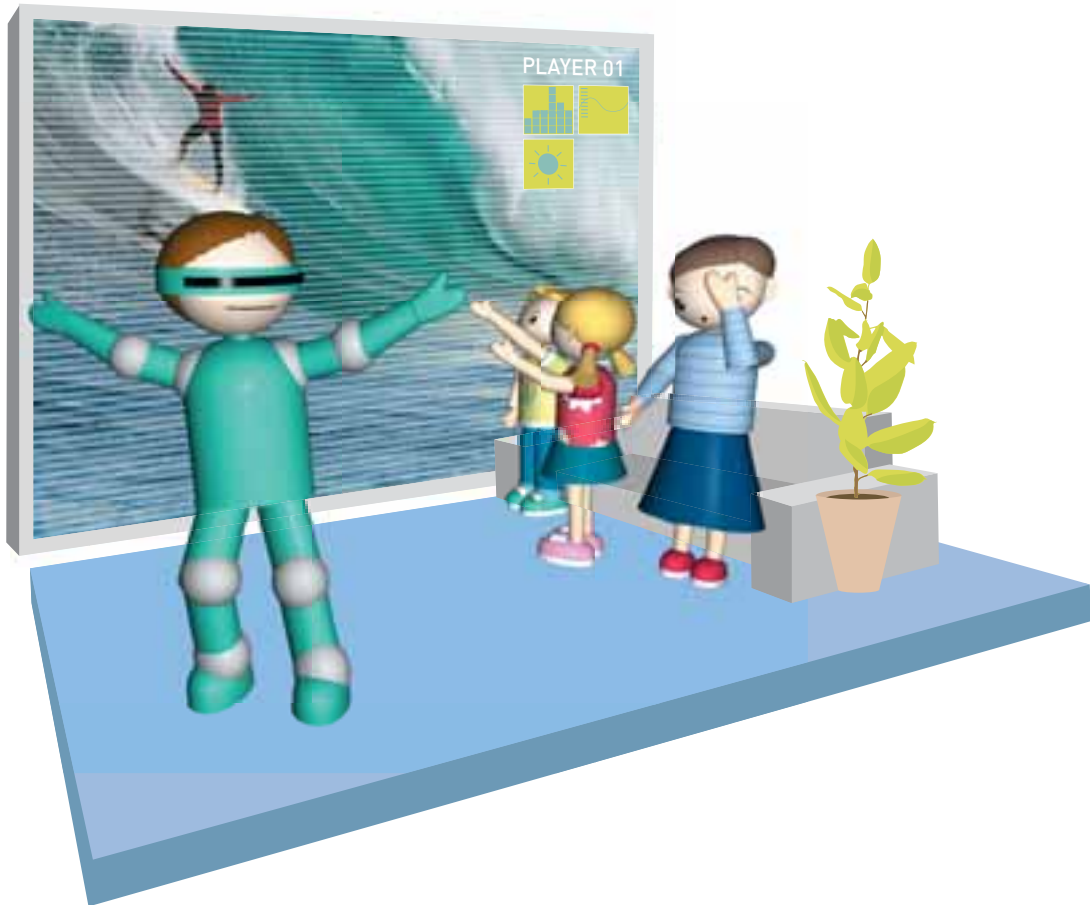
You find yourself, on a Saturday afternoon, trying to build the flat-pack table you recently bought from the online furniture superstore. Embedded in the table are instructions on how to put it together which play in your ears as you put the pieces next to each other; this leaves you with your hands free to fit the pieces together. To help you even more, you take your notebook from

your pocket and this shows you a 2D plan of how the pieces should connect. Unfortunately you find it difficult to connect the pieces in front of you with the picture in your hand, so you switch to 'real mode' and the display gives you an augmented reality view projected on to the pieces you have already assembled. Using your 3D glasses you see the where pieces are supposed to be and you are finished in no time.

