



Curtin University

THE INTERNET OF THINGS (IoT): EDUCATION AND TECHNOLOGY

The relationship between education and technology for
students with disabilities

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Make tomorrow better.

Internet of Things (IoT): Education and Technology

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technology for students with disabilities

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While this report addresses the pedagogical implications of how students with disability use the Internet of Things (IoT), a broader IoT policy review – *Internet of Things (IoT) Education: Implications for Students with Disabilities* – was also prepared for the World Wide Web Consortium as a contribution to the next-generation Silver accessibility guidelines as part of this research project.

Executive Summary

In 2016 Curtin University launched its vision for 2030 which frames the development of the campus as a 'City of Innovation' as part of its 'Greater Curtin' branding. The Internet of Things (IoT) is a key feature of this vision. The IoT enables advanced services through the interconnecting of information and communication technologies. While much of the popular literature about IoT focuses on implications in the home, its benefits to education are just starting to be explored. The creation of smaller, wireless devices that require little power to meet the core functionality – that is, in most cases, to be controlled by a smartphone – provides significant new opportunities for student engagement in the areas of automation and remote controlling of devices. However, many of the IoT uses appearing in education are still in their infancy. As such, there is little information about the benefits, risks and access implications of current IoT solutions for students – this is particularly the case for those students with disabilities.

This report details findings of the Curtin University Teaching Innovation funded project *Internet of Things (IoT) Education: Implications for Students with Disabilities*. This project aimed to provide insight into both the potential risks and benefits of the IoT for tertiary students with disabilities, particularly in the current university climate where this cohort utilise mobile devices as a key resource in their learning. Our key objectives included to:

- Assess the educational benefits of current and emerging IoT products;
- Assess the benefits and risks of IoT within a single-interface, app-based interface and whole-of-ecosystem IoT classroom solution by competing providers;
- Determine the relevance and implications of IoT as it relates to the educational needs of people with disabilities;
- Undertake interviews with currently enrolled students with disabilities to identify the practical needs of this cohort in an educational context; and
- Provide recommendations and strategic guidance on appropriate IoT solutions with policy recommendations for Curtin University, the tertiary education sector and industry.

The report begins with an overview of the history of the IoT and offers a series of definitions of this term. A comprehensive literature review of the IoT follows, addressing both the risks and benefits of the use of IoT in a general as well as in an educational context. This is followed by an in-depth examination of the role of this emerging technology in the lives of students with disability as they move into and through higher education contexts. The report questions the tendency to see technology as an unequivocal benefit to disabled people's lives and examines the complexities of how technology is integrated into contexts and embodied realities. For example, while the IoT is easily framed as a new and radically nuanced technology that redefines accessibility, an equally decided consideration of the wider significance of the relationships between technology and society, education and disability, access and literacy, also needs circulation. While the IoT can be configured as a champion of and for the social model of disability – where environments can be changed and modified to suit different disabilities – the technology to establish an effective and reflexive IoT infrastructure is not yet at a point where it could be effectively deployed in learning and teaching at the university level.

The final section of the report details findings from interviews with currently enrolled Curtin University students with disability. In addition to the risks and benefits outlined in the literature review, these students raised a number of important insights. From the interviews, it can be seen that students with disability at Curtin University state that:

- The IoT is in a very early stage of development. As such, its possible uses and practicalities are unclear at this stage.
- They prefer Android devices.

- Technology must be adaptable. The students we interviewed regularly modify technology to suit their specific needs.
- They share a widespread willingness to try new technology, and equally a willingness to abandon that technology if it doesn't provide the support they require.
- They have different learning styles, for example some are visual, others are aural etc, and therefore require different technologies.
- Lecturers continue to be unaware of the access needs of students with disability – for example, lecturers are often of the view that if it is digital it is accessible. This was a widespread concern amongst the interviewees.
- Although the IoT offers great opportunities, it is vital that lecturers retain control of the classroom.
- They already feel overloaded with information – there is a fear that the IoT could exacerbate this.
- They hope that the IoT will be able to offer flexible and timely ways to better manage accessing educational materials.

These interviews provided insight into what students with disability understand about the IoT, the smart devices they use, and how their learning is facilitated by those devices. However, a more fully-fledged and formed answer to the educational benefits for this cohort can only be speculated on in these early stages of the technology. The report concludes with recommendations about how Curtin University might move forward in creating intelligent design within a campus setting to ensure that students can access cutting-edge education using the IoT. This can take many forms – from the ability to navigate spaces to get to classrooms to being able to download and read online materials in a timely and effective manner – and requires a wide and critical lens.

This report recommends, in relation to the deployment of the IoT in an educational setting, that:

- Curtin University should not immediately deploy IoT technologies, but that careful consideration and planning be undertaken for how this might best be done in the future and what implication this might have.
- Priority should be given to incorporating IoT within specific pedagogical issues regarding learning and teaching, with particular consideration being given to the integration of students with disabilities. This is in addition to Curtin's current focus on integrating IoT technologies primarily in association with facilities management.
- Any IoT equipment associated with learning should have the ability to provide its output to students via a learning management system or app. This would ensure that students with disabilities can process the data with their preferred assistive technology.
- Any future implementation of IoT solutions should focus around the use of personal smartphones as the primary IoT interface device for students with disabilities.
- All IoT-related implementations must also consider privacy, security and interoperability.
- Any IoT solution must be accompanied by training to ensure that all staff and students are able to use it effectively.
- The applicability of using a digital assistant as a real-time captioning device warrants further research.
- A trial of the use of existing technologies and further consultation with industry and students should be undertaken over 2018.

Introduction

The relationship between education and technology has been long and complex. Tools that assist students in activating and deploying information, that mediate the methods and modes of transforming that information into knowledge, have been at the heart of sound pedagogic praxis. Having the right equipment – that helps open up pathways for student activity, assists in the processing and mobilisation of ideas, and connects those ideas with the contexts that surround them – forms the basis of the teaching and learning environment. As such, this education—technology relationship has been spotlighted as part of education policy and practice critique. Complaints about falling education standards, unemployable students, redundant curricula and backward institutional organisation, have therefore been punctuated by the debates about the role and place of technologies in the classrooms. By technology we refer to more than computing – technologies extend the human body, from pens to eye glasses to clothes.

However, it is the arrival of computers, the internet and the digital age which has really accelerated these arguments, with politicians promising to “put a computer in every child’s hands” (Roediger & Pyc, 2012, p. 242) and to network schools in order to produce ever better learning outcomes. Indeed, the ubiquity of computers, the internet and digital forms of communication have now made their integration into the classroom mandatory. From smartboards to learning management systems such as Blackboard, to PowerPoint and Facebook groups, technology has often been championed – with limited criticism – as the saving grace of (perceived) old and redundant modes of didactic education that apparently disempower students. These technologies are seen to be transformative for students, inclusive, interactive and valuable, therefore making teaching easier and learning simpler. They are coded to centralise the student in the learning process instead of the teacher, therefore enabling greater flexibility in learning styles and engaging student attention through multimedia delivery of materials.

These are all noble outcomes. However, the deployment and activation of ‘technology’ has, to date, been largely unchallenged despite the fact that it is often at the expense of the considerations of literacy and effective pedagogy – it is as if the presence of a computer is all that is necessary to produce digitally aware and active students. Tara Brabazon (2002) famously recounts the narrative of New York University that was forced to close its online learning arm after “pumping \$25 million into the offerings – courses that only attracted 500 students at its height” (p. 32). Of course, many things have changed since the time of Brabazon’s writing and online delivery has become a significant part of many universities’ offerings. Yet, her caution remains an important one – the excitement over new technologies must be tempered with the needs and concerns of teaching and learning, particularly with regard to how literacy is woven through these concerns. Too often and too easily ‘new’ technology is hailed as the saviour for modern education without due consideration or critique – this caution must therefore also be applied to the IoT.

This report aims to focus on such matters, specifically the potential impact of the IoT for students with disability at university. As such, this report aims to generate considered and weighted examination of the role of this emerging technology in the lives of students with disability as they move into and through higher education contexts. While medical models of disability revel in the potential for technologies to supplant or mask disability entirely, there is an equal celebration of the potential for these technologies to offer not just methods for moving through everyday life but to also enhance these interactions. The figure of the cyborg is prevalent in these imaginings, punctuated by the figure of the disabled athlete whose implants and attachments render them ‘superhuman’. That is, we can use technology to make the human fit the environment, and even transcend it.

However, this tendency to see technology as an unequivocal benefit to disabled people’s lives does not situate the terrain of our examination. Instead, we offer a deeper consideration

of how the complexities of technology are integrated into contexts and embodied realities. For example, while the IoT is easily framed as a new and radically nuanced technology that redefines accessibility, an equally decided consideration of the wider significance of the relationships between technology and society, education and disability, access and literacy, also needs circulation. Indeed, the IoT can be configured as a champion of and for the social model – where environments can be changed and modified to suit different disabilities – the technology to establish an effective and reflexive IoT infrastructure is not yet at a point where it could be effectively deployed in learning and teaching at the university level. Further, its relationship to educational interests and outcomes is also currently largely a theoretical consideration rather than a practical reality.

