



Current Perspectives on Assistive Learning Technologies

2012 review of research
and challenges
within the field

The Kellogg College Centre for Research
into Assistive Learning Technologies



Report prepared by Lorna McKnight and Chris Davies
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Executive summary

This report describes a review of literature on assistive learning technologies, or digital technologies designed to support learners with special needs in education. The intention was for the review to take a broad and interdisciplinary approach to the topic, with the aim of building up a picture of the state of research in the field, as well as highlighting areas where the research is lacking, in order to identify possible topics for future research.

Education is seen as a human right that all are entitled to, and in the case of disabled people accommodation of an individual's requirements must be provided, and support must be given to ensure that this entitlement is made available to all learners. Assistive technologies are proposed as one solution to help provide this support and remove the barriers to education.

A wide variety of disciplines contribute to the field of assistive learning technologies, meaning that there are differences of opinion as to how these technologies are defined, as well as how and when they should be used. For example, a distinction can be made between technologies that aim to remediate a disability, or those that aim to compensate for it. There is also a conflict between designing special purpose technology that best suits a learner's specific needs, and in designing mainstream technologies so that they are more suitable for a wider range of users.

One challenge faced by the field is the need to involve users of assistive technologies in research studies, which many researchers advocate, but there are disagreements as to the extent and nature of participation that should take place. For some young people, participation can be difficult, and there is also the issue of being able to give informed consent to taking part in a study. There is also the need to consider the wider context of use, including involving parents and teachers in studies, and taking input from professionals from a variety of disciplines. To find an effective solution, this requires an understanding of at least three factors: the needs and abilities of the learners, the capabilities of the technology, and the context of use such as the educational setting that the technology aims to support.

Considering assistive learning technologies from the point of view of the learners helps to identify approaches that are tailored to support specific impairments, as well as gaining greater understanding about issues facing learners with specific learning difficulties such as dyslexia, dyscalculia, dyspraxia, autistic spectrum disorders and ADHD, as well as physical disabilities such as visual or hearing impairments. Some disabilities are clearly given greater attention by researchers than others, and there is a need to consider where research in different fields may

overlap. There is also a need to consider not only accessibility and access to learning, but also social issues: while inclusion and social interaction are given substantial attention, other issues such as independence, anxiety and self-confidence may often be overlooked by researchers.

Taking the technology viewpoint, there are clearly a large number of technological approaches to assistive learning technologies being investigated, and there is perhaps a tendency for research to focus on the technology rather than its uses. Solutions have been found using voice recognition technologies, mobile devices, tangible technologies, surface technologies and symbol-based interaction, with some proposals also for the use of augmented reality, virtual reality and robotics. While this research offers some promising approaches for the future, many of these technologies are not likely to be in widespread use at present, and there is a need to consider affordable technologies or those that are already widely available.

Lastly, looking at the educational contexts that assistive learning technologies may be used in, one of the most pressing issues is that of provision. While technology may be provided by schools and higher education institutions, reports suggest that technology provision is inconsistent across different stages of education, as well as often varying across the country. There is also a need to address the issue of technology support for lifelong-learning, including support for informal and self-directed independent adult learning.

This review has shown that while a huge body of research exists on the topic of assistive learning technologies from a variety of disciplines, there is often a lack of consistency and collaboration between different domains. There is a growing understanding of the needs of learners and the capabilities of technologies, and there is evidence of benefits that technology can have to learners with special educational needs. However, there is a need for more longitudinal studies considering the wider context of use, and considering the impact of technology on a person's whole education and wellbeing throughout their life.

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1. Introduction

“Over the past decade, evolving technologies have revolutionized the way we do business, communicate, make war, farm, and provide medical treatment. New technologies are also transforming education, and in no domain more dramatically or successfully than in the education of students with disabilities” (D.H. Rose et al., 2005).

The intention of this report was to conduct a review of literature on assistive learning technologies, exploring the field of digital technologies designed to help young people with specific learning difficulties. This is taking a broad focus, trying to build up a picture of the nature of the research field, as well as the current views, debates and opinions as to approaches that can be effective in education. This means that an interdisciplinary approach has been taken to this review, covering a large number of sources from a wide variety of backgrounds. This also aims to highlight some of the potential areas where knowledge is lacking or more research is required, to identify possible avenues of research for the future.

Education is defined by the United Nations as “both a human right in itself and an indispensable means of realizing other human rights” (UN Economic and Social Council, 1999). The Convention on the Rights of Persons with Disabilities reiterates this in the context of disabled people, mandating that “States Parties recognize the right of persons with disabilities to education. With a view to realizing this right without discrimination and on the basis of equal opportunity, States Parties shall ensure an inclusive education system at all levels and lifelong learning” (UN General Assembly, 2007). This includes ensuring that “reasonable accommodation of the individual's requirements is provided”, and that “persons with disabilities receive the support required, within the general education system, to facilitate their effective education”. Assistive technologies are seen as a means of potentially providing the support that is needed to facilitate education, but it is important to remember that this is a means to an end which people should be entitled to, and that every effort should be made to ensure that this right is not denied to any people.

It is also important to note at this point that this report is being approached from the point of view of relative newcomers to the field (if a single coherent academic field in fact even exists). There is a danger therefore that the use of language in this report may at times be naïve, as it can be difficult to identify the implicit cultural and political positions behind different terminologies. The meanings and acceptability of words change over time, and while it is important to recognise current sensitivities, it is also important to note the difficulty in finding terms which are not offensive to any individuals. For example, in the USA, it seems that the term 'people with disabilities' is currently considered more politically correct, based on the idea that people come first and their disability should be seen as

secondary, whereas in the UK the term 'disabled people' is currently more acceptable, based on the social model of disability which says that the people are being disabled by society (Smith, 2010; The Goldfish, 2008; British Paralympic Association, 2012). Some people would not consider themselves as 'disabled', even though they have been diagnosed with a condition which some people would count as a 'disability': for example the Deaf community (see section 3.6) tends to take the standpoint that the inability to hear is not a disability but a way of life (e.g. Drolsbaugh, 2012), and some people prefer to take the view that autism is not so much a 'disorder' but a difference (see for example Dommett, 2011). Terms such as 'handicapped' and 'retarded' originally meant to be 'held back', but are now considered some of the most offensive terms by many people (e.g. D. Rose, 2004). The term 'special needs' is currently considered acceptable in the UK, and schools routinely use the term Special Educational Needs, but this term is also seen as problematic and offensive to some who would prefer a more equal and inclusive approach (Seahorse, 2008; D. Rose, 2004). Some people may prefer the term 'learning differences', although others recognise that this term is also difficult, as every learner will have differences, and while from an educational perspective it is important to recognise this, it does not help to distinguish learners who might be in need of more help and support than the system currently provides.

The authors of this report are sensitive to the fact that this is a highly charged issue which should not be taken lightly, and that it is not always possible to proceed without offending some readers, but at the same time recognise that it is important that these difficulties do not prevent research from taking place in this field. For example, it has often been noted that the difficulty in finding universally acceptable terms can prevent people from talking about issues at all – as a journalist noted in a discussion of language used around the 2012 Paralympic Games, “the fear factor is high and in my long experience of these things, can sometimes stop programmes going out or disabled contributors being used on air because some people just really badly don't want to get it wrong” (D. Rose, 2012).

Therefore, although this report is being written after many consultations with people with more expertise in the field of disabilities and education, it has to be accepted that mistakes in language may still be made, and so apologies are sincerely due for any unintentional offence which is taken by the language or terminology used, and we would always welcome entering into a dialogue as to how to improve our practices. It should also be noted that this report is particularly being prepared with respect to current attitudes towards disabilities that are considered acceptable in the UK, as this is the country and the educational context that the authors are based in. While the aim is always to show as much respect as possible for the people being talked about, this report is intended to simply present findings of what the research literature is currently saying, without meaning to justify any particular stance or approach. It is hoped that this may help to initiate the dialogue of what is currently published on this topic, and how far this reflects current thinking, and the experiences of those involved.

On this topic, it is worth noting that there are several different models of approaching disabilities. For example, what is termed the 'medical model' is perhaps the traditional approach, but is now often considered insensitive and damaging to the individuals concerned. Under this model, people are considered to be disabled by their impairments or differences, with a view that they can and should be 'fixed' by medical means, and a disability is defined as “any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner, or within the range, considered normal for a human being” (Kuno, 2008). In contrast to this, the social model of disability posits that the disability is due to the way that society is organised in order to restrict participation in activities for those with impairments. Under this model, a disability is defined as “the disadvantage or restriction of activity caused by social factors which take little or no account of people who have impairments and thus exclude them from the mainstream of social activities” (Kuno, 2008). While other models exist which combine aspects of these two, such as the synthesised model, the culture model, the affirmation model, the inclusion model, and the post-modern model (see Kuno, 2008 for a description and comparisons of each of these), the medical and the social models remain the most common and the most important to be aware of. Although the social model of disability has been subject to many critiques (see for example Dewsbury et al., 2004), this is the model currently promoted by many charities and pressure groups in the UK as the most socially accepted model in this country at present (e.g. see Scope, 2012), and the Office for Disability Issues in the UK encourages government departments and social researchers to adopt this model (Farmer & Macleod, 2011). One of the proposed advantages of technology is that it creates the potential to enable changes to society that can help remove barriers to equal participation, moving away from the medical model and towards promoting positive social change.

Originally the aim of this report was to focus on what are termed Specific Learning Difficulties (SpLDs). This is a term in common use in UK schools to cover a range of difficulties, most commonly including dyslexia, dyspraxia, dyscalculia, attention deficit disorders, and autistic spectrum disorders. However, over the course of this work, the focus widened to include other difficulties which would be classified as Special Educational Needs, as well as some of the wider issues involved with providing technology to support learners with differing needs.

Given our position, based at a UK higher education institution, we are particularly interested in research which is relevant to the UK education system, but research from other countries has not been excluded here. Partly this is due to realising that there may be more published research from other countries (particularly the USA), and also it is useful to include this to learn from it as research should span countries, and some issues may be common across different cultures.

Also, the aim of this report is not to appear in favour of technological determinism -- this report is not aiming to make a case for technology, or for technology to drive change, and recognises that other approaches may be more appropriate or successful in some instances.

Furthermore, as Dewsbury et al. note, “the challenge is to provide support for individuals, rather than create new, technological, forms of dependence” (Dewsbury et al., 2004). Therefore, rather than promoting technology, this report is instead simply aiming to look at the role that technology can play in this context to provide support, and how this fits in with the broad picture of support for different learners across education.

This report will continue in the following way. Section 2 will begin with a general discussion of the field of assistive learning technologies as discovered from the review, in order to position this work within the existing research and define the scope of this review. This includes defining the terms that delineate the work (Section 2.1), and outlining challenges to the field that have been discovered (Section 2.2). The following three sections will then review findings on approaches using assistive learning technologies, considering it from the point of view of the learners’ needs (Section 3), the features of the technology (Section 4) and their educational context (Section 5). The report will then aim to draw conclusions from this review in the hope that lessons learned will help to set out a way forward for future research.

2. Considering the field and scope of assistive learning technologies

The field of assistive technology as a topic for research is one which encompasses many different backgrounds and approaches. Following a review of literature on providing access to assistive technologies for disabled people, Hoppestad (2007) states that “no one profession should have a monopoly on research for computer access, but should be a collective effort between rehabilitation specialists, medical professionals, family members, trained educators, qualified psychologists, biomedical engineers, computer experts, and AT recipients”, and that “consultations by various professionals in specialized fields should be incorporated into the assessment process as required”. This is echoed by Langdon and Thimbleby (2010), laying out a mandate for inclusive design as a research field, who stress the need for an interdisciplinary focus, encompassing cognitive science and engineering, as well as the need to understand the social, environmental and individual factors. Similarly, a UNESCO report on innovative practice in educational technology for disabled people makes the following recommendation:

“ICT in education for people with disabilities must be considered a ‘trans-sectoral’ field. There are many different sectors of expertise and information that need to be taken into account in developing, implementing and evaluating policies: stakeholder input and views; education and specifically the education of people with disabilities in inclusive settings; ICT in education and the Information Society generally; the training of teachers and educators. Coherent cross-sectoral policies must be based on a consideration of all these sources of inter-related information” (Watkins, 2011).

The UNESCO report goes on to recommend that a shared language is needed for assistive technologies in education, and that all stakeholders need to understand terminology and key concepts involved. Griffiths & Price (2011) also talk of the need to involve people from different backgrounds when choosing assistive technologies for an individual, and suggest that a framework is needed to assist decision-making that encompasses all the different viewpoints which may come into play. This multidisciplinary approach can be vital in order to take into account all the factors which play a part in developing and deploying effective technological solutions for people with special educational needs. As Raskind (1994) has said: “it is of paramount importance that specific technologies be chosen relative to the individual, the function to be performed, and the context of interaction.” In other words, for an approach to work, there needs to be an understanding of the specific needs of the user, the problem that needs to be overcome, and how the technology works. Involvement and appropriateness are also key to continued usage of assistive technologies. In a study of factors associated with discontinuance of assistive technology use, Riemer-Reiss & Wacker conclude that “the consumer must be involved in the entire process and the technology must meet an important functional need” (Riemer-Reiss & Wacker, 2000).

When scoping the field, it is important to note that there are a wide variety of publications which may address the topic, as researchers may be working on assistive technologies from the perspective of the learning difficulties (the user), the technologies, or the educational (and/or social) implications. In a review of literature published in 2002, Edyburn identified 28 journals that had published articles that year containing articles on special educational technology (Edyburn, 2003). These included 4 with a focus specifically on special educational technology, 15 on special education, and 9 on educational technology (a total of 221 articles which were considered to be relevant to the topic in that year). However, this total increases when other disciplines are taken into account, as well as the natural increase over time.