Later in the evening, you remember you need to do some training for the surfing course you've booked onto. You put on your force feedback suit and hook it up to its frame. Donning your goggles you trigger the surfing programme and start practising. Again and again you struggle to stand upright and end up flat on your face on the living room floor (much to the delight of your family), but finally, after an hour (and a lot of advice from your everyone) you have begun to get to grips with the basic principles and are beginning to try out different tricks and weather conditions.

Meanwhile your brother tries out the new data cap with his virtual reality game console. It picks up his brain activity directly from his head and allows him to control the power suit his character is wearing in the game much more directly, leaving his hands free to solve the puzzles he comes across. Playing the X-Men game has become a different experience. No more shift-ctrl-alt keys anymore and you can really control all the psychic powers without any effort.

The next day, the family visits friends who are thinking about getting an extension built onto their house. As you look at the blueprints you are able to move rooms around with your fingers and add doors, windows and other features by pointing to them from a palette of options. You can then build a mini-prototype using your dynamic matter 3D printer. Being allowed to look at it in 3D helps all of you to see where the problems might arise and you can push the walls around to revise your plans. You can also ask for 3D models of houses you've seen elsewhere to be brought up from your life recorder memory banks, and you can move through these as well, picking up features you liked and including them in the new design.



Questions for education

By 2020 we should see a liberation from the constraints of paper and text and the development of much more intuitive forms of interaction with digital resources, knowledge and ideas. Drawing, movement, voice and other inputs will increase in prevalence, and ideas will more often be presented through media other than written text. Why describe a building in language when it can be presented as a model? These changes raise questions, again, about the sorts of curriculum we might expect and require in future, and the sorts of 'new basics' that might be needed.

At the same time, the emergence of virtual and immersive worlds, which allow safe exploration of risky environments, opens up the possibility for learners to engage in complex simulations, to try their hands at a variety of activities in authentic environments, before they actually get started. These developments open up the possibility of immersive learning environments, and ask us to examine the question of the role of immersion and experience (if not limited by concerns of time, space, feasibility) in education – to what extent is this desirable or not?

An interesting question remains as to whether reading and print has a special place in cognition and learning. Even though we have various media available to us today, we (and many others) continue to choose the printed form to distribute our thinking in this area. We could have chosen audio, video, podcast or any other form but we choose a combination of words and images. Is this because text and language offer some fundamental benefits for thinking and learning processes or merely because they offer advantages at this moment in time?

Indicative R&D

This article in MIT's technology review describes current research into how people can use their brain to control paralysed muscles (www.technologyreview.com/BioTech/17842) . Duke University has already shown that monkeys can control robot arms by just thinking (dukemednews.org/news/article.php?id=69) and the University of Washington has built a robot controlled via a Brain Control Interface (www.cs.washington.edu/homes/pshenoy/BrainControlledRobot.html). Intel and Carnegie Mellon University collaborate in a research project that makes dynamic physical rendering

possible to create the 3D printer described (www.intel.com/research/dpr.htm and www.cs.cmu.edu/~claytronics) as part of Intel's research into new interfaces (www.intel.com/research/exploratory/essential/physicality.htm). Virtual and augmented reality is a research topic in many universities; the Virtual Environments and Computer Graphics group at UCL is probably a good example of the current research in this area (vecg.cs.ucl.ac.uk).

3.6 Summary

The significant developments in digital technologies by 2020 can be summed up in the following top-level prediction:

Interaction with digital technologies will be more pervasive, seamless and invisible than today and will facilitate much of our everyday lives – enabling ongoing interactions with people, buildings and materials and with a constantly connected network. We will be able to tap into unimaginable computing power and reliable storage capacity on the network, which will enable us to interact with more intelligent (and responsive) technologies, to 'outsource' memory, and to use simulations and visualisation tools to solve problems, experience alternative realities and prepare for new experiences.

4. Key challenges for education

We have already identified a number of challenges that these developments may pose to educators, but now we expand upon a number of key issues that we feel merit particular attention.