The Internet of Things: Literature Review

History

The Internet of Things (IoT) is a phrase widely considered to have been coined by Kevin Ashton at the end of the twentieth century (Mitew, 2014, p. 5):

As a term, the Internet of Things originated in 1999, with the work of two Massachusetts Institute of Technology [MIT] research labs: the Auto-ID Center and the MIT Media Lab. Kevin Ashton and Neil Gershenfeld respectively argued for the enfolding of things into the internet in an active role – either in terms of making the world comprehensible for things, or adding things to the internet. In this context, the IoT was seen as a paradigmatic shift from the internet of discrete desktop/mobile computers, to a broadly defined ambient connectivity permeating trivial material artefacts, therefore granting them agency visible to humans.

Ashton, writing in 2009, framed its potential as a system that might assist humans in processing massive amounts of data (Ashton, 2009, para. 2):

Today computers, and therefore the Internet, are nearly wholly dependent on humans for information ... The problem is, people have limited time and accuracy, all of which means they are not very good at capturing data about things in the real world. And that's a big deal.

Such a claim is born out of the rapid expansion of the internet. In addition, the potential embedded in the massive amounts of data found online and the development of more nuanced processing of data for effective decision-making in our ever-complicated lives promotes such ideas. According to Ashton (2009), making informed choices in all areas of our lives – from how much exercise to do to who to vote for – must be born out of a data-mined cache of information that can account for and rationalise specific outcomes and consequences. For Ashton, this is a matter of developing a system that might help us process this data – masking the possibilities of emotion and instinct and instead reifying enlightenment and scientific rationalist approaches. Importantly, for Ashton, humans are flawed – they thereby compromise their role in data entry for our massive networked systems and this therefore means that our machines are also flawed. He argues that machines are better at objectively capturing information about the real world and that harnessing that potential can assist us in making better decisions. In the same article, Ashton (2009, para. 5) affirms “we need to empower computers with their own means of gathering information, so they can see, hear and smell the world for themselves, in all its random glory”.

Yet, for some, this vision reveals all the potential possibilities and problems with how we relate to machines in our everyday lives. In such terms, “the resulting dynamic can be described as a de-centering of humans from the position of sole enunciators of agency, with serious implications for conceptualisations of sociability, agency, and identity” (Mitew, 2014, p. 9). These imaginings are polarised – we have visions of the fictional artificial intelligence (AI) of Skynet punctuating the prose. Instead, we argue that Ashton’s vision is far too technologically determinist and rudimentary to account for the complex relationships between humans and machines. Machines require discipline from humans, yet we must also adopt and adapt to the needs of mechanisation.

For example, during industrialism, machines demanded repetitive embodied labour. The luddites who emerged at this time to beat-up machines “were not against machines per se, or technological progress” they were worried about the impact these machines – as well as the processes that integrated them into contemporary workplaces – were going to have on

“their way of life and mechanisms of solidarity and workmanship nurtured over generations” (Standing, 2016, p. 18). They were – rightly – worried about the ways in which the machines changed embodied and emotional connections and actions. In more modern times, until recently – and even still – we situated ourselves in front of the computer in a static location and enact a series of learned actions involving the keyboard and mouse. For years we have stopped conversations with real humans to answer the ring tone from our phones in our homes – today we do so wherever we may be. Indeed, as the ability to miniaturise has exploded in electronics, the arrival of mobile phones and its evolution into a ‘smart’ device perpetuates the perception – correct or not – that machines are adapting to us.

Importantly, however, the IoT involves a fundamental reconfiguration of those relationships, and offers potential for the streamlining of experiences in the everyday. It is an early glimpse into the potential for machines to listen to, engage with and connect humans. However, in order to interface with us, a whole range of controversies – involving privacy, security and potential Skynet fears – need to be addressed. Understanding the IoT as it is emerging is therefore vital as it assists in thinking through the potentials for integration so that, rather than retrofitting fixes into flawed paradigms, skilled and reflexive IoT contexts can be engineered upfront to offer accessible and inclusive infrastructures for all students, including those with disabilities.

The etymology of the word ‘things’ is important in this context. In old English, ‘thing’ means assembly, but is commonly deployed now to mean an object or “that which is considered to exist” (see www.etymonline.com/word/thing). In this context, the Internet of ‘Things’ is deployed in both these means. Firstly to enable the range of devices, objects and items that can be networked in this specific way – allowing them to be as wide as possible to leave space open for an evolving and changing terrain – and secondly to mobilise the ways in which these items might ‘meet’, that is assemble or talk to each other. It also enables a reimagining of the range and scope of the internet as that which moves out of an implicit cyberspace and virtual imagining to be situated in real life and to involve concrete objects beyond the computer. These include not just mobile phones, but also refrigerators, thermostats, pace-makers, toasters and lighting systems.

An early and perhaps the most well-known deployment of an IoT device was LG’s Digital DIOS Refrigerator released in 2000. It featured a built-in web browser and e-mail capability that could detect when groceries needed replacing and could then order them for the consumer online. Of course, this was a widely ineffective and impractical device and was not successfully sold on any meaningful scale. Its US\$20,000 price tag meant that in Australia one company, Winning Appliances, only sold 10 or 15 (Baxter, 2010). There were myriad problems – in most regions the fridge required dial-up internet connectivity and as such would tie up the telephone line. This, in turn, meant that if people wanted to use the web or check their e-mail they would be forced to use the built-in features on the refrigerator, and the primitive interface made it uncomfortable for people to use such features while standing in their kitchen. Furthermore, the refrigerator required the user to manually enter the locations for each object so it knew which products were present or missing and, even if the refrigerator was successful in detecting the absence of a product, at that time there were few online grocery stores in existence that could automatically order a replacement.

This early-adopter fridge serves as an early example of the ways in which ordinary items could be connected and networked, digitised and dialogued with the internet. Nevertheless, it is important to remember that these early attempts were largely linear, meaning that they involved a single device connecting to the internet infrastructure and operating much like a computer. Today the IoT is a vision of networked objects that utilise digital infrastructures to offer a range of complex interactions and possibilities. Accordingly, “an IoT object has a unique identity and is capable of dynamically engaging with, and registering change to its location and state” (Mitew, 2014, p. 5).

Definition

The IoT “is not a single technology; rather it is an agglomeration of various technologies that work together in tandem” (Sethi & Sarangi, 2017, p. 1). A more formal definition positioned by the International Telecommunications Union defines it as “enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies” (International Telecommunications Union, 2012, para. 3). Mitew (2014, p.5) clarifies the parameters in more detail:

... the IoT stands for the connection of usually trivial material objects to the internet – ranging from tooth brushes to shoes or umbrellas. At the very least, this connectivity allows things to broadcast sensory data remotely, in the process augmenting material settings with ambient data capture and processing capabilities. Once connected, each thing acquires a network address making it uniquely identifiable. The object usually has some sort of layered sensing capacity allowing it to dynamically register changes to its environment and transmit that information over the internet.

Accordingly, there are four essential characteristics for a device to be considered a ‘thing’ in IoT terms (Palma, Agudo, Sánchez, & Macías, 2014, p. 7000):

- 1. The device must be capable of collecting and transmitting data: IoT devices need to exist in environments in which information can be collected and either sent to another device or directly to the Internet.*
- 2. The device must have the ability to operate with action-based responses: IoT devices can be programmed to act according to particular conditions.*
- 3. The device must have the ability to receive information: IoT devices must be able to receive information from the network.*
- 4. The device must be able to support communication: IoT devices by nature belong to a network of devices that can communicate with each other through other nodes in the same network.*

In essence, the IoT is made up of three ‘layers’. The first is the so-called physical layer in which RFID (radio frequency identification) tags, sensors – both connected and wireless – and actuators are used. The devices in this layer operate in physical space to gather data and act on and through the environment. The second layer is the network layer – this is made up of small cellular networks and local area networks (LAN) as well as the much larger cloud computing storage network. In order for these benefits to manifest, IoT systems need to enter into a common communications protocol via middleware –software that enables the communication and management of data – so that interpretation of the data can occur and be deployed within IoT applications. When this middleware is activated, the data becomes useful to humans and consumer goods are imbued with new meaning. This then forms part of the final layer, the application layer, which comprises the apps or digital communication technology we ‘see’, examples include Alexa, Google Home and Fitbit. Put together with the other layers, this enables machines to interact with their environment and ‘talk’ to other machines as well as humans. In this process, they enact the data gathering and processing that Ashton (2009) foregrounded and transmit that information to other machines and to humans, usually via a smart device. Humans are then able to take that information and make decisions in their everyday lives, or automate particular areas of their lives so that decisions do *not* have to be made.