Journals which regularly publish work in the field include the Journal of Assistive Technologies, Journal of Special Education Technology, International Journal of Special Education, Journal of Learning Disabilities, British Journal of Educational Technology, European Journal of Special Needs Education, Educational Technology Research and Development, Computers & Education, Interacting with Computers, International Journal of Human Computer Studies and many more, including topic-specific journals such as Autism, Annals of Dyslexia, Reading, and so on. The computing and technology disciplines often favour peer-reviewed conferences over journals, so it is also worth mentioning the conferences of Human Factors in Computing (CHI), the International Conference on Computers and Accessibility (ASSETS), International Conference on Computers Helping People with Special Needs (ICCHP), International Convention on Rehabilitation Engineering & Assistive Technology (i-CREATe), Interaction Design and Children (IDC), the International Conference on Pervasive Technologies Related to Assistive Environments (PETRA) and others. Many charitable organisations will also publish guidance and case studies on topics, see for example AbleData, AbilityNet, JISC TechDis, EmpTech, BDATech, ATAccess, and many more. The British Educational Communications and Technology Agency (Becta) also historically published reports in the UK, though the organisation is now disbanded (an archive of research materials is available through the Institute of Education¹). The Foundation for Assistive Technology (FAST) holds a database of research projects related to AT in the UK on their website², but this may not be up to date. Given all this, it is unsurprising that in reviews of literature on assistive learning technologies, Edyburn (2003; 2004) voices the concern that researchers in the field may suffer from an overload of information.

Because of this overload of information, literature reviews and syntheses become very important in order to collate and reflect on the existing knowledge available. Naturally therefore, many such literature reviews have been conducted already: for example comprehensive yearly reviews on special education technology were conducted by Edyburn between 1999 and 2003, after which the amount of literature available made the task too

¹ Becta research archive: <http://www.ioe.ac.uk/services/49060.html>

² FAST database of assistive technology research projects: <http://www.fastuk.org/research/projects.php>

difficult, but between 2004-2010 this same author has also produced lists of 'must-read' articles (see Edyburn, 2012). A broader review of literature from 2007-2010 and guidelines for researchers in the field of assistive technologies has been published by King's College London, following an ESRC-funded seminar series on the topic (Abbott et al., 2011). Such reviews are also frequently published in journals, including some with a particular focus (e.g. Alper & Raharinirina, 2006; Day & Edwards, 1996; Floyd et al., 2008; Maor et al., 2011).

From the educational perspective, assistive technology also fits in with the Universal Design for Learning (UDL) framework – these are research-evidenced principles for curriculum development that aim to give all learners equal opportunities to learn, following in the footsteps of movements such as Universal Design and Universal Usability (Shneiderman, 2000). Assistive Technology and UDL can be said to have similar goals, such as increasing access and participation in education, though they take different approaches (see for example D.H. Rose et al., 2005). While assistive technology approaches are “unique, personal (travels with the individual), customized, and dedicated”, UDL approaches are “not unique or personal, but universal and inclusive, accommodating diversity” (D.H. Rose et al., 2005). Nevertheless, the two can be compatible. UDL has three primary principles: 1) provide multiple means of representation; 2) provide multiple means of action and expression; and 3) provide multiple means of engagement. These principles are also subdivided into 9 guidelines, which are split into 31 more specific 'checkpoints'. The idea of UDL is that these principles are designed into the overall curriculum, but technology may play a key role in enabling this. In fact, checkpoint 4.2 is 'Optimize access to tools and assistive technologies', identifying assistive technologies as a way of providing the individual support which makes achieving the principles possible. The Centre for Applied Special Technology, where the guidelines are published, says that: “Technology tools, if designed according to the Web Accessibility Initiative (WAI) and UDL guidelines, can be created to support the individualization necessary to engage all learners” (CAST, 2012).

2.1 Defining terms: what do we mean by assistive learning technologies?

It is important to consider what is meant by the term ‘assistive learning technologies’, or even assistive technologies in general. Assistive technology is a term in common use to cover a wide range of different products and services, and many different definitions exist. The Foundation for Assistive Technology (FAST) defines it in this way: “Assistive Technology (AT) is any product or service designed to enable independence for disabled and older people” (FAST, 2001). The British Educational Communications and Technology Agency (Becta, now defunct) defined assistive technology as: “the software and technology which helps people with disabilities and special needs to overcome the additional barriers they face in communication and learning” (Becta, 2003). In the USA, assistive technology is defined in the Individuals with Disabilities Education Act (IDEA): “Assistive technology device means any item, piece of equipment, or product system, whether acquired

commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve the functional capabilities of a child with a disability” (Individuals with Disabilities Education Improvement Act, 2004), but no other country currently has a legal definition such as this.

A more detailed definition is provided by Raskind, who chooses to define it in terms of its aims:

“In some instances the technology may assist, augment, or supplement task performance in a given area of disability, whereas in others it may be used to circumvent or “by-pass” specific deficits entirely. Assistive technology is not intended to “cure”, “fix”, or remediate learning disabilities, nor is it intended to teach or instruct (as is computer-aided instruction, CAI). Furthermore, it strives to accentuate strengths rather than weaknesses, to enable expression of abilities at a level commensurate with intelligence, and, ultimately, to enhance the quality of life of persons with learning disabilities” (Raskind, 1994).

Differing terminology is also often used depending on the use of the technologies, and it can be useful to distinguish between them. While assistive technologies are simply those that are intended to help people, there are a lot of different types of ‘help’ that could be offered. For example, remedial technologies are those which are intended to help by ‘fixing’ a problem (for example software to provide training in specific skills which are lacking), while compensatory technologies are those that help by accommodating for it, in order to move towards a more equal environment for learners (for example text-to-speech software for those that struggle to read, or speech-to-text software for those that struggle to write).

While Raskind’s definition above states that assistive technology does not aim to ‘fix’ disabilities, remedial technologies may sometimes fall under the general heading of assistive technologies depending on the type of remediation which they offer.

Although the concepts of remedial and compensatory technologies often occur in the research literature, it should also be acknowledged that this concept of ‘remediation’ may be politically insensitive, and brings to mind the outdated term of ‘remedial education’ – it also raises problems, as not all disabilities can be ‘fixed’, nor should they be. The appropriateness of remedial technologies is highly dependent on the type of disability being supported – for example, many in the Deaf community would feel they have no need to be ‘fixed’ (Portolano, 2012), whereas educators do propose that learning difficulties such as dyscalculia can be addressed through targeted early education (e.g. Butterworth et al., 2011). For this reason, remedial technology as described in this report does not normally aim to ‘fix’ a disability, more to provide educational strategies for overcoming it within a learning context.

However, there may not be a straight choice between the two approaches, and it may be that a mixture of the two is needed. For example, Edyburn (2006) proposed that a

‘remediation vs compensation equation’ is used, with support teams deciding on a percentage score for each type of intervention and the amount of focus it will be given depending on the circumstances (for example they may decide to spend 30% of their time and effort on remediation, with 70% given to compensation), which may then be adjusted over time as needed. This shows how careful thought must be given to the overall approach which is taken in relation to an individual.

The type of assistive learning technologies we are most interested in are perhaps more in the class of enabling technologies, or those that allow some form of learning that was not previously possible to take place (Abbott, 2007), which may include some remedial and/or compensatory technologies. Knowledge and understanding of the user and context of use is vital to choosing the approach to take, for example, Raskind suggested that compensatory approaches may be more appealing for adults with learning disabilities than remedial approaches, particularly where remedial approaches have already failed:

“For many adults with learning disabilities, the use of assistive technology is appealing, since it offers a more immediate solution to a particular problem than that promised by a remedial approach [...] Adults with learning disabilities often require immediate solutions with immediate results and do not have the “luxury of time” to receive remedial training” (Raskind, 1994).

Different types of technologies also raise questions about different types of approaches that could be employed. For example, there may be conflicts between an approach which aims to provide alternative (e.g. compensatory) materials for those with special needs, or one which aims to design technological environments which are suitable for all users.

Discussing the design of inclusive technology, Langdon & Thimbleby (2010) talk about 3 types of design approach: 1) special purpose design that caters for specific impairments (this might be considered the AT approach), 2) modular or customisable design so one product can be configured to suit the user’s needs, and 3) user aware design that aims to extend mainstream products to accommodate as many users as possible (which might be considered the universal design approach).

Universal design is a design philosophy which is long established, previously in architecture but more recently also in software and hardware design, with the view that products should be designed to be usable by all people irrespective of impairments. This approach has many advocates; as one example, a UNESCO report on innovative practice in educational technology for disabled learners concludes that “a concept that appears to be critical in promoting basic ICT literacy is ‘Design for All’. [...] This concept applies to the design and development of new ICT tools, but it is also a concept that must underpin the pedagogy of using ICT in education for people with disabilities. Teaching and learning approaches should also be as far as possible accessible to all people – this is an underpinning principle of inclusive education – at all stages of lifelong learning” (Watkins, 2011). However, the universal design approach is not always straightforward to adopt, particularly when aiming

to support users with very specific needs – for example Feng et al. discuss challenges to the universal design approach when designing software for children with Down Syndrome, who may have a range of impairments in different channels of ability (such as physical, cognitive and linguistic limitations), yet a comparative strength in social skills, which means that it is difficult to devise educational software which does not cause difficulties due to any impairment yet is educationally suitable for their cognitive level and also age-appropriate (Feng et al., 2010). A note produced by the Parliamentary Office of Science and Technology on ICT for disabled people also highlights another possible drawback to the move towards universal design which should be kept in mind: “some argue that one possible side effect of putting accessibility features into mainstream products might be an increase in the prices of very specialist devices as their market share might decrease” (Nath, 2012). Nevertheless, the traditional assistive technology approach of special purpose design can equally lead to problems with marginalisation as users can feel socially excluded through having to use devices which are 'uncool' and different from those of their peers (e.g. Shinohara and Wobbrock, 2011).

The most appropriate approach to use will generally depend on the specific context of use, but may lie somewhere between the universal design and modular design approach – for example it should be possible to have mainstream devices which are designed for as many users as possible, but with options for customisation to support particular needs. An example of how this can work is shown in Keates et al. (2002), who illustrate the ‘inclusive design cube’, where a core of user-aware design is augmented with external 3-dimensional layers of modular design, special purpose design, and assistance from a carer, as the capabilities of the users move from more to less able in terms of functional motion, sensory and cognitive abilities. Specially designed assistive technologies, therefore, may be only needed to provide individualised support for people with particular and specific needs which are not yet incorporated or understood by the mainstream, or in particular a way to test technologies before integrating them into mainstream devices (as has been seen for example with voice recognition technology). The universal design approach may be seen as the ultimate goal by designers, but in reality the act of developing technologies which are suitable for all users is a long process. Assistive technologies are therefore vital to provide support in the meantime, and to help build understanding which is needed in order to discover the technologies which are most appropriate for different users with different needs, with the hope that these may be included in mainstream devices in the future.

As a field of research, assistive technology takes a different focus from that of accessible technology – while accessibility research aims to allow users to use technology without any disadvantage due to an impairment or disability, assistive technology aims specifically to support and aid users. However, the two fields may have sizeable overlaps, as making mainstream technology accessible means that this can be used in place of specialist technology. Methods designed to make technologies or information accessible therefore may be counted as assistive technology approaches, as the approach is assistive, even if the technology is not necessarily so.

One way of looking at assistive technologies is put forward by Abbott (2007), who proposes splitting up assistive technologies into three types by their uses, all with a focus on learning: 1) technology uses to train or rehearse, 2) technology uses to assist learning, and 3) technology uses to enable learning. Under this definition, he describes technology to assist learning as technologies which may compensate for a disability in order to move towards equality with other learners. Technology to enable learning, on the other hand, is described as “a much rarer process whereby the intersection of technology, user and practice leads to a learning gain, where none would otherwise have taken place”. It seems that there is the potential for a notable overlap between these two categories of technology – for example, compensatory technology such as voice recognition software may only appear to assist by providing a simpler way for learners with writing difficulties to produce text, and yet in some cases this may enable them to work independently where this would otherwise not have been possible without a human scribe, and produce a higher standard of written work (e.g. Higgins & Raskind, 2005). It may also be worth considering a separate class of assistive technology within this context, which is that of technology to enable access to learning. For example, a wheelchair might provide vital access to a school, or a screen reader could provide access to written material for the visually impaired, yet these technologies are not designed to benefit learning, nor are their benefits limited to learning alone. Rose and Meyer also distinguish between access to information and access to learning, saying that “although access to content and activities is often essential for learning, access to information is neither sufficient for nor synonymous with learning”, showing that while both are important, one does not necessarily imply the other (D.H. Rose & Meyer, 2002). Therefore, it may be helpful to separate the more general field of assistive technologies from the field of assistive learning technologies, or those which are specifically intended to support and/or enable learning.

Abbott (2007) describes his first class of assistive technology – technology to train or rehearse – as having “limited educational validity”, classing this as technologies such as drill and practice software, which he says “continues to maintain its role as an income stream for developers if not always as a meaningful educational experience for those involved”. This may seem to be quite a damning view of this class of technology, and yet there are a few technologies in this class that may provide clear benefits, particularly when taking a wider view of what counts as 'learning'. For example, technologies to train or rehearse social skills may provide benefits for learners with autistic spectrum disorders, helping to lower anxiety as well as increasing independence and inclusion, which can have marked benefits to learning (e.g. Dautenhahn, 1999; Hourcade et al., 2012; Piper et al., 2006). It may however be useful in some cases to distinguish this type of 'assistive' technology from other types, for example as Raskind (1994, quoted above) points out, there is already the term Computer-Aided Instruction (CAI) which could be used to encompass this. This should however be seen as different from the fields of Technology Enhanced Learning (TEL) and Computer Aided Learning (CAL), which have moved on to consider other topics in the broader area of 'learning', including informal learning, creation and

maintenance of learning communities, and the building of digital cultures (see for example Lewin et al., 2011).