4.1 Reviewing 'the basics'

The development of new communication tools, the creation of resources that allow us to record our lives and everything we see and interact with, the development of constant connectivity and instant interaction with our environment, raise profound questions about what it is that we need to know and be able to do as humans as we become increasingly like cyborgs. What conceptions of intelligence might we need to work with in the 21st century, what definitions of 'independence' might need to be reviewed? What will constitute the 'basics' in an age of multimedia interactions?

What ethical, spiritual and emotional needs are also engendered with these new tools? Will the ability to find stability and anchorage in the midst of constant mobility and change become a newly important human capacity? Will the ability to find silence amidst information flows become a pre-requisite for survival? How too should we engage with the potentially massive increase in disparity at a global level between technology-rich and technology-poor nations? What do human rights look like in the context of constant surveillance, connectivity and biometric data files?

4.2 Who decides?

Historically, the digital technologies that come to be used in education are, particularly in the case of hardware, hand-me-downs from the leisure, defence or business worlds. The desktop and laptop computer, the PDA, the whiteboard – all were first designed for adults, all were first designed for the business of business, not the business of education. Similarly, if we look at the history of the development of 'ICT skills' in education, these have been introduced primarily in the service of an economic agenda. Schools have been equipped with hardware and software and ICT has been introduced to the National Curriculum in order to ensure that schools are updated and that children have the skills to compete in the workforce. One result of this has been the idea that the introduction of digital technologies to education is simply a question of 'modernisation', in which the fundamentals of teaching and learning, curriculum and institutions do not need to be changed.

And yet, when we look at the challenges that are posed to our understanding of what 'identity' means, of what 'place and space' means by some of these forthcoming developments; when we look at the capacity emerging technologies may offer to reorganise the institutions, practices and people of education, the issues raised are broader than those raised by the needs of future employers. The challenges raised are more significant than can simply be addressed by educators harnessing the second-hand offcasts of the business world for education. As such, we cannot leave discussions of the future role of technology in education only to the technology industry, or indeed, only to educators.

Instead, we need to develop the mechanisms for an open and public debate on the nature and purpose of education in the digital age which goes beyond safe slogans such as 'meeting the needs of every child' (who can disagree with that?). Instead, we need to confront the fact that longstanding assumptions about what education is for, who conducts it, and how it is assessed, may need to be challenged. And this challenge will need to take place in the public spaces of the media, not the confines of the education community – with families, children, businesses, technologists, religious leaders and scientists all making their case for how education may need to change to meet the social, environmental, spiritual and human needs of the future.

The scenarios that are mapped out in this paper are not inevitable – they happen if society wants them to happen (or simply looks the other way and hopes they go away). If we want to shape this future, we need to get a wider network of people involved in these discussions, and quickly.

4.3 Innovation, experimentation and development of new models of education

One of the reasons we lack a sustained and coherent debate about the future challenges for education is because, at the present time, the UK education system significantly under-invests in educational research and development. While the Building Schools for the Future programme promises £45 billion capital spend on new educational institutions, none of that resource is identifiably set aside for investment in research and development to guide that strategy. While the overall DfES budget for schools is massive, investment in education research in universities and colleges is significantly lower than might be expected. What is more, there is a profound disconnect and failure of 'knowledge transfer' between university-based research and school-based

practice, and between technology and education research.

It is not possible to make decisions about the future of education in a vacuum – we need to systematically model and build a new education system and offer examples of possible futures that are accessible not only to researchers, technologists and politicians but to parents, children and local communities. There are some developments already in place to this end. The Economic & Social Research Council and the Engineering & Physical Sciences Research Council have joined forces to fund interdisciplinary research in technology-enhanced learning. Who, though, is funding the ethical and curricular research that might sit alongside the technical and pedagogic innovations that will be explored through that programme? Moreover, how are the barriers to interdisciplinary research embedded in the Research Assessment Exercise to be eroded and overcome to ensure collaboration across these sectors is embedded practice rather than project-specific?