We will consider first the physical layer and its gathering data devices of RFID tags, sensors and actuators. RFID tags were invented in the 1970s and were initially used to track cattle and other large items. They are “a small microchip attached to an antenna” (Atzori, Iera, & Morabito, 2010, p. 2790) that have a unique identifier and they are simply used to track a

thing to its location in space. As the name indicates, this device uses radio waves to communicate and are low-tech. RFID tags are mostly passive in that they are only activated within the presence of a scanner or reader to register the item – the power of the reader is used to power the tag. Increasingly, however, the reader or scanner does not need to be in proximity. Instead, the tag harvests energy from the radio frequency waves emitted from the reader and antenna. As such, passive RFID tags do not have their own internal power supply, meaning they are cheap and long-lasting.

However, more recently, active RFID tags – more commonly known as beacons and transponders – have entered the market. These upgraded tags have an onboard battery and are being used to facilitate the transmission of data, not just about the location of an object but also other complex details such as temperature and movement. According to Atzori et al. (2010, p. 2790):

... key components of the IoT will be RFID systems, which are composed of one or more reader(s) and several RFID tags. Tags are characterized by a unique identifier and are applied to objects (even persons or animals). Readers trigger the tag transmission by generating an appropriate signal, which represents a query for the possible presence of tags in the surrounding area and for the reception of their IDs. Accordingly, RFID systems can be used to monitor objects in real-time, without the need of being in line-of-sight; this allows for mapping the real world into the virtual world. Therefore, they can be used in an incredibly wide range of application scenarios, spanning from logistics to e-health and security.

Sensors are also old technologies that are used in most daily objects, from computers to smartphones to toasters. Sensors detect changes in the environment and turns that into an electrical impulse that can be interpreted. For example, the first pop-up toaster was invented by Charles Strite in 1919 using a mechanical timer. However, since the 1930s these toasters have operated using a thermal sensor that detects the heat of the bread and triggers the release mechanism to pop the toast away from the heating elements. They have a variety of different uses and can, for example, be acoustic, chemical or electrical. The modern day smartphone has a number of sensors, including an accelerometer, ambient light sensor, GPS sensor, compass, proximity sensor, pressure sensor, gyroscope and magnetometer. All of these works to deliver the core experience that we have come to expect from our smart devices – offering real-time information based on our immediate needs.

Applying the benefits of both sensors and RFIDs to the new IoT technology, sensor networks will “cooperate with RFID systems to better track the status of things, i.e. their location, temperature, movements, etc. As such they can augment the awareness of a certain environment and, thus, act as a further bridge between physical and digital world” (Atzori et al., 2010 p. 2790). So, while the sensor will gather data, the RFID system and wireless sensor networks will enable the transmission of that information to other devices or into the cloud through the deployment of middleware – this leads us to the second layer of IoT, the network layer.

The network layer of the IoT is made up of two elements – perception nodes and perception networks. Examples of perception nodes are RFID tags and near field communication (NFC) which are short-range, low-power communication technologies; Bluetooth, Zigbee and WiFi are medium-range. However, RFID is championed as the defining perception node element in the IoT because of its low cost, ubiquity, simplicity and long life. The benefit of RFID is that passive tags lay dormant until read. RFID is also easily integrated into wireless sensor networks which gives it greater flexibility to communicate with a variety of devices and potentially over a wider area.

In addition, RFID’s integration with wireless sensor networks enables its frequency to expand and cover more territory. However, there exists one core problem in the IoT – standardisation. That is, the variety of devices brought together in the IoT poses a problem

for interoperability – as an example, RFID frequencies in the US are not compatible with those in Europe. Middleware software is therefore used to “hide the details of the smart things ... [and] act as a software bridge between the things and the applications”. In other words, “the middleware abstracts the hardware and provides an Application Programming Interface (API) for communication, data management, computation, security, and privacy” (Sethi & Sarangi, 2017, p. 15). This enables different devices with different protocols to ‘talk’ to each other. This is essential for the cloud computing networks that enable the IoT data to be harvested, archived, processed and interpreted. Indeed, the massive amounts of data potentially produced by wireless sensor networks and RFID tags will need to be stored for processing and archiving. It is as a result of this processing and interpretation that information is sent to applications, the third and final layer of the IoT.

This layer is where the full potential of the IoT is realised – when environmental changes can happen as a result of contextually aware technology that automates delivery of real-time data and actions into that environment. For example, “A sophisticated example of an actuator used in IoT is a digital finger, which is used to turn on/off the switches (or anything which requires small motion) and is controlled wirelessly” (Sethi & Sarangi, 2017, p. 9). Indeed, [this is where the true benefits of IoT really come to fruition.

Benefits

For people with disabilities who face daily barriers to accessibility in both physical and virtual environments, the IoT offers a method for potentially removing these obstructions. The ways in which this can occur are almost endless (see Borne, 2014 and Table 1 for some examples) and is in the application layer that new imaginings around smart cities, smart homes, smart transport, smart health come to fruition. However, the two methods we highlight in this report relate to its use mainly in an educational setting, namely the use of smart devices and systems such as digital assistants and the establishment of a more inclusive, ‘smart’ campus. However, issues of security and privacy remain and this will also be discussed.

Table 1: Some benefits of the IoT

BENEFIT	EXAMPLE	SOURCE
Tracking behaviour for real-time marketing	If our IoT-enabled devices determined it was raining in our current GPS location, advertisements relating to umbrellas and information on the nearest store could be provided so that we could respond to the situation in real-time.	
Enhanced situational awareness	Features such as updates on traffic based on movement and GPS sensors in cars and smartphones could provide an opportunity to understand our changing real-time environment and make changes such as taking a different route home from work where there is less traffic.	
Sensor-driven decision analytics	Big data could record lots of information at once which can then be analysed, such as information collected from telescopes analysing space phenomenon.	Lenz, Meisen, Pomp, & Jeschke (2016)
Process optimisation	The use of sensors could monitor the speech rhythm, pitch and tone of a lecturer to determine the optimal requirement for student engagement.	Heng, Yi, & Zhong (2011)
Optimised resource consumption	An electrical appliance could complete a task, such as washing clothes, based on its ability to determine the optimal point at which the power and water costs are cheapest.	
Instantaneous control and response in complex autonomous systems	A series of sensors could monitor different aspects of a patient in a hospital, adjusting medication and treatment in real-time.	Loke (2017)

Smart Systems

The surge in the popularity and uptake of IoT applications that has occurred in 2016 and 2017 can be accounted for in a variety of ways. The first is the decreasing size of RFID tags that enables miniaturisation of everyday products. In addition, by 2010 the cost of RFID tags had declined – passive RFID tags cost between 5 cents and \$5 while active ones range from \$50-100, with readers being much more expensive. Further, the reliability of the performance of the tags has improved, possibly related to the widespread integration of RFID into US military distribution and logistics infrastructure by 2004 (Mitew, 2014). Finally, the development of a stable international standard around ultra-high frequency (UHF) passive RFID tags has also increased its reliability and use. As of 2016, 81 countries had conformed to the standards (see GS1, 2016 for more details on how these are applied).

At the 2016 Consumer Electronics Show (CES), the world's largest consumer technology event held annually in Las Vegas, major manufacturers – including Samsung, LG and Amazon – were actively creating products for the IoT space including smart washing machines, smart lighting and even the return of the smart refrigerator. By just the following year, at CES 2017 the catchphrase of the conference was 'Alexa everywhere', a reference to Amazon's digital assistant being built into a range of connected devices including cars, lamps, ceiling fans and security systems (Kastrenakes, 2017). In addition, the first popular consumer standalone smart speaker, Amazon Echo, also features Alexa technology. Alongside Google Home, which entered the market in 2016, this has significantly contributed to a rapid rise in IoT popularity – currently Amazon Echo retains 74% of the market, with Google Home reaching 24% (Darrow, 2017). Apple Homepod will make its debut in 2018. These applications are set to be very popular as they launch in Australia – not only are they relatively affordable, they also feature a conversational user interface that enables easy use and non-threatening integration into an already existing digital literacy.

Yet digital assistants are not new. Handheld computers – also known as personal digital assistants or PDAs – have been around since the 1980s, although they have largely been discontinued due to the ubiquity of the mobile phone that performs the same duties but with added extras. The most well-known of these were the Palm Pilot and the Pocket PC – both were used extensively in health and education settings. They featured either a conventional keyboard input or touch screen to allow easy input and retrieval of information. In education, PDAs were unevenly beneficial and were mainly “considered as a tool to support learning and teaching practice rather than as an instructional material for pedagogical purpose” (Park, Kim, Lee, Son, & Lee, 2005, p. 174).