Many assistive technology approaches are prescribed by legal requirements, depending on the country concerned. In the UK, it is important to be aware of the Equality Act of 2010, which ensures that disabled people can access services and information without discrimination. This includes access to education, bringing together previous rules from the Special Education Needs and Disability Act of 2001 (SENDA) and the Disability Discrimination Act of 2005 (DDA). There is also wider international legislation to be aware of, such as the UN Convention on the Rights of Persons with Disabilities, which was adopted in 2006 and ratified by the UK in June 2009. This convention mandates that access to education and to technology (among other things) are ensured for all disabled people without discrimination (see UN General Assembly, 2007, and for a plain-English explanation see Pineda, 2008). According to this convention, there is also a general obligation “to undertake or promote research and development of, and to promote the availability and use of new technologies, including information and communications technologies, mobility aids, devices and assistive technologies, suitable for persons with disabilities, giving priority to technologies at an affordable cost”. A large number of countries have signed this convention (see the United Nations Enable website³), but many will also have their own national legislation – for example in the USA, assistive technology is legally defined in the Individuals with Disabilities Education Act of 1990 (IDEA), and educational practices are also affected by the No Child Left Behind Act of 2001 (NCLB). (Many of these are discussed further in J.A. Wright et al., 2011.) These requirements aim to ensure equal rights and opportunities for disabled people, but they may also dictate the technology choices that are made. At the time of writing however, there is currently no law in the UK enforcing procurement of accessible products (Nath, 2012).

It is also important to note that although legislation and guidelines exist, these are not always followed. For example, although public sector websites in the UK are required to conform to an AA standard of accessibility following the Web Content Accessibility Guidelines⁴, a survey conducted in 2011 of 350 central government websites showed that none reached this standard on every page (Nath, 2012). Less than 5% of websites in the private sector were thought to meet the A standard, although lack of accessibility can lead to legal action being taken against the service in question (e.g. see RNIB, 2012b). One main difficulty arises through the fact that although legislation calls for 'reasonable adjustments' to be made, there is no clear legal precedent as to what is considered 'reasonable' (Nath, 2012).

As mentioned earlier, another difficulty arises through the varying terms and definitions used for user-groups – for example descriptions of a person with literacy difficulties may

³List of signatories to the UN Convention on the Rights of Persons with Disabilities:
<http://www.un.org/disabilities/countries.asp>

⁴Web Content Accessibility Guidelines: <http://www.w3.org/TR/WCAG20/>

vary between being classed as dyslexic, having reading difficulties, specific learning difficulties, learning disabilities, and so on. People looking for information on technology for users with Asperger's syndrome may find sources on Asperger's, autism, autistic spectrum disorders (ASD), or they may be classed as behavioural or communication disorders. As another example, the term 'dyspraxia' (which is in common use in UK schools) yields very few sources from the research community, but the term 'developmental coordination disorder' yields many more. In Edyburn's 2002 review of literature (Edyburn, 2003), it was found that only 29% of 221 articles found explicitly referenced a specific disability (many approaches are multi-purpose) – this was 23% in the same review conducted the following year (Edyburn, 2004). There is also a noticeable variation across countries, for example the term 'mental retardation' is commonplace in some parts of the world, yet is considered highly politically incorrect in others. Some studies will also not accurately describe participants, including co-morbidity of other impairments, which makes it difficult to classify a study or speculate as to whether or not it will generalise to other people (see Gersten et al., 2005; Gersten & Edyburn, 2007).

Another important difficulty arises in defining disabilities according to clinical diagnoses. For example a controversial article by Elliott & Gibbs (2009) makes the point that it may not be helpful for educators to distinguish between people with diagnosed dyslexia (which is acknowledged to vary greatly between individuals) and those with identifiable reading difficulties but no clinical diagnosis; they argue that a more helpful strategy in planning interventions may be simply to focus on giving help to those who are seen to need it. For this reason, for some design approaches it may be more helpful to think in terms of functional ability (e.g. 'reading difficulties') rather than disability status (e.g. Keates et al., 2002; Bohman & Anderson, 2005; Langdon & Thimbleby, 2010).

Furthermore, following the social model of disability, the disability should not be considered to lie entirely with the individual, or to put it another way, “disabilities are defined by the interaction between the environment and the individual” (D.H. Rose et al., 2005). This means that it is not just the clinical diagnosis of an individual that needs to be considered, but also the task they are trying to accomplish and the reasons why it is difficult for them. As an example of this, in the UDL model, it is considered that it is the curriculum that is disabled, not the person. Following this model, it would make more sense to focus more on features of the learning experience that do not work for people, rather than the huge range of specific impairments that people may experience, all of which may vary hugely from person to person. This approach can though make it difficult to find information when thinking about a specific user group.

2.2 Challenges of the field

There are many challenges to the field of assistive technologies, both from a research perspective and from an implementation perspective. This section will outline some of the key challenges that have been identified from existing literature in the field.

One of the most important challenges of the field of assistive technology design is the need to consider the individual needs of the user (e.g. Maor et al., 2011; Alper & Raharinirina, 2006; Edyburn, 2006; Phillips & Zhao, 1993, and many more). Understanding the user is a key aspect in traditional human-computer interaction (see for example Dix et al., 2004), but can have a particular importance when designing assistive technologies for users with special needs, as the designer cannot assume that the user's needs are similar to their own. This can include needing to understand the type of approach that is likely to be effective, for example Raskind (1994) suggested that compensatory approaches may be more appealing for adults with learning disabilities than remedial approaches, particularly where remedial approaches have already failed. Detailed knowledge of the needs and abilities of users with a particular impairment is vital if they are to be well supported, for example not just considering functional ability, but also understanding the social implications of using assistive technologies (e.g. Shinohara & Wobbrock, 2011). For this reason, there is a lot of literature that looks in depth at specific impairments, with the aim of increasing understanding about the difficulties that the users may face (see Section 3). While this may help to increase general knowledge about a diagnosed disability, what may work for one individual may not work for another with the same diagnosis. As Hoppestad has said, "it is futile, particularly when dealing with a person with severe disabilities, to try to estimate which device, out of the hundreds available, will meet the unique needs of a particular person" (Hoppestad, 2007). Some have suggested that personalised approaches are most likely to work, for example Farr talks about how technology offers potentials for personalised solutions and how this may be beneficial in particular when designing for users with autism spectrum conditions (Farr, 2010), though the implications of exclusion due to using non-standard devices should also be considered as previously discussed.

Another serious issue to consider when thinking of the user's needs is the level of access to and provision of assistive technology that they have available to them. In a review of technology access, Hoppestad notes that "persons with disabilities are typically underserved in the realm of AT due to their own lack of knowledge, limited availability of trained personnel, and a dearth of resources" (Hoppestad, 2007). There are a great deal of assistive technologies available which users could choose between, including both commercial and free tools, and it is important that all options are explored. For example, a JISC TechDis article notes that the first step should often be to adapt existing tools and software, and that "commercial assistive technologies come last on the list not because they are a last resort – they will often offer value for money – but because you can only make an informed and intelligent choice when you've tried the simpler systems and worked out what you're missing" (McNaught, 2011). Issues related to funding for technological devices, complexity of devices and not being aware that options are available can affect many people, irrespective of (although perhaps exacerbated by) any impairments if they are disabled. However, provision of assistive technologies in education is not always straightforward, and can vary greatly depending on the stage of education (see Section 5).

More than simply considering the users of the technology however, the need to involve users themselves through active participation in both academic research and product-orientated R&D has been strongly advocated by many (e.g. Hart, 1992; J.A. Wright et al., 2011; Langdon & Thimbleby, 2010; Buhler, 2001; Druin, 2002; Watkins, 2011; Farmer & Macleod, 2011). This is partly because users are expected to know best about their needs and what would work for them, including even some younger users – for example Jeffs et al. (2006) talk about disabled children aged 9-12 self-selecting assistive technologies that maximised their interests and strengths, and which also most closely matched the demands of the tasks they were trying to accomplish. As well as this however, this involvement, and the ability to make the technology appropriate to the user, is also seen as critical to adoption and continued use of assistive technologies (e.g. Riemer-Reiss & Wacker, 2000). Ideally, many state that this involvement should involve more than simple prototype evaluation, and needs to be managed to avoid tokenism (Farmer & Macleod, 2011), but this can be challenging in some circumstances, for example when working with children. There is already a body of work on involving children in technology research; for example Druin (2002) promotes the idea of young people involved in the design process as not just users, but as co-designers and co-researchers (see also Hourcade, 2008). In the field of interaction design, the established co-design movement is beginning to include young people in the design process more frequently, and identifying methods to facilitate this (e.g. Dindler et al., 2005; Druin (ed.), 1999; Read et al., 2010), although many in the co-design field believe that involvement of children is best used as 'informants' to inspire and guide designers, rather than in arriving at concrete design ideas (e.g. Scaife et al., 1997). Some researchers feel it should be taken further though: for example, in an influential essay written for Unicef, Hart (1992) promotes the idea that for children to fully participate in a project or piece of research, the project needs to be child-led, with decision-making shared with adults; meanwhile, in the UK the Office for Disability Issues promotes 'emancipatory research' as one approach to take that goes further than collaboration, wherein disabled people involved in the research should have control over the entire research process and agenda, although they do also warn that this approach makes it difficult for research to remain impartial and objective (Farmer & Macleod, 2011).

Co-design with children can be challenging enough, but may be even more difficult if the children have particular needs. Frauenberger et al. (2012) discuss the challenges and opportunities of full-participation co-design with disabled children, but also propose that co-design in these circumstances not only needs to consider what the children are able to do (which they argue is following the unfavourable medical model of disability) but should think instead about enabling the children, and what would make the experience more positive and enjoyable for the children involved. However, even simple involvement for product evaluation often remains difficult to achieve with some user groups. For example, as Davis et al. say, in the case of designing for autistic children:

“On the one hand, characteristics of autism such as a limited flexibility of behaviour, a tendency to focus on matters of detail and a difficulty in understanding references to remote objects, mean that it is particularly

important that the design is fit for this specific user group. On the other hand, autism is characterised by a deficit in the ability to understand and interact within the social world so many user-centred software design and evaluation techniques, such as participatory design, or simply the asking and answering of questions, may not be appropriate for this group” (Davis et al., 2010).

In the field of HCI, many evaluation methods designed for use with children are intended to rely as little as possible on textual information and written responses, and may be suitable for a wide range of participants with different levels of literacy (e.g. Read & MacFarlane, 2006; Barendregt et al., 2008; Zaman, 2009; Markopoulos et al., 2008). For example, the Problem Identification Picture Cards method was designed using PCS symbols that were intended for children with communication difficulties (Barendregt et al., 2008). However, as Davis et al. (2010) illustrated, methods which require a large amount of social interaction and communication such as contextual inquiry (Druin, 1999) which may be advocated for use with young people to increase participation (see for example Hourcade, 2008), or interviewing techniques (e.g. Zaman & Abeele, 2010) may not be appropriate for all user groups with special needs. Some research has sought to address this, exploring methods for enabling participation in the design and evaluation of software; for example, Checkley et al. (2010) discuss the difficulty of obtaining feedback from children using Voice Output Communication Aids (VOCAs), and suggests that the use of an 'expert witness' may also be helpful, particularly when several sources are used (e.g. teachers and parents), as a single source may have a particular bias which may not reflect the child's views fairly. Millen et al. (2011) report some success with modifying existing participatory methods to better suit the participants, for example through presenting a visual schedule of the tasks to be conducted, prompts and discussion points for difficult concepts, and structuring design activities through mind maps. Davis et al. (2010) put forward a list of guidelines for conducting trials of software with autistic children, stressing the need for researchers to be familiar with their intended user group (both in theory, e.g. knowledge of their needs and limitations, and in practice, e.g. being familiar to them so as not to cause distress), and the need to plan a study carefully to ensure a smooth and stress-free experience for all. In fact, this is advice which holds true when designing for research with any users, and has already been promoted when designing studies involving children (see Markopoulos et al., 2008), but, as Davis et al. point out, it is particularly important to remember these guidelines when the users may have particular difficulties in adapting to difficult or unfamiliar situations.

Related to this is the issue of ‘informed consent’, which is seen as vital for participation in research studies. For example, the British Psychological Society’s Code of Human Research Ethics cites ‘Valid Consent’ as one of the key principles that need to be addressed when conducting research with people (BPS, 2010). This code of practice is considered key to psychology research, and has also been adopted by other social science disciplines. In the context of working with young people, the code states that “the consent of participants in research, whatever their age or competence, should always be sought, by means

appropriate to their age and competence level. For children under 16 years of age and for other persons where capacity to consent may be impaired the additional consent of parents or those with legal responsibility for the individual should normally also be sought.” Ability to withdraw consent is also considered critical to ethical involvement of participants, particularly for those where they may have difficulty in making the decision to give or refuse consent: “In the case of very young children, and persons with very limited competence, their assent should be regularly monitored by sensitive attention to any signs, verbal or non-verbal, that they are not wholly willing to continue with the data collection” (BPS, 2010). Sometimes, even the act of giving consent may be difficult for some young people; for example Waller et al. (2009) mention that for their study involving young people with cerebral palsy who relied on augmentative and alternative communication (AAC), children had to use a rubber stamp with a yes or no symbol to indicate giving consent to take part. Where there is a difficulty with people with profound learning disabilities, communication or cognitive impairments providing informed consent, researchers need to be aware of the requirements of the Mental Capacity Act and ensure that inclusion in research is carefully justified (see Farmer & Macleod, 2011).