4.4 “The future is already here, it’s just unevenly distributed”¹

One of the key issues that will confront education in the context of emergent and ubiquitous digital technologies is the question of whether the state will want to compensate for inequalities in access to digital technologies outside school or leave individuals to fend for themselves.

At the present time, the state makes no systematic effort to compensate for differences in access to computers, mobile phones or internet outside school for children. While information is still accessible via print media, while teaching and learning and assessment remain dependent upon face-to-face interaction and print media, this lack of engagement with socio-technical inequalities can, within limits, be excused.

As information becomes available increasingly only through digital media, as digital devices become not only desirable extras but essential tools for learning, the sustainability of this position will be challenged by those seeking social justice. If material and financial inequalities are not to be institutionalised within the education system, therefore, the investment of the state in educational resources is likely to need to shift from a focus upon the institution (the school) to an attention to the resources available to and accessible by the individual learner.

¹ William Gibson

5. Future visions – when digital meets biomedical

The predictions and scenarios presented so far have been relatively secure in that their content is felt to be achievable by significant sectors of the technology and telecommunications industries. It is worth flagging up, however, that many people believe that the biggest practical impact of developments in digital technologies will be in the biomedical field. These predictions should be treated with caution, but they represent some of the current imaginative (or dystopian) possibilities being explored by the computing and biomedical industries and have potentially profound implications for education.

By 2020 each of us will have access to computers with several orders of magnitude more processing power than a human brain has. In the medical field, this means that the capabilities of scanners and other diagnostic equipment are likely to be massively improved. This, in turn, should lead to significantly better understanding of how the brain and body works. Will there be a transformation in our understanding of the biological aspects of learning processes?

In 15 years' time we may have the capability to intervene at the cell level in the human body. This means we can change, repair or improve parts of the human anatomy. What this will look like on a day-to-day basis isn't quite clear. Some people think we will be able to grow new body parts to replace failing ones. Others think it will be possible to send in nano-machines that can make changes on cell level. This could be taking out cancer cells or repairing tissue that is damaged and might lead to things like a heart attack or a stroke.

In 15 years' time, technological developments may lead to computer interfaces that can directly connect to different parts of the brain. We already see some examples of this today: implanting a pacemaker is only day surgery and cochlear implants are commonplace. Retinal and optical nerve implants are coming out of the research stage. If we consider the developments in micro-surgery over the last 15 years we can only begin to imagine where the next 15 years will lead us.

Biomedical knowledge and changed biomedical practices may, therefore, have more significant implications for education than any direct application of technology in educational processes. For example, by 2020 the human lifespan will be greatly extended and will be adding a year of longevity or more for every year that passes, with supercomputing driving this process. What will lifelong learning look like in this context?

As Kurzweil says:

“We won’t experience 100 years of progress in the twenty first century - it will be more like 20,000 years of progress (at today’s rate)... Within a few decades, machine intelligence will surpass human intelligence, leading to The Singularity - technological change so rapid and profound it represents a rupture in the fabric of human history. The implications include the merger of biological and nonbiological intelligence, immortal software-based humans, and ultra-high levels of intelligence that expand outward in the universe at the speed of light.” (Kurzweil 2005)

Are we, as educators, parents, teachers, policy makers and citizens, ready to tackle the challenges and opportunities that these developments may offer for the nature, purpose and practice of education in the 21st century?

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Computing infrastructure

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About Futurelab

Futurelab is passionate about transforming the way people learn. Tapping into the huge potential offered by digital and other technologies, we are developing innovative learning resources and practices that support new approaches to education for the 21st century.

Working in partnership with industry, policy and practice, Futurelab:

- incubates new ideas, taking them from the lab to the classroom
- offers hard evidence and practical advice to support the design and use of innovative learning tools
- communicates the latest thinking and practice in educational ICT
- provides the space for experimentation and the exchange of ideas between the creative, technology and education sectors.

A not-for-profit organisation, Futurelab is committed to sharing the lessons learnt from our research and development in order to inform positive change to educational policy and practice.

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