Importantly, however, they were singled out as particularly useful to students with disabilities. Early studies demonstrated that “students with identified special needs were the strongest users of the handhelds, consistently indicating daily use and preference for handhelds” (Bauer & Ulrich, 2002, p. 20). Particularly noted in one study was the function of the PDA as an unobtrusive device so that the student did not feel that they ‘stood out’ amongst their peers, an important benefit to students who do not wish to identify as disabled. Certainly, the current ubiquity of the smartphone offers the same unobtrusive presence within the classroom for some students with disabilities. However, the importance of the widespread commercial arrival of digital assistants such as the Amazon Echo and Google Home – as home devices – facilitates the wider normalisation of this type of assistance. Its “ideal user interface design” is blurring the barriers so that there is “nothing appearing to mediate between the will of the user and the result delivered by the operations of the machine” (Burgess, Mitchell, & Highfield, 2017, p. 2).

The digital assistants outlined above show how complex IoT architecture nodes are beginning to intersect and interact in intelligent and contextually aware ways. This potential is also being expanded beyond the home and activated in policy and planning initiatives around smart cities, smart transport and, in education, the smart campus.

Smart Campus

The potential to create environments of responsiveness and command via tracking, data collection, communication and interaction can be seen in the rise in attention – from media, legislators, managers, urban planners and CEOs – on the increasingly common usage of the word ‘smart’ as a prefix. Used in its meaning of clever, smart is attached to a variety of nouns to convey intelligent interactions between devices, the internet and applications and environments. Beginning with smart bombs to make the waging of war more palatable, we now have the more sedate and seductive smart transport, smart cities, smart devices, smartphones, smart health. The convergence of the definitions of smart and intelligent is also a blurring of automation and AI – the lines between these ideas are constantly being stretched as well as pushed together. That is, in the IoT, automation is being championed in the hopes of leading to a form of AI that is not just assistive but also transformative. Atzori et al. (2010, p. 2789) hold this vision for smart items as creating intelligent environments:

Smart Items. These are a sort of sensors not only equipped with usual wireless communication, memory and elaboration capabilities, but also with new potentials. Autonomous and proactive behaviour, context awareness, collaborative communications and elaboration are just some required capabilities.

It is this imagining of a fully reflexive and responsive AI future of devices, that is, products that accommodate our needs and wants, that percolates through the ubiquity of the word smart in our lexicon. For example, for universities, the notion of a smart campus is increasingly an important marketing point.

In 2016 Curtin University launched its vision for 2030 which frames the development of the campus as a ‘City of Innovation’ as part of its ‘Greater Curtin’ branding. For students, the strategic objectives include delivering “a seamless, responsive and innovative digital environment” (Curtin University, 2017d, para. 2) to facilitate their study and generate energy into their expectations of future employability. In the master plan, the development and refurbishment of buildings is framed by language conveying “high-speed wifi and learning spaces featuring rich AV [audio-visual] systems to provide an engaging and immersive student experience” – Building 501 is highlighted as a future example of this (Curtin University, 2017b). Building 215 (Figure 1) is also singled out as a ‘living laboratory’ which “gives students an environment in which to explore real life engineering theory by examining a static building” (Curtin University, 2017a, para. 1). This building features the ability for students to “monitor live system data on the building’s interface, temperature, humidity, thermal efficiency, air and cooling/heating water pressure dynamics” Curtin University, 2017a, 2017, para. 4).

This Teaching and Learning strategy is paired with the wider ‘Smart Campus Vision’ which seeks to implement an IoT infrastructure to gather data on student movement and attendance to “provide analytics that support a smart campus” (Curtin University, 2017c, para. 6). For example, facial recognition has already been used in big data collection on campus (Bindi, 2017). These approaches connect with the wider educational perspectives that champion the role of technology in enhancing student experience and learning.

Along with the emphasis on the prefix smart, the shorter ‘i’ prefix also predominates these debates – the iCities and the iCampus concept is equally powerful in conveying the digital significance of networked environments for greater learning. Thomas et al. (2013, p. 6) affirms the importance of the iCampus as a strategic network of relationships that is flexible enough to deliver a variety of outcomes for students, administrators and instructors:



Figure 1: Building 215 Curtin University (Curtin University, 2017a)

The purpose of the iCampus is not just to enhance interactivity in education, but to create a campus made up of appropriately intelligent computer-systems. Those systems must therefore understand the individual contexts of individual students, as well as having an intelligent understanding of the environments in which they study.

The authors make a subtle distinction between ‘smart’ and ‘intelligent’ to justify the ‘i’ prefix, affirming the need for (Thomas et al., 2013, p. 6):

... flexible, media-rich and remote learning... That requires significant investment in sensor networks, mobile technologies and associated data processing, but with equally significant pay back in terms of connectivity between learning, research and the surrounding environments within which students live.

For students with disability, these technological interventions open the possibilities offered by a nuanced, integrated and subtle ‘personalisation’ of education beyond clichés. This type of personalisation is not about comfort and ease but rather about effective, timely and appropriate access to learning infrastructures, materials and personnel – as well as information, knowledge and its deployment as expertise within the parameters of need defined by an individual in their relationship to their disability. The integration of an effective and operational smart campus therefore offers an environment where these types of interaction are normalised (Kiryakova, Yordanova, & Angelova 2017, p. 83):

The smart devices for remote control of home equipment, parking, which can be activated and managed by touch, gestures or voice, sensor indicators for orientation, text-to-speech modules, Radio-frequency Identification (RFI) and others, can be used for creating a learning environment for learners with special educational needs.

These environments hold the potential for the creation of “unique learning contexts” (Thomas et al., 2013, p. 6) that can service the individualised needs of students with disability. Perhaps most importantly, these are not prescribed or defined by those with little or limited understanding of how the management of a student’s disability interfaces with their educational needs and outcomes. Instead, the environment is sensitive and responsive to all users – it can modify, alter, enhance or change depending on need.

Risks

Privacy and Security

However, while the initiatives outlined above are framed as a benefit to students – by optimising the delivery of educational product, enhanced learning experiences and timely management of campus infrastructure – it belies the deeply troubling concerns with privacy and security that percolate through the IoT debate. That is, while there is much cheerleading for the possibilities offered by “anywhere-anytime-study” (Thomas et al., p. 6), interoperability and optimisation – situated by “connected devices transform[ing] learning from passive to active” (Kiryakova et al., 2017, p. 82) and by the attendant emerging reality that “individuals entering in an area where a sensor network is deployed cannot control what information is being collected about themselves” (Atzori et al., 2010, p. 2802) – is often masked in this debate. Indeed, while RFID tags have been widely championed as revolutionising our technological world, in their book *Spychips: How major corporations and government plan to track your every move with RFID*, Katherine Albrecht and Liz McIntyre (2005) are more disparaging. They argue that because of their small size, ability to transmit their data without a ‘line-of sight’ scan, and their increasing ubiquity, RFID tags – and the IoT by implication – form the most serious threat to our privacy in the modern era. These tags can be integrated into almost anything without any obvious indication that an object might contain such as device. As a result, consumers – or students – may not know that information about them is being tracked and registered. The tags also broadcast their data or information whenever they come in contact with a signal, the radio waves from a reader – this means that a tag can be accessed and read without the knowledge of the individual in possession of the object that contains the tag. So, while some have explained their use as a data collection tool similar to that of barcodes, in this aspect this is not the case – barcodes require a line-of-sight scan by a device in order to be read, whereas RFID can also be scanned or read through walls, doors and other obstructions. Atzori et al. characterise RFID’s relationship to the IoT and the potential security problems in more detail:

The IoT is extremely vulnerable to attacks for several reasons. First, often its components spend most of the time unattended; and thus, it is easy to physically attack them. Second, most of the communications are wireless, which makes eavesdropping extremely simple. Finally, most of the IoT components are characterized by low capabilities in terms of both energy and computing resources (this is especially the case for passive components) and thus, they cannot implement complex schemes supporting security. (Atzori et al., 2010 p. 2801)

Atzori et al. (2010) also demonstrate that security and privacy issues are irrevocably intertwined. Not only is the ability to secure the IoT – despite authentication and passwords, encryption and data management – extremely difficult, it is actually counter-intuitive to the intentions and expectations of the system that promotes the free movement and accessibility of data in real-time. Indeed, free and accelerated sharing, communication, transmission and interaction are core tropes of the IoT. However, these needs of mobility and timeliness, along with the advocacy of context-aware technology that is embedded in the IoT construct, means that privacy – the ability to control who knows what about us when – is extremely compromised. Indeed, these low-tech, highly mobile constructs of the IoT can lead to extraordinarily invasive conditions of surveillance where “unseen by users, embedded RFID

tags in our personal devices, clothes, and groceries can unknowingly be triggered to reply with their ID and other information” (Atzori et al., 2010, p. 2793). These circumstances create situations where individuals are being monitored and transmitted in time and space – information such as where they are, where they have been, how much time they spent in a location are just a few examples. Our prior research shows that people with disability are particularly resistant to intensive monitoring of this kind (see Ellis, Kent, Locke, Hollier, & Denney, 2017).