Informed consent, however, also implies that participants fully understand the implications of taking part in an activity. There has been a lot of research noting the difficulty of informed consent for young people, which is made even more difficult when working with young people with special needs (discussed further in J.A. Wright et al., 2011). To give informed consent, participants need to understand what data they are giving and what will be done with it, the purpose of the research, perhaps even aspects such as the overall aims or funding sources for the research – this may not be obvious for some people who are not familiar with research, and may be particularly hard for young people to understand. Some conditions or impairments may also make it harder to ensure informed consent, for example Feng et al. (2010) note a difficulty with children with Down Syndrome being overly trusting and struggling to comprehend why their personal security is important. The question of how to effectively ensure informed consent from children, particularly those with disabilities, remains a topic that is in need of more investigation.

In a related matter, the BPS code also states that “researchers will respect the privacy of individuals, and will ensure that individuals are not personally identifiable, except in exceptional circumstances and then only with clear, unambiguous informed consent” (BPS, 2010). This is in direct conflict with a different approach in research with children, where some researchers feel that children who are acting as co-researchers should be given appropriate recognition and credit for their contributions, including naming them in the acknowledgements of published work or even as co-authors (e.g. see Kidsteam at the University of Maryland⁵). The British Educational Research Association (BERA) notes this conflict in their ethical guidelines for educational research, noting that “researchers must recognize the participants' entitlement to privacy and must accord them their rights to confidentiality and anonymity [...] Conversely, researchers must also recognize participants'

⁵ Kidsteam: <http://www.cs.umd.edu/hcil/kiddesign/>

rights to be identified with any publication of their original works or other inputs, if they so wish” (BERA, 2011). This is a difficult issue, particularly since children (or parents) may be happy to give consent at the time of being asked, but may not realise the implications of being named in published works or web pages which will be archived and persist over time, and which it may be very difficult to remove names from at a later date. Ultimately, ethical decisions are usually left to the discretion of researchers, ethics boards and institutional policies on a case-by-case basis, with the potential for huge degrees of variation across disciplines, institutions and countries, meaning that it may be very difficult to determine if research is being carried out ethically. The Office for Disability Issues provides advice for researchers on how to manage meaningful involvement from disabled people in social research which may be a useful starting point (Farmer & Macleod, 2011), but the BPS also give these words of caution which may be appropriate for all researchers in this field: “no code can replace the need for psychologists to use their professional and ethical judgement” and that “thinking is not optional” (BPS, 2009).

Several sources point to the need for more longitudinal work in the field of assistive technologies (e.g. Maor et al., 2011; Hourcade, 2008; Gersten & Edyburn, 2007). As for a lot of research work conducted in education and social sciences, a large number of studies are based on short-term experimentation or medium-term interventions which may only span a few weeks or months. Several researchers have identified the need to follow up after interventions, to see if there has been any lasting effect or real positive change. This is particularly important since discontinuation is a known issue with technology and particularly assistive technologies (e.g. Phillips & Zhao, 1993; Riemer-Reiss & Wacker, 2000).

Another factor which is hard to cover in short-term studies is the need to consider the wider context of use. In a review of journal articles on assistive technologies for disabled individuals published between 1988 and 2003, Alper and Raharinirina noted that very few studies considered the use of technologies in the home, or the involvement of families, which was felt to be a key issue in the adoption and continued use of technologies (Alper & Raharinirina, 2006). Hayes et al. (2010) note the importance of involving and supporting communication with caregivers, and also between the many different types of caregivers which may play a part in a child’s life. Wright et al. also suggest that the involvement of families including grandparents can be beneficial to interventions, and that reframing parents’ expectations is a key part of interventions (C. Wright et al., 2011). Jeffs et al. echo this, stressing the importance of parental involvement to overcome barriers to adoption of assistive technologies, particularly those caused by difficulties in getting schools to adopt new approaches: “Family, school, and community partnerships can provide avenues to cross the barriers that face implementation of assistive technology and literacy learning in our schools. In order to infuse AT into the lives of children with disabilities, parents and school personnel must join forces in listening, learning, and sharing information and resources” (Jeffs et al., 2006).

The family are not the only parts of the learner's wider context that may have been overlooked in studies. For example, an article by Beigel notes the importance of considering all environments that education may encompass (Beigel, 2000). Alper and Raharinirina (2006) also suggest the need to involve teachers more in studies conducted with their pupils, and the need to investigate “effective teaching strategies for maintenance and generalization”, and Elliot et al. (2003) note that “successful implementation of assistive technology depends on the ability to satisfy both student needs and educators' values”. This is echoed in a UNESCO report on innovative practice concerning ICTs in education for disabled people, where one of the recommendations made is that teachers’ knowledge of assistive technologies and their attitudes towards it are vital:

“Promoting positive attitudes towards the use of ICTs within different stakeholders groups may be as important as providing learners with a range of specialist ICTs. The attitudes teachers in particular hold in relation to using ICT are crucial. Positive attitudes can be fostered by the provision of appropriate training, support, resources and practical experiences in using ICTs. Teachers require access to such experiences to help them develop the necessary positive attitudes to using ICT effectively to support the needs of learners with disabilities” (Watkins, 2011).

Viewing education as a social practice, in which the relationship between the learner and the teacher is vital, then the knowledge and the attitudes of the educators towards technology in general, and assistive technology in particular, are key factors which should not be overlooked.

Another serious issue that several researchers have commented on is the need for more academic rigour across the discipline (e.g. Maor et al., 2011; Edyburn, 2010; Gersten et al., 2005; Gersten & Edyburn, 2007). In an early paper, Stevens & Edwards (1996) discussed the difficulty with conducting evaluations of assistive technologies in a scientifically rigorous manner, and it seems that this remains a difficulty for researchers in the field. Hoppestad (2007) notes that “many of the success stories regarding AT interventions are anecdotal in nature due to a shortage of controlled experiments on the efficacy of AT.” Similarly, Hourcade has also called for more empirically grounded guidelines for young people’s use of technology in general (Hourcade, 2008), suggesting that this is a shortcoming of related fields as well, perhaps due to the difficulty of conducting controlled experiments with young people and new technology. Edyburn also notes that persistently more is published in the field of practice involving special educational technology than research on it (Edyburn, 2003; 2004). Integrity of research is vital to the field, as without this there can be no compelling evidence for the use of one approach over another. Nevertheless, it is an inherent challenge of a multi-disciplinary research area that all disciplines have their own (and often conflicting) understandings of what makes ‘good research’, and practices which may be commonplace to researchers from one background may not be familiar to others. Similarly, while legislation such as the No Child Left Behind Act in the USA calls for interventions to be based on ‘scientifically-based research’, the meaning of this may not be clear to all educators, who may not understand how to critically assess research papers for

rigour, objectivity and validity (see Edyburn, 2010). Aiming to address this, specific guidelines for assessing the quality of research on educational technology for special needs have been produced (Gersten et al., 2005; Gersten & Edyburn, 2007), but it may be difficult to put this into practice across all disciplines.

2.3 Structuring a review of approaches and solutions

Moving on from the more general discussions relating to the field in general, the next question that arose in this work was how to split up the vast literature on more specific assistive learning technology approaches. It has already been stated that the intention of this review was to focus on technologies specifically for learning, and using Abbott's three classes of assistive technologies (Abbott, 2007, discussed in Section 2.1), it was decided that it would aim to focus for the most part on enabling technologies. Nevertheless, this still leaves us with a huge body of literature covering a range of different learning needs and solutions, and there are several different 'lenses' through which the work could be investigated.

For use of assistive learning technologies to be effective, this arguably requires an understanding of three key concepts: 1) the user's needs, abilities and goals, 2) the technology itself and its capabilities, and 3) the context of use (for example in this case the educational context). This therefore provides three different ways in which to divide up the literature, for example by type of users (e.g. a specific impairment), by type of technology, or by educational setting.

All of these broad categories are problematic though, and each has their limitations – for example, there can be an overlap between technologies (such as tablets blurring the line between mobiles and surface interaction), difficulties in defining disabilities (see Section 2.1), and an inconsistency of education systems between countries (for example 'pre-school' varies considerably in age ranges between different countries). 'Educational setting' might include specific topics or learning goals being addressed when using the technology, such as reading, writing, or numeracy, or also wider goals such as sequencing or organisation; alternatively it might focus on the context such as the type of educational establishment (e.g. kindergarten, primary school, secondary school, college or university), and the style of learning which is being expected of the users.

Aside from these three categories of work, there is also the possibility of dividing the literature around discussions of specific issues to be addressed, such as anxiety, self-confidence, independence or inclusion. This also proves to be difficult, as with the exception of inclusion, the research on these areas seems sparse. Perhaps the main reason for this is the fact that topics such as self-confidence or independence are highly dependent on the persons involved, so there is a need to consider how to address these issues for each specific user group in a given context – for example, exploring what would make dyslexic learners at university more independent, or what makes school-aged learners with autism

anxious. Arguably, one main aim of all assistive learning technologies is to address all these issues, in order to create learning environments that are suitable and comfortable for all learners, but perhaps more research is needed on the effectiveness of addressing these specific social factors.

Therefore, for this review the decision was made to address the three broad concepts of users, technology and educational context separately in the first instance. It is hoped that this would help build up a picture of the main themes that are being covered by researchers at present, with the hope that this may help to guide more in-depth reviews of specific topics in the future.

3. Considering learners' needs and abilities

This section of the review will address research that concerns the specific needs of the learners, and some of the conditions and impairments that need to be taken into account.

It is worth noting that some impairments seem to be addressed to a much greater degree than others in the literature. For example, there seems to be a large amount of research on technology for autistic spectrum disorders, especially high-functioning autism and Asperger's syndrome, and on learning difficulties such as dyslexia, as well as visual impairments, while in contrast there seems to be very little on technology to support hearing impairments, and almost no literature on technology to support learners with dyspraxia. This is exacerbated by the fact that some disability groups have active pressure groups, whereas others, particularly people with complex difficulties or no clear 'labels', may not be so well represented or understood. With the wide range of problems people may encounter, it may be better for educators to sometimes think more in terms of their learners all having learning differences rather than some of them having disabilities.

It is also worth noting that many of the disorders covered are spectrum disorders, which may affect different people to different extents, and that a greater difficulty will arise when trying to design technology for learners with a complex set of needs, such as for example as are seen in Down Syndrome (see for example Feng et al., 2010) or Cerebral Palsy (e.g. Waller et al., 2009). It should not be assumed that people sharing a clinical diagnosis will have the same needs or goals, and in providing support there is always a need to consider people as individuals, taking into account their backgrounds and personalities, but there may be some consensus on strategies which are more or less effective for particular groups. This part of the review will not attempt to cover all possible impairments which could affect a learner, but will gather together research on common difficulties or classes of disability which have been studied extensively, in the hope that this will help to build up a picture of common usage of assistive technologies in education, and the state of the research field in general.

3.1 Autism and autistic spectrum disorders

“Autism is a lifelong developmental disability that affects how a person communicates with, and relates to, other people. It also affects how they make sense of the world around them. It is a spectrum condition, which means that, while all people with autism share certain difficulties, their condition will affect them in different ways. Some people with autism are able to live relatively independent lives but others may have accompanying learning disabilities and need a lifetime of specialist support. People with autism may also experience over- or under-sensitivity to sounds, touch,

tastes, smells, light or colours. Asperger syndrome is a form of autism. People with Asperger syndrome are often of average or above average intelligence. They have fewer problems with speech but may still have difficulties with understanding and processing language” (The National Autistic Society, 2012).

Most sources agree that young people with autistic spectrum disorders are a highly heterogeneous population, showing huge variability between individuals and across the spectrum. Nevertheless, some similarities have been noted across the whole population, for example people often refer to the 'triad of impairment' – communication, socialisation, and repetitive/unimaginative and stereotyped patterns of behaviour, play and interests; however, young people's levels of difficulty with these issues, and strategies for dealing with them, may vary greatly. It is also worth noting that opinion is divided over whether autism is best considered a disorder, a disability, or a difference (Dommett, 2011), and autism as a condition is often misunderstood (see for example Muskie, 2002). In accordance with the social model of disability, some have suggested that a person's environment determines their diagnosis of autism more than their score on an autistic spectrum quotient, with not all people needing a diagnosis in order to receive help and support (Dommett, 2011).

A literature review conducted in 2006 (Alper & Raharinirina, 2006) suggested that little research could be found on assistive technologies for autism. This certainly does not seem to be the case now – for example, there seems to be a great deal of research focussing on technology for encouraging social skills and communication in young people, as well as scheduling and organisation skills. However, although there is a growing wealth of literature on assistive technologies for learners with autistic spectrum disorders, Davis et al. (2010) and Farr (2010) both point to the prevalence of research on high-functioning rather than low-functioning autism, suggesting that there is still much work to be done in this area.

There have been many studies on the difficulty of working with users with autistic spectrum disorders in a participatory manner (see Section 2.2 above on participation), though as previously noted there have been many attempts to improve understanding of how to work with this group and involve more potential users. For example, Davis et al. (2010) suggest guidelines for conducting research with children with autistic spectrum disorders, based around a careful understanding of their needs. Similarly, Millen et al. (2011) suggest a method for involving children with autistic spectrum disorders in participatory design through careful structuring of the task. Checkley et al. (2010) also explored the difficulty of obtaining feedback from children using voice output communication aids (VOCAs) in usability evaluations. The SIDES project, which involved the development of a cooperative tabletop game to teach social skills for children with autistic spectrum disorders did involve participatory design with target users, but the researchers noted that interviews in particular were difficult, and they found that group interviews worked better than one-on-one interviews (Piper et al., 2006). Hayes et al. (2010) also discuss an intervention using automatic capture of photographs using a Microsoft SenseCam in an effort to provide non-

vocal children with a form of child-generated media that aimed to give them a 'voice' in communication with others.

It can also be difficult testing new software with users who have difficulty in being flexible, as changes to a user interface they were previously familiar with may cause distress (e.g. Hourcade et al., 2012). Piper et al. (2006) discuss how introducing a new technology as part of the SIDES project caused behavioural problems, as their enthusiasm meant they were talking over each other rather than turn-taking as they had been taught. While this remains a challenging group to work with, it seems that understanding is improving in how best to work with young people with autistic spectrum disorders, meaning that technological solutions can be developed to better suit their needs.

There is a suggestion that technology solutions are particularly effective for this user-group as people with autistic spectrum disorders may benefit from predictable and highly visual environments with clearly defined activities and reward structures, which may be personalised to a user's particular needs and goals (e.g. Hourcade et al., 2012). In fact, some studies have pointed to programmes involving technology as being more effective than standard social skills training, due to the fact that they leverage a motivating aspect for the children involved, allowing the participants to work on something they can feel confident about, and share a genuine common interest with other participants (C. Wright et al., 2011, Wainer et al., 2010). As a therapist using a tabletop game to teach social skills commented, "it's like you're sneaking in learning without them knowing it" (Piper et al., 2006). A quote from a mother of a boy with an autistic spectrum disorder in a different study supports this, as she says "always before when we would go to camps or go to things, he was always quiet in the car. Even with social skills classes. He would go and he participated but he wouldn't refer to them as friends. They're all smart. They understand when we're putting them in social skills classes. They know what we are up to" (C. Wright et al., 2011). Yet in these studies the participants involved unexpectedly displayed a surprising level of social skills when engaged in activities which they enjoyed. Findings from a small study on developing an online portal for learners with Asperger's Syndrome also supports this, suggesting that participants were more engaged in talking with each other about their issues than with forum moderators, as they had a shared understanding of the problems they experienced (MacLeod, 2010).

Many studies talk about the advantage of simply providing a 'positive experience' in remedial skills training, which can help participants build confidence, so this may be another factor in the effectiveness of interventions involving technology. It is however vital that technological solutions are not used in place of 'real' social interaction, as it may encourage dependence on technology, and it is desirable for young people with autistic spectrum disorders to engage in social skills training to remediate this deficit. Since social skills are one of the key aspects which are affected by autism spectrum disorders, there has been a great deal of research into this area, as noted above, including methods for

encouraging collaboration and cooperation as well as addressing inclusion in young people with their peers, which has led to investigating the use of novel technologies to support this.

Large multi-touch surfaces such as tablets and tabletop technologies (see Section 4.4) offer opportunities to support collaboration between users, and this can offer benefits for young people with autistic spectrum disorders, not only to aid inclusion of children who may be at risk of marginalisation, but also to support training in social skills which these individuals may benefit from. Because of this, several researchers have investigated this approach. As a first example, Piper et al. describe the development of a tabletop game which aims to foster collaboration in children with autistic spectrum disorders through the gameplay; while they found the environment worked well for this user group, they also discuss the pros and cons of strict collaboration rules, as some players found this to provide a helpful structure to gameplay which they found reassuring, while others found this to cause an inflexibility which was frustrating when it did not match what they wanted to do (Piper et al., 2006). Building on this, Battocchi et al. (2010) describe the development and testing of a collaborative puzzle game where an interaction rule to force collaboration was found to be beneficial. Similarly, Giusti et al. (2011) describe a suite of tabletop games which require collaboration by players with autistic spectrum disorders, but in this case the software was designed to be used with the support of a therapist in Cognitive-Behavioural Therapy sessions. Hourcade et al. (2012) also explore the use of multi-touch tablets to support social skills such as collaboration and self-expression in children with autistic spectrum disorders through a suite of games; unlike Battocchi et al. and Giusti et al.'s approaches however, in this case, the interaction was not required to be concurrent, but instead required the tablets to be shared and passed on in a turn-taking fashion, as the researchers found this to be more effective with tablet technologies. While the technology seems to be a promising way of supporting social interaction for this group of users, the specific mechanics of the gameplay need careful attention in order to be effective.

Tangible technologies (see Section 4.3) are another novel technology that have been used to promote social interaction in young people with autistic spectrum disorders. As an example, Farr et al. have shown the benefits of tangible technologies to aid collaboration and social interaction for children with autistic spectrum disorders in a number of studies (Farr et al., 2010a and Farr et al., 2010b). Digital construction toys such as Topobo and an augmented Playmobile set were compared against standard Playmobile and Lego toys, with video coding used to analyse social behaviours. Results in both studies indicated that the physical objects which were augmented with digital information proved beneficial to collaborative play, resulting in more cooperative and collaborative play in users with autistic spectrum disorders. The authors suggest that this is due to the interactive nature of the tangible technologies, as contingency analysis indicated that the activities using these devices created more entry points for play, thereby leading to more transitions into collaborative actions.

As well as social skills, scheduling and organisation is another area which has received a great deal of attention, as people with autistic spectrum disorders can struggle with short term memory, organisation and handling events outside a fixed routine, and may need help particularly with transitions between different activities. Clear schedules have been advocated as a way of providing structure in order to reduce anxiety and encourage learners to move from one activity to another, and these have been noted to help when conducting research activities with young people with autistic spectrum disorders (Millen et al., 2011). Traditionally these have been produced using clear pictures such as photographs or visual symbols (see Section 4.5), usually printed on cards, but digital alternatives are beginning to emerge.

One example of a scheduling system used to good effect for young people with autistic spectrum disorders is the vSked system (Cramer et al., 2011; Hayes et al., 2010; Hirano et al., 2010; Yeganyan et al., 2010). Designed to replace existing visual schedules which used symbols on paper to represent activities which would form the plan for the day, vSked instead presents the schedules on mobile devices held by each child in a class, which are then also all visible on a large projected display at the front of the class. The main advantage of the system is arguably for the teacher, as the system does not require huge folders full of pictures to be kept and maintained, and for the paper images to be physically placed on the schedules, which can be time-consuming – instead, the teacher manages the schedule for the whole class from the display at the front, and a huge library of digital images could be used. However, other benefits also became apparent in use, as pupils could clearly see the schedule for the whole class, so they knew what their peers were working on, yet could see their own schedule clearly in front of them. The system also allowed them to keep track of reward tokens which they were working towards, which provided additional encouragement, and there was no chance of error due to a teacher forgetting to give a reward or a child ‘cheating’ by putting extra tokens into their schedules to get rewards sooner. Increased motivation was seen in the use of visual feedback, and even led to more social behaviour being seen, as pupils cheered for their peers when they reached a goal. A further benefit of the system which is less obvious in use is the ability of the technological solution to provide automatic data logging, which can be vital for creating progress reports and visualisation of improvements over time, and can also help to automatically ‘fade’ or remove the visual learning scaffolds over time. Use of this system was studied over the course of a year in two classes of children with autism, yet would need further study to determine long-term effectiveness, as motivation due to the novelty of the system may have played some part in its effects – nevertheless, these studies provide compelling evidence as to the potential benefits that technological solutions may offer over existing solutions.

Studies such as those described above may suggest that young people with autism are keen computer users, and might be expected to make use of a wide variety of assistive technologies. In a study which sought to explore the needs of users with autism beyond the context of the classroom or lab-based studies, Putnam and Chong (2008) conducted a large

anonymous online survey, exploring the overall goals that users wished to have supported in their daily lives, and the technologies that they habitually used. Surprisingly, this survey of technology use suggested that most people who replied did not use assistive software (only 29 out of 114 respondents reported use of software designed for their needs).

However, it should be noted that this did not seem to include any use of mobile or tablet apps, which were presumably not prevalent at the time. In fact, portability was one of the features that their respondents reported as desirable, and it would be interesting to see the results if a similar study were to be conducted again. This suggests that while there may be benefits to software solutions to support young people with autistic spectrum disorders, usage at present may not be as widespread as researchers in the field may wish, and they should be wary of making assumptions as to the use of assistive technologies in the home by this user group.

3.2 Dyslexia and literacy difficulties

“Dyslexia is a hidden disability thought to affect around 10% of the population, 4% severely. It is the most common of the SpLDs. Dyslexia is usually hereditary. A student with dyslexia may mix up letters within words and words within sentences while reading. They may also have difficulty with spelling words correctly while writing; letter reversals are common. However Dyslexia is not only about literacy, although weaknesses in literacy are often the most visible sign. Dyslexia affects the way information is processed, stored and retrieved, with problems of memory, speed of processing, time perception, organisation and sequencing. Some may also have difficulty navigating a route, left and right and compass directions” (The British Dyslexia Association, 2012a).

“Dyslexia is a common type of learning difficulty that primarily affects the skills involved in the reading and spelling of words. Dyslexia should be recognised as a spectrum disorder, with symptoms ranging from very mild to very severe. In particular, people with dyslexia have difficulties with: phonological awareness; verbal memory; verbal processing speed” (NHS Choices, 2012a).

These two definitions show the difference between a clinical definition, provided by the NHS, and a more social definition from the British Dyslexia Association (BDA) that takes other factors of life into account. The most noticeable symptom of dyslexia is likely to be that a learner is having difficulty with text, either reading or writing, although as the definition above from the BDA points out, there are other difficulties that are likely to arise due to dyslexia. It has also been pointed out that many of the symptoms of dyslexia may also be apparent in other learners who have not been assessed, and likewise the interventions that can be beneficial for dyslexic learners may be equally helpful for others (Elliott & Gibbs, 2009). Other accounts propose that dyslexic difficulties occur on a

continuum, with no clear distinction that can be made between those who have it and those who do not (J. Rose, 2009). This means that it may be helpful to address in this section not only individuals classed as 'dyslexic', but also all learners with identifiable literacy difficulties.

Guidelines for presentation of text for dyslexic readers may include the use of coloured overlays or different coloured backgrounds, which has been claimed to reduce visual strain. For example, the BDA has produced a Dyslexia Style Guide which advises the use of cream or a soft pastel colour (BDA, 2012b). Going further, the campaign group CHANGE who give advice on preparing materials for people with learning disabilities state that "any pastel shade is better than white but people with dyslexia find yellow especially helpful" (CHANGE, 2012). This belief that 'yellow is the optimal colour for dyslexia' may be slightly misled. A small-scale study involving a prototype of a customisable word-processing environment suggested that reading ability and perceived ease of reading could be improved when learners were allowed to customise the background colour as well as the text size and font (Gregor et al., 2003). However, a more extensive review of the literature on coloured overlays and tinted lenses (e.g. Irlen lenses) pointed to an inconclusive picture, and the authors concluded that the research could not currently support the use of this approach (Cotton & Evans, 1990). They suggest alternative reasons for why coloured overlays may be beneficial in some cases, such as aiding motivation and improving attention by drawing focus to a specific part of a page. This suggests that the effects indicated in Gregor et al.'s study may be more influenced by personalisation, motivation and confidence rather than the colour of the backgrounds having a particular effect, meaning that it would be hard to suggest a colour which is 'best'. Nevertheless, personal preference plays a large part in motivation and comfort when learning, and so it still seems sensible where possible to allow users to customise a display so that they feel comfortable with it. This may include being able to change not only the colour of the display, but also the size and style of font.

Some guidelines are available for presentation of text for people with dyslexia, such as the Dyslexia Style Guide provided by the BDA (The British Dyslexia Association, 2012a). This includes recommendations such as the type of paper which should be used, font, layout, and writing style, as well as different formats which could be used. The approach of 'Clear Text' has also been put forward as useful for learners with dyslexia or visual impairments, which incorporates aspects from the BDA's style guide (Evetts & Brown, 2005). The characteristics of Clear Text include text formatting and presentation guidelines to aid reading, as well as writing style guides to aid comprehension and reduce phonological difficulties, and also guidelines which take into account the requirements of text which may be read aloud by a screen reader or text-to-speech system. The advantage of this approach is that it should be equally appropriate for learners without identified learning difficulties, taking guidance from the Plain English Campaign which is intended for all readers, and which may also benefit learners with other difficulties such as those who are non-native language speakers, who are dealing with a subject which is difficult to understand, or who are simply tired. For this reason, having text that is clearly and simply written (i.e. without

jargon) and presented in a clear and non-distracting manner is also well covered by standard usability guidelines for interface design. For an example of this, see Usability.gov's set of research-based guidelines (U.S. Dept. of Health and Human Services, 2006), Guidelines 2:9, 11:1, 11:3, 11:7, 11:8, 14:1, 15:2, 15:3, 15:6, 15:7, 15:8, 15:9 – it should also be noted that all of these are sourced from the general-purpose usability guidelines and do not include the 'accessibility' guidelines.

Problems with processing text can also lead to problems when trying to fit within otherwise pedagogically sound environments – for example Woodfine et al. discuss the difficulties which arise when students with dyslexia are expected to use text-based synchronous e-learning environments such as online chat rooms (Woodfine et al., 2008). Here the difficulty arises not just from a difficulty in reading text, which was difficult as it passed by the user quickly, but also from a difficulty in writing at the speed of other students using the system, leading to miscommunication errors, and to low self-confidence. While the ability to collaborate on a problem with peers in real time may be advantageous as a learning experience, educators need to ensure that the environments do not disadvantage some learners in the process: for example, use of asynchronous chat-rooms might help to hide difficulties and provide an environment where all learners can collaborate more easily (e.g. MacLeod, 2010).