All of this over-vigilance can lead to consumer outrage and protest. Such was the case in 2003 when Italian clothing company Benetton revealed they intended to tag an entire line of their clothes at more than 5000 stores globally, involving 15 million chips (Violino, 2003). While Benetton eventually reneged on the idea after the ‘I’d rather go naked’ campaign launched by CASPIAN (Consumers Against Supermarket Privacy Invasion and Numbering) drew public spotlight to the plan, the company still received widespread criticism. However, other companies have not been deterred and, with less fanfare, have slipped RFID tags into their inventory. Gillette had already purchased 500 million tags in 2003. In 2004 Wal-Mart and Abercrombie and Fitch utilised RFID in their logistics, the latter following Benetton’s idea but instead placing the tags in all their items instead of just one collection.

Yet this does not mean that no attempts have been made to counter these issues. As early as 2001 a US patent application was lodged for a device which addressed the privacy and security issues involved in RFID tracking. It claimed that “the widespread use of RFID tags on merchandise such as clothing would make it possible for the locations of people, animals, and objects to be tracked on a global scale – a privacy invasion of Orwellian proportions” (Hind, Matthewson, & Peters, 2002, para. 0011). Tellingly, however, commercial interests always seem to win – just 3 months later the same team lodged another patent to identify and track persons using RFID-tagged items in store environments. Indeed, over the years, it appears as though the widespread – and socially and commercially accepted – potential of RFID has masked or silenced much of the anxiety about its possible privacy problems.

This lack of concern is in part due to the perceived benefit of – and trust in – the middleware used in the IoT. This software is tasked with solving security problems and therefore “must include functions related to the management of the trust, privacy and security of all the exchanged data” (Atzori et al., 2010 p. 2793). Yet exactly how middleware will achieve this has been the subject of much speculation. The general consensus appears to be that middleware must solve a problem specific to the IoT as “traditional security countermeasures and privacy enforcement cannot be directly applied to IoT technologies due to their limited computing power” (Sicari, Rizzardi, Grieco, & Coen-Porisini, 2015 p. 146). Importantly, middleware must also be able to provide security at all three major layers of the IoT network – the perception layer (RFID tags), the network layer (wireless networks) and application layer (devices).

However, the context-aware nature of the IoT means that devices are constantly gathering and distributing personal information – ranging from a person’s location, to their purchase preferences, to the ambient temperature of their living environment or even the serial number of their pacemaker. Thus, any security system must address the issues of “authentication, confidentiality, and access control” to offer a secure and robust privacy paradigm (Sicari et al., 2015, p. 148). The heterogeneous nature of the IoT network also means that different devices with different protocols must be able to talk to each other with a common security protocol that is able to maintain “anonymity, trustworthiness and attack-resistance” (Sicari et al., 2015, p. 148). These difficulties mean that “Most existing middlewares’ authentication-based partial security solutions are insufficient for a number of IoT applications” (Razzaque, Milojevic-Jeric, Palade, & Clarke, 2006, p. 90), thereby demonstrating how difficult it is to provide viable and functional security protocols to ensure complete privacy protection throughout the IoT.

While these concerns are significant, they do not, however, seem to dampen enthusiasm for the IoT. This confidence – or at the very least lack of care – can be due to the complexities with how consumers and citizens view the relationships between information, technology, trust, privacy and power. We are at once increasingly sceptical and more liberal with our expectations of privacy. Indeed, particularly since the 9/11 terror attacks in 2001 there has been a widespread shift in the expectations of citizens in the US, and increasingly Europe, Australia and New Zealand, that personal freedoms must be curtailed to safeguard against terrorism. For example, the implementation of the Patriot Act in the US (with Patriot standing for Providing Appropriate Tools Required to Intercept and Obstruct Terrorism) in the aftermath of these attacks integrated a number of incursions and sweeping changes into personal privacy, including the ability of law enforcement agencies to search an individual's home without notice and without informing that individual (Rubel, 2007). This 'status quo' in privacy went unchecked and unconsidered for a number of years. However, in 2013 Edward Snowden's leaks involving the National Security Agency (NSA) and PRISM – the code name for the NSA body which collects internet-based communications and carries out covert surveillance against American citizens – offered a correction in public attitudes towards privacy. Nevertheless, with ongoing violence, particularly in Europe, involving Islamic State, the need to 'empower' police and anti-terrorist organisations remains a powerful trope in the public imagination.

Furthermore, the role of social media has blurred expectations of privacy – users of Facebook for example utilise the platform to share personal information to both friends and strangers despite its long history of poor privacy protections. In 2005 users' passwords were being sent across the web without encryption. According to Debatin, Lovejoy, Horn, & Hughes (2009):

Even the most lauded privacy feature of Facebook, the ability to restrict one's profile to be viewed by friends only, failed for the first 3 years of its existence: Information posted on restricted profiles showed up in searches unless a user chose to opt-out his or her profile from searches. This glitch was fixed in late June 2007, but only after a technology blogger made the loophole public and contacted Facebook.

However, despite this, Facebook has often only made adjustments or introduced protocols when users have outraged en masse. Therefore, with governments seemingly regularly invading the privacy of citizens, and with corporate capitalism insinuating itself as the dominant means by which we relate to each other and world, people now seem to be more willing to put their faith in corporations to protect their privacy. The attractions of the IoT – the interaction with real-time data and delivery of information, contextually aware systems meeting spoken and unspoken demands, personalisation of environments and control over micro-experiences – offers up privacy as the terrain upon which a struggle over self and security take place. Indeed, the IoT is positioned in the space where the circulation of personal information is required for the system to effectively operate – the desire to have personal information known, tracked, logged and interpreted is the core trope of the IoT. Ensuring that information is not being transmitted to an unsanctioned third party – either human or machine – is therefore a core tension within the IoT architecture.

For example, Thingful is a search engine for the IoT (<https://www.thingful.net/>) which offers an interface to search for and locate any IoT device in the world. It assures users that "Our mission is to enable an interoperable Internet of Things, in which connected objects find and use each other's data with the active consent of their owners" (Thingful, 2017a, para. 1). However, it is not made clear how this active consent is obtained, except that users/owners are invited to input or register a device. Further, in a video presentation at the ODI (Open Data Institute) Summit in London in 2015, founding partner of Thingful Usman Haque made rather opaque claims about the nature of the search engine and the way data is managed (Open Data Institute, 2015):

We've worked out how to enable the data owners to retain total control of their data but still make it discoverable and for data clients to access that data on-the-fly in the easiest way while still getting that data directly from source.

It is therefore unclear how Thingful protects the privacy of the owners of the IoT data and how it enables such timely searching and utilisation of data. For example, the framing discourses of open data seem to advance an approach to free access to information, yet a significant push of their project appears to be potentially monetising the IoT. Adding to this, on a blog post from the BIG IoT Project – a scheme that pushes for increasing ecosystem interoperability between devices – Thingful is defined as the future for IoT delivery (Thingful, 2017b, para. 2):

The cash breakeven on the investment will require sustained subscription and growth of subscriber base and potential monetisation paths outside the traditional customer base. This is where a truly interoperable IoT holds its power and promise.

There is no doubt that the BIG IoT project has projects that are innovative and transformative, yet there appears to be little debate about the wider consequences of the outcomes of the IoT except to focus on its benefits. For example, in Germany a BIG IoT project is summarised thus (Big IoT, 2017):

[a] Northern Germany Pilot [of] the BIG IoT technology is tested in the cities of Berlin and Wolfsburg and the transregional corridor connecting the two cities. The Northern Germany pilot puts focus on key topics of future-oriented mobility targeting on an optimized usage of Public Transport, E-mobility, Smart Parking solutions and multimodal routing information for the cities and the corridor. In Wolfsburg we are incorporating a city-wide WLAN network, live tracking of public buses, as well as public e-charging stations. Further, we are doing real time crowd management by using existing security cameras and crowd-sourced detection of human crowds through mobile apps. Berlin city-wide real time information on traffic volumes and traffic speed, real time parking data, data on available charging stations and bike sharing data are integrated. Also, Siemens' novel, streetlight-mounted and radar-based smart parking detectors are integrated. In addition, incident news for public and private transport and traffic news provided via on-street information panels are integrated.

Importantly, however, what is not overtly acknowledged by the authors of Thingful nor the BIG IoT Project, is the potential problems associated with this level of surveillance and its potential for abuse, not just by its everyday users but by criminals and by governments and other authorities. That is, the increasing tendency for governments, councils and law enforcement to use CCTV and geolocation in crime fighting opens up an entirely complex terrain for debate that is being masked in the rush to the IoT. In 2011 for example, there were a number of interactive online maps that tracked the evolution of the London riots (Benedetti, 2011). This may be an important resource for ensuring the safety of citizens and the correct enforcement of the law against perpetrators of violence and harm, but it may also open up potential abuse of this system and unjust persecution of particular groups and individuals in a society. Indeed, while security and privacy concerns such as this pepper the literature involving the IoT, there appears to be little right now that is actually operationally sound within the architecture and, as such, organisations continue to push the boundaries of what information they gather in the name of service provision and marketing (Crawford & Schultz, 2014, p. 94):

... in 2012, a well-publicized New York Times article revealed that the retail chain Target had used data mining techniques to predict which female customers were pregnant, even if they had not yet announced it publicly. This activity resulted in the unauthorized disclosure of personal information to marketers.