Many sources advocate audio solutions as a way of bypassing difficulties with text, for example through the use of text-to-speech and speech-to-text software which can act as compensatory technologies and which may prove highly useful for some learners. Text-to-speech software can help those who have difficulty reading, or having text read aloud may provide help in checking their written work for mistakes, while there are reports that highlighting the words as they are spoken helps to focus attention and help understanding (BDA Technology, 2011). Pre-recorded audio in e-book formats (including DAISY format) may also be useful for the same purpose. Meanwhile, speech-to-text, or voice recognition, can help learners who have difficulty with writing by allowing them to dictate to the computer, which can save time, ensure words are spelt correctly, and help with confidence (Litten, 2012). A wide range of software products exist for text-to-speech and speech-to-text purposes, including freeware solutions such as MyStudyBar⁶. For more on speech-to-text technology, see the later section on voice recognition (Section 4.1).

There is also evidence from the research body that audio solutions may prove beneficial to learners. There are two discrete uses for audio in this context – using it in a compensatory manner, by representing text in a preferable format, and using it in a remedial manner, aiming to increase phonological awareness. For example, Pandey & Srivastava (2011) describe the design of 'Tiblo': tangible blocks which fit together using tessellating shapes. Similar to other existing audio-recording products such as Talking Tins⁷, the Tiblo blocks can store and play back short audio clips, but they are specifically designed to support

⁶ MyStudyBar: http://eduapps.org/?page_id=7

⁷ Talking Tins: <http://www.talkingproducts.com/>

children with dyslexia, by allowing them to actively build connections between the audio and visual information.

Phonological awareness is known to be important in developing literacy, and so audio has also been explored for this use; for example recently Shamir et al. (2012) have explored the use of e-books which speak text aloud as a means to promote literacy in pre-school children identified as being at risk from learning difficulties. Identification of homophones may be particularly difficult, which is why software to assist writing (e.g. Read & Write Gold) often includes not only text-to-speech capabilities, but also a homophone detection tool, which has been shown to be beneficial as a compensatory technology to improve spelling (Lange et al., 2006), and aid proofreading (Lange et al., 2009), although remedial effects seemed small.

The UDL guidelines (mentioned previously in Section 2) also suggest that multiple means of information representation should be made available if a curriculum is to be made universal, with Checkpoint 1.3 saying to ‘offer alternatives for visual information’, and Checkpoint 2.5 advising to ‘illustrate through multiple media’ (CAST, 2012). However, for educators choosing a medium through which to present learning materials, there is also some evidence that text may in fact be the best presentation material. A study reported by Beacham & Alty (2006) and Alty et al. (2006) tested experimentally the effectiveness of three different conditions of media presentations: text, text with diagrams, and spoken text with diagrams. While students without learning difficulties performed best in the condition with spoken text and diagrams, students with dyslexia surprisingly performed best in the condition with just text. The authors suggested that the other types of media may impose additional cognitive loads on the students, and divide attention, which serves to exacerbate the difficulties that dyslexic students experience. This may particularly be the case for those who have already developed coping strategies for dealing with text, such as students in higher education or adult learners, and so provided there is time for them to read it, this may be the preferable format for e-learning materials at this level. The authors suggest that it may be more important to focus on the content of the material rather than the style of presentation, and ensure the students are not distracted by the medium used (Beacham & Alty, 2006). It is however important that text should be presented in a format which is compatible with screen readers and text-to-speech software for those with severe reading or vision difficulties who choose to use these technologies (see Evett & Brown, 2005; The British Dyslexia Association, 2012a). Awareness of users' needs, together with clearly and carefully designed materials can be an important first step, with options for customisation and personalisation where needed.

3.3 Dyscalculia and numeracy difficulties

“A condition that affects the ability to acquire arithmetical skills.

Dyscalculic learners may have difficulty understanding simple number concepts, lack an intuitive grasp of numbers, and have problems learning

number facts and procedures. Even if they produce a correct answer or use a correct method, they may do so mechanically and without confidence” (The British Dyslexia Association, 2012b).

Dyscalculia has been often referred to as 'dyslexia for numbers', yet as an impairment receives much less attention than dyslexia. A report on mental health and wellbeing by Beddington et al. noted that “developmental dyscalculia is currently the poor relation of dyslexia, with a much lower public profile. But the consequences of dyscalculia are at least as severe as those for dyslexia” (Beddington et al., 2008).

Research has been conducted on dyscalculia from a neuroscience perspective, providing evidence for a core deficit in processing numerosities (Butterworth et al., 2011). However, another way to think about dyscalculia is that it could be symptomatic of the type of maths teaching used in schools, as Butterworth et al. suggest: “one way of thinking about dyscalculia is that the typical school environment does not provide the right kind of experiences to enable the dyscalculic brain to develop normally to learn arithmetic” (Butterworth et al., 2011). The suggestion that arises from this view is that if technology is to be used alongside regular teaching for the support of dyscalculia, then remediation through educational software (i.e. computer-aided instruction) should be considered more than compensation (for example through use of calculators) at least in early education, and particularly that education should focus on manipulation activities, providing informational feedback and intrinsic motivation, with adaptive software possibly providing the means to do this (Butterworth et al., 2011). Some solutions have aimed to do this, both specifically aimed at learners with dyscalculia (e.g. Pareto, 2005) and at more generally aimed at numeracy (e.g. Manches et al., 2010). A great deal of software is available to improve numeracy skills in different ways, and a wide variety is used across schools, as identified in a report by Laurillard & Baajour (2009). A particular strength of the software that was noted in this report is in being able to personalise it to the user, and also have it customised by a teacher – the aim, the authors say, is not in replacing the teacher, but in extending the amount of targeted practice that the learner can do, complement the tasks being done in the physical world through interactive tasks that are unique to a virtual environment, and allow the SEN teaching community to share their best ideas and teaching strategies.

Overall, there is a call for more recognition of the condition, and more research in the area (Beddington et al., 2008; Butterworth et al., 2011). However, while there is a dearth of literature on assistive technologies specifically for dyscalculia, it should be noted that there is a vast array of literature in the field of numeracy and mathematics education, including a wide range of technology solutions, particularly in the field of computer-aided instruction. There is also a sizeable literature on topics such as ‘maths anxiety’, which despite having a very different focus may still prove useful in this area.

3.4 ADHD

“Attention deficit hyperactivity disorder (ADHD) is a group of behavioural symptoms that include inattentiveness, hyperactivity and impulsiveness. Attention deficit disorder (ADD) is a type of ADHD. Common symptoms of ADHD include: a short attention span; restlessness; being easily distracted; constant fidgeting. Many people with ADHD also have additional problems, such as sleep disorders or learning difficulties. However, ADHD has no effect on intelligence” (NHS Choices, 2010a).

ADHD is not always considered a learning difficulty, but some argue that it should be treated as one. For example, in 2004 the National Attention Deficit Disorder Information and Support Service (ADDISS) conducted a survey of over 50 children with ADHD and 90 parents, and identified factors associated with ADHD which caused severe difficulties for children in schools, and subsequently claimed in its conclusions that “parents know only too well that ADHD is often perceived by others as purely a behavioural problem rather than a learning disorder. This cruel denial must constantly be challenged and overturned if our children are to be properly helped” (ADDISS, 2005). It is also common for young people with other conditions such as autistic spectrum disorders to also be diagnosed with ADHD, meaning that ADHD may affect many young people in education.

Perhaps because of this confusion about the classification of ADHD, there is little literature on technology approaches to supporting learners specifically with ADHD, although it is often addressed in literature on support for autistic spectrum disorders due to the common comorbidity with this condition. It can be hard for designers to find guidance on designing for ADHD, yet following standard usability guidelines carefully may be sufficient, at least as a first step (McKnight, 2010). Technological solutions which are aimed at supporting learners with ADHD can include tools to encourage learners with attentional difficulties to focus on tasks (e.g. Hribar, 2011), computer-aided instruction to rehearse appropriate social behaviour (e.g. Fenstermacher et al., 2006) as well as software to support inclusion and collaboration (e.g. Tan & Cheung, 2006; Paananen & Myllykoski, 2009). This latter type of software is equally important, as peer acceptance and inclusion can be a problem for children with ADHD, since they may find acceptable social behaviour to be difficult. This shows how remedial technologies (i.e. those to rehearse appropriate behaviour) may not be the only suitable choices for a group of learners, and may be best mixed with compensatory technologies (e.g. those to make tasks easier to focus on), as well as sympathetically-designed environments which are suitable for learners with special needs to use alongside their peers.

3.5 Visual impairments

“Visual impairment is when a person experiences some degree of sight loss which cannot be corrected using glasses or contact lenses. There are two main categories of visual impairment: being partially sighted, or sight

impaired – where the level of sight loss is moderate; blindness, or severe sight impairment – where the level of sight loss is so severe that a person is unable to complete any activities that rely on eyesight” (NHS Choices, 2012b).

According to the RNIB, “almost two million people in the UK are living with sight loss” (RNIB, 2012a), although this includes sight loss due to age-related conditions. Visual impairments are not classed as a learning disability, but they may cause difficulties in learning and so are worth covering briefly here. Many technology solutions aimed at individuals with visual impairments may be classed more as technologies to provide access to learning rather than assistive learning technologies, due to their wider benefits (see Section 2.1). However, the UN Convention on the Rights of Persons with Disabilities includes requirements that States Parties take measures towards supporting people with visual impairments in education that go beyond simply providing access to information, including “ensuring that the education of persons, and in particular children, who are blind, deaf or deafblind, is delivered in the most appropriate languages and modes and means of communication for the individual, and in environments which maximize academic and social development” (UN General Assembly, 2007: Article 24, 3c).

Assistive technology solutions for visual impairments are well covered in the literature. For example, computer systems for blind users are discussed in some of the earliest HCI literature on assistive technologies. A report in the Communications of the ACM from 1964 on computer programming for blind people even claims that that “the blind may be especially suited for programming work. Because of intense training in and constant experience with locating objects in the unseen environment and also because of superbly trained memory, the blind brings to the work of programming, skills which the sighted has had little need to acquire. These qualifications should result in fewer debugging problems and make the blind a valuable addition to any systems group” (Sterling et al., 1964). At this stage though, workstations needed to be specially designed to accommodate blind users. In contrast, by the early 1990s, ACM reports were noting the wide variety of assistive technologies available for blind and vision impaired individuals working with mainstream personal computers, such as screen readers and speech synthesizers, although they noted a difficulty when working with graphical displays (such as Windows), and that for people with vision impairments who preferred not to use a screen reader, “the 80-character wide by 25-line deep text display of the normal computer screen is far too small to be read easily by individuals with limited vision” (Brown, 1992).

These days, a wide variety of technology solutions exist for those with visual impairments to use standard educational equipment, such as screen readers and text-to-speech systems (simple versions of which are often built into operating systems as standard), and on-screen magnification or handheld electronic magnifiers for printed texts. Specialist equipment includes Braille keyboards and displays, or audio players for example using the DAISY standard. Technology research also often addresses ways to adapt mainstream technology

for non-visual use, for example touch-screen mobile phones (Neff et al., 2010) or game interfaces (Yuan & Folmer, 2008). A paper by Power and Jürgensen provides an overview of information presentation formats for people with visual disabilities, such as audio and tactile methods, and including the difficulty of representing graphical and mathematical information (Power & Jürgensen, 2010).

Research in this field is also moving on to consider the social implications of technology used and the wider context of use. For example, Calder (2010) proposes that a 'digital ecosystem' approach is needed in the design of devices for people with visual impairments, and that this can result in devices which better suit the users' requirements. Going further, Shinohara & Wobbrock (2011) conducted in-depth interviews of 20 assistive technology users, 15 of whom had vision impairments; they took a grounded theory approach, aiming to build an understanding of how the technology they used affected their lives, and in particular their peers' perceptions of their technology use. They noted that their participants had a strong desire to use technology to do things "just like everyone else", as this quote from one blind participant illustrates: "You know, if someone's using an iPhone, and I'm using an iPhone, that's normal, right? It's the same thing... like universal design, you build the accessibility directly into the products, then you're not using some clunky, blindness specific product. [...] cell phones have, like, all these neat features and stuff, but, ...the BrailleNote's just catching up. [...] it doesn't even have like, 802.11n, which is the new networking standard. You know, but it costs six grand. I mean, come on" (quoted from Shinohara & Wobbrock, 2011). Participants spoke of a desire to have equal access to information as their peers, and said they felt empowered by use of their devices, but they were also highly aware of the attractiveness and desirability of the devices they used, and the self-consciousness that arose from using non-mainstream devices. They also spoke of misunderstandings from people around them, who often wrongly believed that either the technologies eliminated a disability, or that the person would be 'helpless' without their devices. This suggests that a culture of understanding is needed in environments where different people may be using different technologies, and that universally designed mainstream devices may help to alleviate some of the 'stigma' attached to assistive technology devices.

Research on interfaces for users with low vision has also highlighted the need for careful user-aware design. Evett & Brown (2005) suggest the need for interface designers to use 'Clear Text', which advocates strategies such as use of a clear font with good visual contrast from the background colour, careful use of spacing, consistency in navigational aids and other visual design features, as well as appreciation for those using screen readers, for example ensuring punctuation after bullet points, full stops after headings, and avoiding unnecessary use of tables.

3.6 *Hearing impairments and d/Deaf learners*

“Hearing impairment, or deafness, is when your hearing is affected by a condition or injury. Some people are born with a hearing loss while others may develop it as they get older. Most commonly, hearing loss happens with age or is caused by loud noises” (NHS Choices, 2011).

As for visual impairments, hearing impairments are not classed as learning disabilities, although again this is a condition which may impact on learning, and which requires ensuring that education is delivered in the most appropriate means, so is worth briefly covering here. First though, there is a distinction which must be drawn between 'deaf', which is a medical term indicating some degree of hearing loss, and 'Deaf', where the capitalisation is used to indicate membership in a cultural group which some (but not all) deaf people feel they belong to (see Action on Hearing Loss, 2012; Portolano, 2012; MSM Productions Ltd., 2012; Drolsbaugh, 2012). The concept of a Deaf culture is protected in the UN Convention on the Rights of Persons with Disabilities, including requirements for “facilitating the learning of sign language and the promotion of the linguistic identity of the deaf community”, and agreeing that “persons with disabilities shall be entitled, on an equal basis with others, to recognition and support of their specific cultural and linguistic identity, including sign languages and deaf culture” (UN General Assembly, 2007: Article 24, 3b; Article 30, 4). In Deaf culture, many Deaf people view deafness not as a disability but more similar to an ethnic minority (MSM Productions Ltd., 2012) or simply as a “different way of being” (Portolano, 2012). When considering the nature of educational tools to support deaf learners it is important to recognise this, and to consider how the technology can be used to help remove barriers to education in a way that is appropriate to a person's culture, sub-culture and beliefs.

A variety of technologies are available to support hearing impairments depending on the level of impairment, with hearing aids and induction loops being perhaps the most well-known. However, many of these technologies can be considered to provide access to learning rather than being assistive learning technologies (see Section 2.1). Computing support for hearing impairments has also been addressed from a surprisingly early stage, with software designed to replace computer beeps and error tones with visual warnings, and word processors which monitor text for spelling and grammar errors that people with hearing difficulties are more likely to make (see Brown, 1992). However, while some software support is available, there are still areas of research left to explore.

One topic of research which seems to need more attention is on the difficulty in communication between children with hearing impairments with their non-disabled peers or classmates. In a recent issue of SEN Magazine, it was suggested that since around 85% of deaf children now receive mainstream education, sign language should be taught as a second language for all pupils, not only reserved for those with hearing impairments (Edwards, 2012). Signing is gaining popularity in common culture however, with a range of

programmes on the children's television channel CBeebies using Makaton⁸, which incorporates signs from British Sign Language (BBC, 2012). While technology can offer communication benefits between people who have hearing impairments and those who do not through the use of alternative methods of communication such as text, increased awareness of sign languages could help promote a culture of understanding.

Teaching sign language to young people with hearing impairments can already be a difficult task, although technological solutions have been proposed to aid this. For example, Henderson et al. (2005) describe a design for a game which requires players to perform a sign in order to perform in-game actions. While online games already exist where a player is encouraged to perform a sign at a prompt (e.g. CBeebies 'Something Special'⁹), Henderson et al.'s proposed solution used gesture recognition to ensure the sign was performed correctly, so that signing (and preferably correct signing) was not only encouraged but required. While the gesture recognition technology struggled to recognise signs accurately, and Henderson et al. had to prototype their system using a 'Wizard of Oz' system (with signs recognised by a hidden human participant), future developments with this technology may offer benefits to recognising and automatically translating signs.

Another approach to teaching sign language which could have more immediate benefits could be found in using tangible technologies (see Section 4.3). For example, Parton et al. (2010) describe a system using RFID tags to associate real physical objects with a video of a person performing a sign, as well as other images showing variations of the object, the written translation and an audio file of the spoken word. The advantages of this approach are that teachers can attach tags to real objects found in a child's environment, which the child can then scan at a computer point to help learn the sign for that object. The flexible and affordable nature of the tags means they can be attached to a wide variety of objects, and easily reused as a vocabulary expands, provided that time is spent in creating the digital materials which are associated with them. This can have benefits for young children who need to learn signs for common objects, but this approach may not work so well for concepts such as sentence structure, or non-tangible concepts such as 'hungry' or 'work'.

3.7 Mobility impairments

The term 'mobility impairment' may cover a range of conditions relating to physical disabilities, including difficulties with dexterity and coordination. Most physical impairments are not considered to be learning difficulties, although learning (and particularly access to learning) may be difficult. Learning through physical 'hands-on' manipulation of objects can also be made difficult, which can affect learning some concepts which would normally benefit from tangible feedback (see for example Cook et al., 2002). Communication may also be affected, for example through speech or writing.

⁸ Makaton: <http://www.makaton.org/>

⁹ CBeebies Something Special: <http://www.bbc.co.uk/cbeebies/something-special/>

There is a great deal of technology that is classed as ‘assistive’ for users with mobility impairments, for example for rehabilitation or increased access, but as discussed earlier many of these may fall under the category of access to learning and not learning technologies, meaning they are partially out of the scope of this review (see Section 2.1). The degree to which an assistive technology to support mobility impairments can be classed as a learning technology might perhaps be related to the type of motor skills which they aim to compensate for – for example, a wheelchair would not normally be counted as a learning technology, although it enables access to learning, but voice recognition or literacy support for users with cerebral palsy or dyspraxia might be. Dyspraxia is a condition which affects movement, yet is often classed as a learning difficulty, and so this is addressed separately in section 3.8.

One issue which should be considered is the topic of inclusion and social interaction for users who struggle with communication. A particular difficulty arises in fostering quality interaction with peers, and there have been many studies into how to address this through technology. While the field of alternative and augmentative communication (AAC) shows there are many opportunities for communication through different measures, they need to consider the wider context of use which a young person might encounter. For example, in describing the design of a tool to generate words through phonics using a joystick, Black (2011) notes that one key feature should be the ability to create ‘undesirable’ words, such as swear words, which would not be possible using many VOCAs. This was found to be enjoyable for users, and also allows for more unrestricted social interaction with peers. In a similar vein, Waller et al. (2009) describe their design for a joke generation tool for children with cerebral palsy who use AAC. Not only does this allow children to engage with their peers in an entertaining and sociable manner, but the researchers argue that use of jokes allows children to rehearse literacy and conversation skills such as turn-taking, which can have benefits to future communication and social interaction. Online communication may also present challenges. For example, Lewis (2010) notes that online social networks such as Facebook can be popular for users with cerebral palsy, who felt that they were important for their independence and communication needs; however, sites such as these were reported to be made frustrating and difficult to use by usability flaws in the interfaces, for example when the interface changed frequently due to re-designs and new features. This is particularly an issue when using switches to access the interface. These studies show that careful attention must be taken not to exclude this group of learners from communication methods and social functions that their peers would expect to use.

3.8 Dyspraxia

“Dyspraxia, also known as developmental co-ordination disorder, is a disability that affects movement and co-ordination. It is thought to be caused by a disruption in the way messages from the brain are transmitted to the body. Dyspraxia is characterised by difficulty in planning smooth, co-ordinated movements. This leads to: clumsiness; lack of co-ordination; problems with language, perception and thought” (NHS Choices, 2010).

Dyspraxia is a specific learning difficulty which is relatively common in UK schools, with the Dyspraxia Foundation estimating that it affects up to 10% of the population, and severely affects up to 2% (Dyspraxia Foundation, 2012). As well as difficulties with coordination and movement, there is evidence that learners with dyspraxia may also experience lower levels of independence and difficulties in interacting with peers (Bart et al., 2011). Yet despite this, there seems to be very little research literature on technology to support dyspraxia.

One recent initiative however which aims to support young children with dyspraxia is ‘Tree Fu Tom’¹⁰, which is a series of television programmes on the CBeebies channel, accompanied by a series of online games on the channel’s website. Developed in collaboration with the Dyspraxia Foundation, the series involves animated fantasy characters who take part in adventures, for which they (and the audience) need to perform ‘magic spells’. These ‘spells’ are performed through physical actions, which are designed to mimic typical movements used by physiotherapists to aid children with movement and coordination difficulties. In this way, by acting along with the television programme or online games, the children are encouraged to practice the movement skills which they need, in a motivating environment. While this is a new initiative, it provides an example of how popular culture may be used to provide environments which are not only supportive but also engaging for young people.

3.9 Considering learners’ needs and abilities: summary and discussion

From this exploration of the needs of some types of learners, it can be seen that there is a strong need to consider the needs of the user carefully in the design of technology, not only so that their needs are best supported, but also as they may not conform to expectations (e.g. Davis et al., 2010; Beacham & Alty, 2006; C. Wright et al., 2011). The needs and abilities of users are important to bear in mind not only when designing software or hardware solutions, but also when designing evaluations or studies which involve young people, as otherwise the data gathered may be misleading due to misunderstandings between the researchers and the participants.

It would also seem that a great deal of literature focuses on specific and diagnosed impairments rather than general difficulties (e.g. dyslexia rather than reading difficulties, dyscalculia rather than poor numeracy), but there are suggestions from some that this may not always be the best approach (e.g. Elliott & Gibbs, 2009). It is also clear that some disabilities are given a lot more attention than others, for example there is a growing wealth of literature on dyslexia and high-functioning autistic spectrum disorders, and a surprisingly long history of computer design for blind users, yet there is a lack of literature on low-functioning autistic spectrum disorders, ADHD and dyspraxia, which may perhaps be due to these having been identified more recently. Moving beyond accessibility, there also appears to be much less literature on non-functional needs of learners, for example dealing with

¹⁰ CBeebies ‘Tree Fu Tom’: <http://www.bbc.co.uk/cbeebies/tree-fu-tom/>

concepts such as self-confidence, independence, and quality social interaction with peers. However, as previous literature reviews have noted (e.g. Edyburn, 2003; Edyburn, 2004), the total amount of information available for all technology use for people with special educational needs can make it very difficult to find specific items.

For educators looking to present materials to learners with special needs, many sets of guidelines exist, most of which broadly seem to follow standard usability guidelines. For example, 'Clear Text' guidelines for users with dyslexia and low vision follow Plain English recommendations (Evelt & Brown, 2005), guidelines for ADHD follow usability heuristics (McKnight, 2010), and similarly guidelines for web design for children with Down Syndrome have been noted to closely follow standard web design guidelines (Feng et al., 2010). This does suggest that usability guidelines are useful to follow, at least as a first step. This does also beg the question of whether or not individual groups need to produce their own guidelines, when they simply confirm existing research. However, there are arguments for why these may be useful. First, perhaps obviously, they may be useful for those who are not familiar with usability guidelines and research in this field. Second, it is of course important to question established or 'accepted' research, and particularly in light of non-typical users – findings which support existing research can only strengthen it, while it is important to identify where standard guidelines are not appropriate. Third, given the large amount of usability guidelines available, specific ones for specific needs can be useful to help designers prioritise requirements. Finally, users with special needs may be more prone to suffer when poor usability is used, so guidelines may need to be followed more carefully when designing for users with special needs, or for mainstream classroom environments which need to support a diverse range of learners, which means that it is important to highlight key points. Building a greater awareness of learners' needs can only be helpful to the learners and researchers alike.

4. Considering technology

It is worth considering that some technology approaches may have benefits for a wide variety of learners, and therefore it may be best to consider them separately in their own right rather than only associated with one group of learners or type of impairment. This is particularly relevant if there is to be a move from solutions based on the individual approach (which might be considered the traditional assistive technology approach) towards mainstream devices and universal design that takes all users into consideration. Many assistive technologies which would have previously been considered specialist are now also becoming more commonplace – for example text-to-speech and speech-to-text functions are becoming available as standard in many common operating systems. This section will therefore highlight some of the key technologies which are recurring in the literature as beneficial to learners with learning difficulties or special needs.

4.1 Voice recognition

Voice recognition, speech recognition or speech-to-text technology acts by allowing a user to speak into a microphone, with their voice input recognised by the computer software. This may then be used to activate commands or perform functions on the computer without the use of a keyboard or mouse, or may be used to dictate text into a word-processing or text editing package. Nuance's Dragon software¹¹ is perhaps one of the best known examples of speech-to-text dictation packages, while voice recognition is also becoming available in Windows and MacOS operating systems as standard, as well as many mobile phones. Dictation software using Windows Speech Recognition is also included in MyStudyBar¹², a toolkit of free applications designed to support a broad range of learning and literacy difficulties.

Voice recognition software may be an appropriate compensatory technology for learners such as those with dyslexia who have severe difficulties with writing. De La Paz (1999) provides a detailed review of the literature on voice recognition software and standard dictation, and although there are conflicting results between studies a potential benefit may be seen, resulting in improved writing for some learners. In one study, Higgins and Raskind (1995) explored the use of Dragon Dictate for students with learning difficulties, and saw a statistically significant increase in essay scores over essays produced without assistance, resulting in the scores relating closely to the scores of non-disabled students. Analysis of the essays suggested that the scores were correlated to the number of long words (over 7 letters), use of which is encouraged by the speech recognition software. In a rare instance of longitudinal observation, further study of these same students over the following 2 years indicated continued increased performance in reading and writing (see Raskind & Higgins,

¹¹ Nuance Dragon: <http://www.nuance.com/dragon/index.htm>

¹² MyStudyBar: http://eduapps.org/?page_id=7

1999). The authors suggest that the software may in fact have a remedial as well as a compensatory effect for students with writing difficulties. Reasons for this are not clear, but the authors suggest that it is linked to increased phonological awareness, which has been shown to affect literacy. However, from a review of a number of studies in this area, De La Paz (1999) shows that the key to achieving success in oral composition may in fact be training in planning and organisation.

4.2 Mobile devices

Mobile devices include mobile phones, but are not limited to this, including also PDAs, multi-purpose devices such as the iPod Touch, and larger tablet or slate technologies (although some medium-sized devices may be categorised under 'surface technologies', as discussed later in Section 4.4). It may also in some cases include smaller laptops and netbooks, or ultra-mobile PCs (UMPCs). There is a growing predominance of touch-screen devices in this category of technology, and a large number of devices have access to an 'app' repository where small applications for the device can be purchased and downloaded directly (e.g. the Apple App Store, Android Market, Nokia Ovi Store, Blackberry App World).