In this example, big data gathering was used to extrapolate information about individuals based on their online and digital preferences. Even if a person does not reveal any personal information online via social media, their digital behaviour can be used to map a whole range of identity indicators including age, gender, location, interests – this is known as predictive analytics. That information can then be sold to marketing companies and corporations without the consent of those being watched.

The IoT is, essentially, a massive big data gathering tool. When one considers that popular IoT interfaces like Amazon Echo are 'on' all the time and therefore potentially 'listening' to all conversations and activity within a particular zone, the consequences for privacy are staggering. While architects and engineers struggle to resolve the inherent security issues, wider debates about the relationship between privacy and access need to be evolving in the public sphere. They particularly need to be engaged in complex spaces like a university campus which contains a gamut of spatial meanings and contradictions that do not always cohere. Further, the obligations that a university as an institution has towards students and staff to protect their wellbeing and their privacy in a space that is both public and semi-private also needs careful consideration. This is particularly important for students with disabilities who may or may not want their disability identified by the university, staff or other students via the data gathered in the IoT.

The Internet of Things and Students with Disability

Background

The World Health Organization states that 15% of people worldwide have a disability. In 2014, 5.8% of students enrolled at an Australian university (Cunninghame, Costello, & Trinidad, 2016, p. 6) identified as having a disability. As students also have the right to *not* identify if they have a disability – any many do not – the number on campus could be significantly higher. Students with disabilities are under-represented in higher education in Australia and have a lower completion rate for their studies than their fellow students. Students avoid identifying mainly due to the public stigma attached to having a disability. In many cases, students can be marginalised and discriminated against not only by other students but also by staff. This may be intentional or unintentional, the latter due to the lack of information and education about disabilities in a university setting. For example, students with disabilities often fear professors singling them out and exposing their disability. Meagan Moses, a studio art undergraduate, says professors have exposed her accommodations to her classmates before. Whether or not the exposure was intentional, she says that students with a disability should follow up with their professors to ensure their accommodations are issued in an appropriate manner. She claims (Moses, cited in Kashar, 2015, para. 6-7):

I had a professor who had never dealt with accommodations before... I needed notes from another student and no other student volunteered, and I was behind on the material for the beginning of the class. Usually, a professor will contact a student directly to be a note taker, but she asked the entire class, and gave the note taker my real email, instead of forwarding me the notes.

This type of inadvertent exposure can make students with disability reticent to fully engage with university infrastructures and cultures. Adding to this difficulty is the often narrow definitions that are applied to ‘disability’. For example, in Australia, the Department of Education categorises students into just six categories – hearing, learning, mobility, vision, medical and other. This last category is too broad and therefore perhaps the least understood. As Mike Kent has demonstrated in his research with the Open University Australia, some 54% of students marked ‘other’ when asked about their type of disability (Kent 2016, p4). While this study looked at students studying fully online, when it was repeated with students studying at Curtin this number was still a notable 49.2% (Table 2). This category almost universally consists of students with a mental illness, intellectual disabilities and acquired brain injuries, indicating that there may be some ambiguity around the ways in which disability is understood and measured. This is particularly notable in table 2 where the students’ survey responses are compared with the statistics from the Curtin Disability Office based on the figures from student’s Curtin action plans (CAP) (Kent, Ellis & Giles 2018).

Table 2: Disability categories, Curtin University and Open University Australia (Kent, Ellis & Giles 2018)

Type of disability/ impairment	Curtin Uni Study		Curtin CAP	OUA Study
	Response percent	Response count	Response percent	Response percent
Hearing	6.1%	7	1.3%	10.2%
Vision	13.2%	15	2.8%	7.2%
Mental illness	43.0%	49	29.2%	44.9%
Learning	26.3%	30	28.6%	8.7%

Type of disability/ impairment	Curtin Uni Study		Curtin CAP	OUA Study
	Response percent	Response count	Response percent	Response percent
Medical	31.6%	36	34.6%	39.2%
Intellectual	4.4%	5	NA	1.8%
Mobility	22.8%	26	3.2%	25.3%
Acquired brain impairment	1.8%	2	NA	4.5%
<i>Answered question:</i>		114		
<i>Skipped question:</i>		11		

The results generated out of this research illustrated the complexity and variance of disability from the students experience. The attraction of the IoT is therefore the potential capacity to deliver service to students in ways that are highly personalised and nuanced to their individual needs and wants. Yet much of the rhetoric surrounding the potential for the IoT is, like the ‘other’ category above, too broad. According to Kiryakova et al. (2017, p. 82), the purpose of the IoT is to “create... a user friendly environment for people with disabilities and help... for their social integration”. That these types of technologically deterministic and condescending narratives still circulate demonstrates that there is much work to be done in configuring the relationship between individualised disability and technology.

Indeed, for students with disability their relationship with technology can be highly complex. In some circumstances, for example for those with severe disability, technology is – literally – a life saver. For others, it facilitates their movement through space, for others their ability to ‘read’ content and access materials. Too often, the medical model is applied to these relationships and technology is used to either mask or enhance. This model depicts disability as in need of correction and utilises technology to alter the human body in cyborgian ways.

The social model instead suggests that disability is created by environmental conditions that are conducive to some body types and not others. That is, people have different bodies and only encounter disability when the built environment creates it. For example, people in wheelchairs can move around just fine, until they meet a set of stairs, so it is the stairs rather than the body that creates disability. This social model argument has been the crux around which disability advocates have been successful at getting accommodations, these include ramps, captions on television and Braille in elevators (Seibers, 2006).

The IoT, as a bridge between physical and virtual worlds, can therefore offer a way to blend both medical and social models together to create a transitional and transgressive approach to disability that is reflexive and nuanced to the needs of the individual. That is, the technological infrastructure of the IoT can create an enhanced environment that utilises digitised interfaces, nodes and devices to impact directly on conditions to create instantaneous and precise accommodations for people with disabilities. To make an interface accessible, disability-specific assistive technology generally needs to be built into the product. Examples of this (Hollier, 2016) include:

- Screen reader: A text-to-speech application that reads out computer and internet-related information to assist people who are blind or vision impaired.
- Screen magnifier: A magnification tool for enlarging screen content.
- Themes: High-contrast themes allow people with visual impairments to change the colours to a more comfortable setting (such as white-on-black), and increase the size of mouse pointers and text.
- On-screen keyboard: Enables people with mobility impairments to ‘type’ by using a pointing device to select letters and words on the screen.
- On-screen alerts: Visual messages can appear in place of audible sounds to help people who are Deaf or hearing impaired.

Using these existing assistive devices alongside the new technology of the IoT could potentially be able to provide an always ready and always present and operational infrastructure and communications protocol for these accessibility processes to perpetually exist in smart devices. IoT in general is already viewed as an assistive technology of benefit for all – for students with disability this benefit is enhanced as it offers an ‘accommodation rich’ learning environment (Kiryakova et al., 2017, p. 80):

The Internet of Things may affect teaching and learning processes, including the approaches of creation of knowledge and its dissemination. The learning process may be directed entirely to the participants’ needs by physically connected devices. The Internet of Things allows achievement of what is often a matter of controversy – the availability of more technical devices and accompanying technologies helps transform learning in more human-oriented process.

The IoT therefore presents the opportunity for the rhetoric about personalised learning environments and spaces to come to reality. The “personalization can be done automatically based on the constructed learner’s profile, his [sic] level of knowledge and achievements, the pace of learning and specific needs” (Kiryakova et al., 2017, p. 82), meaning that delivery of timely materials in a way that is accessible becomes easier. It also opens the way for the vision of Thingful and the interoperability of devices where “all available users’ devices are connected and can be identified, interact and communicate with each other and with their surroundings” (Kiryakova et al., 2017, p. 82). However, the current paucity in activation abilities – the gap between the imaginings of the IoT and the ability to make these a reality – means that much of the potential for the IoT in a learning environment is, at present, reduced to cosmetic interactions like “a control of airflow, an optimization of air quality, temperature and humidity” (Kiryakova et al., 2017, p. 81). These are hardly the cutting-edge interventions in accessible accommodations for students with disability that can transform learning. However, they do construct a starting point from which to begin conversations with students about how the IoT might assist their learning at university. This was the approach taken in this research project when we recruited five students with disabilities to map their understanding of the current tertiary terrain and conduct a thought experiment about how the IoT might, in the future, assist them.

Student Interviews

In order to better evaluate the impact of IoT on the educational outcomes of students with disability, all Curtin University students registered with the University’s Disability Services were invited via email to participate in a short interview to discuss their understandings of the IoT and reflect on the ways it could potentially be used in teaching and learning to them. Questions were grouped into four main categories – technology awareness, using devices, specific IoT uses, and IoT limitations (for a full list of questions see Appendix).

The interview was designed to identify the practical needs of students with disabilities in an educational context and to track student engagement with smart IoT systems and devices. A total of five people with disability across a variety of ages, genders, disability, ethnicity and socio-economic status participated in interviews. Interviews lasted on average half an hour and were held in person and over the phone. Interviews were then transcribed and coded for common themes.

While these interviews did result in a more detailed understanding of what students understand about the IoT, the smart devices they use, and how their learning is facilitated by those devices, a fully-fledged and formed answer to the educational benefits for students with disabilities could only be speculated. As a result, the following section seeks to map the gaps and absences in the IoT and education and disability debate to consider how Curtin University might move forward in creating intelligent design within a campus setting to ensure that students can access cutting-edge education. Examples of this may involve the

ability to navigate spaces to get to classrooms or being able to download and read online materials in a timely and effective manner.

Several prevalent themes and experiences regarding participants' views on the present-day educational benefits of current and emerging IoT products became apparent across the interviews – these were regardless of impairment type. From the interviews, it can be seen that students with disability at Curtin University state that:

- The IoT is in a very early stage of development. As such, its possible uses and practicalities are unclear at this stage.
- They prefer Android devices.
- Technology must be adaptable. The students we interviewed regularly modify technology to suit their specific needs.
- They share a widespread willingness to try new technology, and equally a willingness to abandon that technology if it doesn't provide the support they require.
- They have different learning styles, for example some are visual, others are aural etc, and therefore require different technologies.
- Lecturers continue to be unaware of the access needs of students with disability – for example, lecturers are often of the view that if it is digital it is accessible. This was a widespread concern amongst the interviewees.
- Although the IoT offers great opportunities, it is vital that lecturers retain control of the classroom.
- They already feel overloaded with information – there is a fear that the IoT could exacerbate this.
- They hope that the IoT will be able to offer flexible and timely ways to better manage accessing educational materials.

These will be discussed below, grouped under four main categories to reflect the interview questions – technology awareness (understanding the IoT), using devices (as assistive technology such as smartphones), specific IoT uses (mainly the impact of lecture-based technology and lecturers), and IoT limitations (acknowledging concerns with the IoT for this particular cohort).

Technology Awareness

The students demonstrated different levels of understanding of what the IoT is – these ranged from not having heard of it at all to having a fairly well-formed concept of what it involves:

Actually, I can't say, I haven't heard it until now. But I know what it is, I've just never heard the term for it. It's a thing where objects have Internet access to it, and that interacts with other objects. That's all I know about it so far.

A term in the IT world that refers to the concept of connecting all electronic devices (or computers as an alternate term for electronic devices) to the Internet for the sake of convenience and data collection.

Basically I would say that it's anything that basically has an on and off button and that's also connected to the Internet.

Just the different kinds of ways in which you use the Internet, user interface type things. So the way I use the Internet is different to someone else. That's what I would sort of say, I don't do any social media.

Their answers belied the incomplete nature of the emerging IoT framework – they had some grasp of what it might entail but limited concrete examples of how they might deploy or interact with the IoT. When asked about their familiarity with IoT systems, most reported that they had heard of items like an internet-enabled refrigerator but had never used or interfaced

with one. Two students reported using Google Home. All students reported some familiarity with voice-activated interfaces like Siri and OK Google, but none of them used these facilities. One student identified the potential problems with different voice, pronunciation and accent:

I find [digital assistants] a bit useless because in most cases my voice is not that great, it can't hear my voice and stuff. But I know it's getting better with everyone.

While this student described their voice as being “a bit weird”, issues with accent recognition is a well-recognised and documented downfall of these devices (Dart, 2016). While this is already an issue for Australians (Dudley-Nicholson, 2015), it is exacerbated for people with disabilities who may have speech impairments or different vocal inflections such as people who are D/deaf or hard of hearing.

Using Devices

All students identified smartphones as their main IoT device. Each reported using Android smartphones instead of Apple iPhones, claiming Android as easier to work with non-proprietary systems in order to get the assistance they needed to manage their disability via their phones. This is a significant finding that contradicts our prior research in the area of smartphone use amongst people with disability which found iPhones were the most popular device (Ellis, Kent, Locke, Hollier, & Denney, 2017).

The results of the interviews also showed that smartphones played a large role in assisting the students in their study and in their everyday lives. Each stated to be familiar with assistive features like magnification and screen readers, yet while some students employed these features in their study, most said they relied on their own intuitive initiative to retrofit their own assistance with their favourite technologies. Many confirmed that they had experimented extensively with different technologies to find what works best for them:

I've got some software that [magnifies or changes colour]. And I did find that it worked until I figured out [...] that my ears were more powerful than my eyes. I stopped using any of that sort of stuff.

Of note was that each student demonstrated that the IoT would only be useful if it could deliver a very specific and structured parameter of service that was assistive to their particular disability. That is, the impact of their particular impairment/s affected the ways individual students approached the learning process, thereby confirming the importance of a personalised approach to learning and a personalised approach to technology:

I bought a tablet before anyone knew I was dyslexic, ... taking some advice from someone who has a PhD [who said] to use a tablet because no matter where you went you could have your pdf files, you can be scrolling through them while you're waiting for a train, that sort of thing. I didn't realise though I couldn't comprehend what I was reading. So I bought a tablet but it was no good to me [...] whenever someone sends me something, I can glance through it, but really until I go home and open it up on my computer and use the text to speech reader, that's actually when I consolidate what I've read – ohh, you're talking about that. All the other things that you're sort of talking about all assume your comprehension through your reading is via the platform.

The results of the interviews showed that students demonstrated a nuanced approach to the management of their own specific disabilities by using a variety of devices and interfaces designed to minimise the impact of technological, administrative and accessibility failures within a blanket institutional framework designed to deliver education en masse. The specificity of their disabilities belied the categories used to measure their level of interaction and delivery protocols the university has in place. It is in this capacity that the IoT offers its

greatest potential. The students we interviewed were self-aware and willing to try new technologies; however, lecturers were identified as having a particularly disabling impact on learning and the availability of materials.

Specific IoT Uses

Lecture recordings were also often highlighted by the students as a vital technology / accessibility feature that integration with the IoT could improve. In particular, the ability to automate particular elements of information gathering so that other senses could be either engaged or not overwhelmed by too many tasks was spotlighted. In addition, allowing students greater control over how information was received, ranked and managed was an important theme. Ensuring that recorded lectures have appropriate accessibility features enabled that would be of assistance to these students was also noted – these ranged from clear audio through to searchability and multi-level access on different devices:

... I take notes during class because I tend do two things or three things. I do verbatim, trying to keep up with that. I have no idea what I'm typing because I can't hear what I type. I type what I think you're saying and then hopefully when I re-read it at high speed I'll go, "it was about that", look for the key words that you keep emphasising. Right, this is your bit. Or I listen to the meaning of what you're talking about so what I do is I don't write down the name or the author of the book and what you're doing but you're strongly talking about the ethics of ehhh so I can get the meaning of it and then I hope that it's in the iLecture so that I can get the specifics.

The strength of the IoT in tailoring educational delivery to individuals' specific needs was also highlighted. For example, while some acknowledged specific alternative formats such as real-time captioning in lectures, others reflected on the potential for sensors to interpret a pedagogical method to their lecturers' movements which can at times appear random and frustrating to students with particular impairments:

I would like to see a device that can describe audio to subtitles in real-time, that kind of thing. That would be most benefit for me as a deaf person.

For a colour-blind person, they can use the camera on their phone to do colour correction instead of having to wear those really expensive glasses. Umm... for a deaf person, they can use... they're called IQ buds.... They're kind of like wireless headphones but they have a microphone on the back. So the idea is they're not just for listening to music, it's also for filtering sound coming in.

in my case, I learn much better when [lecturers] move very structurally across the board rather than when they go you know like I've written this down here, I've written this down here, oh look there's a bit of free space there, there's a bit of free space down at the bottom [...] you could measure [a logical structure] by having a sensor on the teacher and seeing how they progress.

What I think might be useful is having like interactive notes for the lecturers' benefit [to discover] what things the students spend more time on or what they highlight.

Indeed, the impact of lecturers themselves was also a key point raised in the interviews. From forgetting to turn a microphone on while recording a lecture, to providing inaccessible pdfs in the library online reserve, the attitudes of their lecturers towards disability accommodation was seen to have a material effect on the success of disabled students at university:

So they all go, oh everything's available on the library, but because it goes through an external website, that external website blocks for plagiarism, I can't

read it. And they go that's an essential reading, it's available to everyone, it's on the Internet. I can't read it. The lecturers have no idea what I'm talking about, no matter how many times you tell them, I actually can't read that part because if you cannot copy it and paste it, the text to speech readers can't read it.

... the lecturers who get to know me, who want to know who I am, will know that my most concentrated moment is when I close my eyes and I look like I'm looking out the window. Because I'm engaging, it's because I'm listening to what are you talking about rather than what are you saying.

However, most of the students interviewed were uncertain how the IoT would be able to assist them with these issues. Yet the IoT could offer valuable 'work-arounds' for the gaps in educators' knowledge about disabilities, particularly with regard to the intensely personalised learning environment – and associated technology – needed to facilitate individuals' education. For example, students often complain about lecturers' – and, indeed, their own – lack of training on lecture systems, formats and learning management systems which can get in the way of educational interactions. The IoT has the potential to provide a network of accommodations for students with disabilities that can circumvent some of these common accessibility issues, meaning that teachers can focus on content rather than on delivery.

Internet of Things Limitations

However, the students still voiced some concerns about the IoT, particularly with regard to issues of security and privacy:

Maybe some students feeling a bit silly can hack into an Internet device, especially if security, if they know their way around it. I know a few people that can do that, especially my friend used to set all these computers and laptops to shut down within ten seconds of starting.

Further, when pressed on what kinds of things they would like to be able to control in a classroom, they remained unsure and ambiguous as to what this might look like, as well as being uncertain about how the IoT might benefit all students and not further marginalise some. As an example, students recognised that the temperature of a classroom could be controlled by individual students; however, most suggested that would be impractical in a classroom context. They also acknowledged students use their devices in classrooms for non-university related purposes such as checking social media and that that impacted on their perceived use as a student with disability using a device for access:

A problem right now... in university lectures is that some students browse Facebook on the laptop instead of writing down notes on their laptop. Primarily Facebook and Twitter, like social networks but maybe YouTube and stuff like that. Where say they try to look something up because they don't understand what the lecturer is saying and then they get like a notification so in general it can be distracting but if you're not careful with your cyber-security then it can also be a hacking issue.

I look at [other students] and I think, you're checking emails the whole time, you're doing Facebook, you're doing this, you're doing that, you're working on the assignment that we haven't even talked about yet... But I'm doing that because if [the lecturer] starts talking about something, I'll go Google it straight away and I'll be listening and I'll be doing that at the same time and I'll look at images and I'll look at things and [...] I'll be recording the information [from the lecture] based by looking at images. So I'll be flipping and flopping around and taking notes and researching and if a YouTube gets thrown up there, then I'll try to grab that URL and then I'll then go and grab that, whereas technically that may be wrong... [it's] very hard because was I being legitimate when I was doing all that when the person next to me is doing Facebook.

This description illustrates how students with disability may use IoT to take a 'second screen' approach to learning by augmenting the information presented by the lecturer with Google and YouTube searches as well as using images as a note taking device. However, whereas this student is using their device in a pedagogically appropriate way, the student next to them using Facebook makes them look questionable. As such, the students highlighted the ways in which technology is differently deployed by students in a classroom and how assumptions about how technology is and is not useful to students with disability can lead to awkward classroom interactions. The students interviewed did not believe devices should be confiscated if caught to be doing the 'wrong thing', rather they hoped for a more effective way to incorporate them into both teaching and learning.

To conclude, from these interviews it can be seen that the IoT – as a networked system of feedback and accommodation for students with disability – means that the technology is an always present background in the classroom, hopefully helping to remove a variety of stigmas not just about disability but about how technology is deployed in the educational context. Indeed, the students offer a range of radical insights into the relationships between technology, their disability and education. They saw the potential in the IoT, but were less clear on how that might manifest in actual classrooms and teaching and learning experiences that involve other students. Privacy and security were a major concern and each student saw the potential for the IoT to be abused. Finding a balance between the needs of students with disabilities, the needs of running an institution, and the limitations of technology punctuated their answers. Each demonstrated that the IoT offers tremendous potential for assisting students with disability at university but there remains a fair degree of abstraction in terms of what this might look like and how it might actually manifest.

Conclusions and Recommendations

Students with disabilities are under-represented in higher education in Australia and have a lower completion rate for their studies than their fellow students. The IoT therefore offers great potential for both the greater inclusion of students with disabilities in higher education and a better and more customised learning experience for all students. However, this research has shown that the technology, while evolving, is not yet at a point where it could be effectively deployed in learning and teaching at the university level.

Nevertheless, it does show great potential. The ability to analyse information from a range of different sources and present it, to alter physical and digital environments to best meet learners' and teachers' needs, and to present customised information and communications options to best suit the needs of a user through a device that they are familiar with presents the opportunity to champion a social model approach to disability where each environment is customised to meet the needs of an individual, rather than that individual being forced to adapt to an inaccessible environment.

For this potential to be realised, consideration of the wider significance of the relationships between technology and society, education and disability, access and literacy, is needed. Concerns about privacy and security and interoperability associated with the technology will need to be overcome, and careful consideration of how the technology can best be adapted to a learning and teaching environment will be needed. However, interviews from this study with students with disability indicate a willingness to overcome these limitations and embrace the potential of these new technologies as they develop over time.

This report recommends, in relation to the deployment of the IoT in an educational setting, that:

- Curtin University should not immediately deploy IoT technologies, but that careful consideration and planning be undertaken for how this might best be done in the future and what implication this might have.
- Priority should be given to incorporating IoT within specific pedagogical issues regarding learning and teaching, with particular consideration being given to the integration of students with disabilities. This is in addition to Curtin's current focus on integrating IoT technologies primarily in association with facilities management.
- Any IoT equipment associated with learning should have the ability to provide its output to students via a learning management system or app. This would ensure that students with disabilities can process the data with their preferred assistive technology.
- Any future implementation of IoT solutions should focus around the use of personal smartphones as the primary IoT interface device for students with disabilities.
- All IoT-related implementations must also consider privacy, security and interoperability.
- Any IoT solution must be accompanied by training to ensure that all staff and students are able to use it effectively.
- The applicability of using a digital assistant as a real-time captioning device warrants further research.
- A trial of the use of existing technologies and further consultation with industry and students should be undertaken over 2018.

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Appendix: Interview questions

Category 1 – Technology Awareness

1. How would you describe the term ‘Internet of Things’?

2. How familiar are you with the following IoT devices?

Scale: not at all familiar; not very familiar; somewhat familiar; familiar; very familiar

- Internet-connected refrigerator
- Internet-connected TV
- Internet-connected lighting
- Internet-connected door lock
- Internet-connected oven
- Internet-connected heating/air conditioning
- Other: please explain

3. What IoT devices, if any, do you use?

4. What type of smartphone do you use?

Selection: none, Android, iPhone, other

5. How familiar are you with the following smartphone features?

Scale: not at all familiar; not very familiar; somewhat familiar; familiar; very familiar

- Apps
- Accessibility features
- Screen reader (e.g. Talkback on Android, Voiceover on iPhone)
- Magnification
- Switch Keys
- Visual assistance (i.e. large text, colour inversion)
- Other accessibility features: please specify
- Digital assistants
- Siri (iPhone)
- OK Google (Google)

6. How familiar are you with standalone digital assistants?

Scale: not at all familiar; not very familiar; somewhat familiar; familiar; very familiar

- Google Home
- Amazon Echo (aka ‘Alexa’)

Category 2 – Using Devices

7. In broad terms, what do you consider are the benefits to you in using IoT products?

8. What do you consider are the main issues of current IoT products?

9. When using IoT products, please discuss the following interfaces in terms of which ones would work best for you:

- Built-in interface, e.g. touchscreen

- Smartphone app
- Smartphone digital assistant (e.g. Siri or 'OK Google')
- Standalone digital assistant (e.g. Alexa, Amazon Echo, Google Home)
- Other please explain:

10. What types of benefits can IoT provide to people with disabilities more broadly?

11. What are the education-specific benefits that IoT can provide in the classroom?

Category 3 – Specific IoT Uses

12. Are you currently using IoT devices to support your education?

13. Which IoT devices would be useful to control in a classroom environment?

14. Would the ability to control devices in the classroom provide disability-specific benefits?

15. What types of issues could occur if IoT devices could be controlled in a classroom?

16. What mechanism do you think would be the best way to control IoT devices in a classroom?

Category 4 – IoT Limitations

17. What type of privacy considerations should be given to the use of IoT by students in the classroom?

18. What type of security considerations should be given to the use of IoT in the classroom?

19. Currently IoT devices tend to favour one particular ecosystem, e.g. compatibility with Apple but not with Google or vice-versa. What do you see as the best solution in terms of how devices interact in IoT in the classroom?

20. What type of support would Curtin need to provide to you in order to maximise the effectiveness of using IoT in the classroom?

21. What other things do you consider would be helpful in guiding universities in their considerations of adding IoT to a classroom environment to assist students with disabilities?