The idea of using mobile devices to support learning in general is not a new one – for example, Alan Kay described the 'DynaBook' in an article written in 1972, which was designed to enable portable computer-based learning (Kay, 1972). The field of mobile learning or 'm-learning' has since been well researched. Pachler (2009) notes that “mobile digital tools, with their small size, ubiquity and functional convergence, enable new possibilities for learning”. He also notes that mobile devices “foreground the socio-cultural dimension of learning in that they enable users to communicate readily with other users. At the same time, they potentially impact on the cognitive dimension of learning, for example by providing new means of lessening the cognitive load for learners associated with not having to commit information to memory in order to have it readily available at any given moment (“always on”). The ability to store digital data locally and access it instantaneously on a portable device, or to access remote data through the internet, frees the learner from the constraints of place that are inherent in data access through libraries or desktop computers” (Pachler, 2009). With all these potential advantages, there is already an argument that the use of mobile devices could be beneficial for learners with varying educational needs.

At the time of preparing this report, mobile devices are not at present considered as assistive technologies that can be funded by the Disabled Students' Allowance. There is nonetheless currently a call for mobiles and tablets to be considered as appropriate tools to support learners (see for example Cision, 2012). Findings from research studies support this, as mobiles, particularly smart-phones and tablets with increased processor power, provide an opportunity to aid learners with special educational needs in several ways:

1) The choice of apps on smart-phones means a user has access to a wide variety of cheap or free software. This is important, as it means they can find software that suits their individual needs. This has been shown to be useful in providing not only a suitable and beneficial solution, but also one which is worth continuing to use (e.g. Phillips & Zhao, 1993; Riemer-Reiss & Wacker, 2000). It is also worth noting that a large number of apps do exist to support learners with special educational needs – for some lists of these, see for example EmpTech¹³, BDA Technology¹⁴, Spectronics¹⁵, A4CWSN¹⁶, Sailers et al. (2012), OpenAutismSoftware¹⁷.

2) Mobiles provide a technological device that the user can carry with them at all times. This means that the device can be used to suit multiple contexts, which might arise particularly when engaged in independent learning (see Raskind, 1994). It also allows the possibility of extending the use from a single learning environment to other activities, including extra-curricular and social uses (Mintz et al., 2012). An article written by a senior advisor at the JISC TechDis service also cites this as desirable, saying that: “the ideal assistive technology tool would be available everywhere because then you can then guarantee you can use it whether you need it in school, college, home or a library” (McNaught, 2011). For example, this article also suggests that learners could email documents to a phone in order to have them read aloud. Having assistive technology tools available at all times also provides support for the multiple contexts needed for lifelong learning – as a UNESCO report on innovative practice in educational technology for disabled people states: “ICTs that support an individual person’s learning must be available to them in any formal or informal learning situation they wish to engage in” (Watkins, 2011).

3) Related to the point above, a mobile which can be carried at all times provides a common device that the user is already familiar and comfortable with. This can have great benefits to reducing anxiety and increasing comfort and acceptance of use (e.g. Mohammedali et al., 2011; Shinohara & Wobbrock, 2011). There is also the concept of ownership which is thought to be useful in allowing learners to take control of their learning environments – for example Pachler argues that “a sense of ownership and the ability to personalise, and appropriate them according to individual needs can result in an increased willingness to utilise mobile devices for learning” (Pachler, 2009).

4) Smart-phones, tablets and other mobile devices with increased processor power usually include an array of in-built sensors, such as accelerometers (movement and tilt sensors), microphones and cameras (which may include light sensors). This allows for the possibility of sensing and context-aware behaviours to be performed by the mobile device's

¹³EmpTech: <http://www.emptech.info/>

¹⁴BDA Technology: <http://bdatech.org/what-technology/small-portable-devices/apps/>

¹⁵Spectronics: <http://www.spectronicsinoz.com/article/apps-for-literacy-support>

¹⁶A4CWSN: <http://a4cwsn.com/>

¹⁷OpenAutismSoftware: <http://www.openautismsoftware.org/> (also described in Hourcade, 2012)

software, which may be beneficial in providing support where and when it is needed (e.g. Farr, 2010; Mintz et al., 2012; Mohammedali et al., 2011).

5) The use of a mainstream device means that it can also be used by a person's peers. This has been shown to help with social acceptance (e.g. Shinohara & Wobbrock, 2011). This also means that devices can be easily bought and used outside school environments, and in the case where a user encounters problems using the device they may be more able to find someone who is able to help them use it than would be the case with specialist assistive technology.

6) The portable nature of the devices lends them well to a classroom environment. For example, they can act as small devices to be given out to all pupils to support working together while seated at their own desks as is seen for example in the vSked system (e.g. Hayes et al., 2010; Cramer et al., 2011; see also section 3.1). There is also some evidence that giving each person their own device (rather than sharing) can aid collaboration (Inkpen et al., 1999), although this is likely to be due to the fact that each person can participate, as there is also evidence that working on a shared device that allows concurrent multi-person input such as a multi-touch surface can also aid collaboration (see Section 4.4 on surface and tabletop technology, below).

7) Multi-touch interaction, as used on a variety of smartphones and tablets, may have benefits for some learners. For example, multi-touch screens have been shown to have benefits when supporting collaboration and social skills, which can be useful when supporting young people with autistic spectrum disorders (see sections 3.1 and 4.4). While many of these studies are concerned with large tabletop surfaces, this research has also been shown to extend to smaller tablet devices, as described for example by Hourcade et al. (2012).

There are however some caveats to take into account when considering mobile devices as a form of assistive technology. First, it is a fallacy that all young people have a smart-phone. Even with usage increasing, many do not have or cannot afford this technology – one recent survey of 799 teens found that only around 23% of 12-17 year olds had a smart-phone (Lenhart, 2012), while official usage statistics for the UK suggest that only 40% of adults currently own a smart-phone as of 2012 (up from 27% in 2011), and 11% own a tablet (Ofcom, 2012). Technological solutions which rely on mobile usage should not make assumptions that all young people already own or use this technology, or that they necessarily want to do so.

It is also worth noting that assistive technologies on mobile devices may also be very 'power-hungry' – for example, a report of a pilot study using handheld devices found that applications such as Dragon (voice recognition) and Inspiration (mind-mapping) drained the battery life of the devices (Ford, 2010). Devices which are intended to be used frequently throughout the day may suffer from issues to do with battery life, meaning that these may

not be the best solution if learners are not intending to work outside a classroom or home environment. For this reason, devices such as netbooks, UMPCs or tablets which can be plugged in may be better for some contexts than phones.

As well as this, it should be noted that the increasing move towards touch-screen technology without tangible or haptic feedback can make the use of mobiles difficult for users with visual impairments, and not all applications take this into account. However, with the increased processor power in the devices some software solutions are available which can address this, and many contain text-to-speech technology as standard. In a press appearance in 2011, renowned musician Stevie Wonder praised the iPhone and iPad for their accessibility for blind users (Kenneally, 2011), suggesting that provision has improved for this user group.

4.3 Tangible technology

With a name coined by Ishii and Ullmer in 1997, Tangible User Interfaces (TUIs) involve representation of digital information through physical objects (Ishii & Ullmer, 1997). This incorporates the concept of 'graspable interfaces', where users can physically manipulate objects in order to interact with the electronic information. This fits in with Mark Weiser's vision of 'ubiquitous computing' (see for example Weiser, 1991). Technologies such as RFID tags can be used to cheaply add associations to digital information onto existing physical objects, and several hardware kits are available which allow a range of sensors and controls to be added onto physical objects with little programming knowledge required, for example phidgets¹⁸ (Greenberg & Fitchett, 2001) or Arduino boards¹⁹.

Tangible technologies have attracted a lot of attention from the research community as they provide opportunities to support different modes of interaction, including multi-modal interaction. This can have benefits for young people with learning difficulties through alternative ways to present and interact with information, which several sources suggest may be helpful – for example this is one of the key principles of the UDL framework (see Section 2; CAST, 2012). Falcao & Price (2010) make the case for tangible interaction to support children with learning difficulties in a set of guidelines for the design of educational resources, suggesting that kinaesthetic approaches may be beneficial as well as providing a variety of ways of representing information with “dynamic visualisations and a limited amount of text”.

There are other functions which tangible technologies are well placed to perform. First, they can provide a way of conveying information to children with limited language abilities; for example Parton et al. (2010) describe a system using RFID tags on a series of representative objects in order to help deaf preschool children to learn sign language,

¹⁸ Phidgets: <http://www.phidgets.com/>

¹⁹ Arduino: <http://www.arduino.cc/>

through the use of a game where scanning an object activates a video of a person signing the word for it.

Another task which physical objects can be useful for is in assisting with teaching the concept of sequencing – the ability to physically manipulate the component parts may assist with comprehension of this. This is a concept which many children with different learning difficulties can struggle with; for example Garzotto & Gonella (2011) describe a system aimed at teaching sequencing through tangible technology for children with language impairments, while Pandey & Srivastava (2011) cite sequencing as one of the possible uses for their design of 'Tiblo' – tangible tessellating blocks which can hold short audio clips, and which are designed as learning aids for children with dyslexia. Manipulating numbers may be beneficial to numeracy education, for example for those with dyscalculia (e.g. Butterworth et al., 2011), and physical manipulation may provide additional possibilities (e.g. Manches et al., 2010).

Finally, the physical nature of the tangible items appears to support collaboration, perhaps due to the potential for collective interaction and the fact they can be easily shared (see for example Falcao & Price, 2010). Farr et al. have also shown the benefits of tangible technologies to aid collaboration and social interaction for children with autistic spectrum disorders in a number of studies (Farr et al., 2010a and Farr et al., 2010b). These studies showed increased collaboration when using digital construction toys such as Topobo and an augmented Playmobile set (compared to non-augmented toys such as standard Playmobile and Lego), and analysis of the sessions indicated that tangible technologies or augmented physical objects can be beneficial to collaborative play, due to the activities having more entry points for play.

A different benefit from the technology can also arise through the physical nature of the interfaces, which requires physical actions in order to interact with the devices. While this may be problematic for some users with motor impairments, this feature can also be used to an advantage, as the movements which are required can be manipulated by the design of the software tasks in order to make them suitable for their target users. For example, Dhillon et al. (2011) describe the design of a system using tangible objects embedded with RFID tags as part of a set of games for children with cerebral palsy, with the actions that form part of the games designed to mimic actions which are beneficial for physical therapy, in order to add motivation to repetitive tasks.

4.4 Tabletop and surface technology

Tabletop or surface interaction is another new area of development that is attracting interest as an assistive technology. This form of technology takes the form of large interactive panels, similar to the 'boards' described in Mark Weiser's vision for ubiquitous technology (Weiser, 1991), which can be hung on a wall or embedded into a table. With advances in technology, these often take the form of multi-touch touch-screens, as may be

found in tablet technologies. Well-known examples include the DiamondTouch table (Dietz & Leigh, 2001), the SMART table²⁰ or the Microsoft PixelSense (previously known as the Microsoft Surface)²¹.

Surface technologies can have advantages through their use of touch-screen interaction, which may be easier to use than a mouse or keyboard for young people or those with motor difficulties. As well as this, the large space offers benefits for collaboration, particularly when using multi-touch surfaces, by allowing all participants to take an active part in the interaction. As well as supporting inclusion and collaboration for marginalised children who might otherwise be excluded by their peers, technology which encourages social interaction may be particularly useful for children with autistic spectrum disorders who often struggle in social situations, and so a number of studies have investigated this approach (e.g. Battocchi et al., 2010; Giusti et al., 2011; Hourcade et al., 2012; Piper et al., 2006 – see Section 3.1).

Some multi-touch tables (such as the Diamond Touch) are also able to distinguish between touches from different people, meaning that they can be used to ensure that collaboration is taking place (e.g. Battocchi et al., 2010; Piper et al., 2006). Other types of surface technology may need to build this into the gameplay, requiring simultaneous touches which would be difficult for one person to achieve, or requiring adult supervision to ensure correct behaviour (e.g. Giusti et al., 2011). The ability to force collaboration through software rules may be beneficial to collaboration (see Battocchi et al., 2010), or it may cause difficulties, depending on the users (see Piper et al., 2006); without this though, some users may dominate or withdraw from using the system, particularly those with behavioural or social difficulties (see Piper et al., 2006).

The main difficulty with this type of technology is the need for a large specialist device – this may be expensive, although cheaper solutions are available if they are built from component parts rather than bought as a whole. It often means that the devices need their own dedicated space, although they can be embedded in a natural school context (i.e. used as a table). There is also the issue that tabletop technologies cannot be taken home or passed around – therefore they are not suitable as individual solutions.

4.5 Symbol-based interaction

Symbols or visual diagrams are often used for people with reading or communication difficulties. These fall broadly into two main types: symbols used for communication, such as PECS²², VOCAs, AAC etc, and symbols used to aid understanding, for example Widgit

²⁰ SMART Table: <http://smarttech.com/table>

²¹ Microsoft PixelSense <http://www.microsoft.com/en-us/pixelsense/default.aspx>

²² PECS: <http://www.pecs.org.uk/>

symbols²³ which are used on SymbolWorld²⁴, and Makaton symbols²⁵. Makaton symbols are intended for signing and cued speech, so can also be used alongside Makaton signs, which are based on British Sign Language signs; for example these are used on the popular CBeebies children's television programmes and interactive online games to support communication, particularly aimed at young children with limited communication who do not use full sign language (see BBC, 2012).

It is worth noting that there has been a large amount of work conducted on Alternative and Augmentative Communication or AAC, but due to its wider benefits beyond education this is perhaps better considered an assistive technology rather than an assistive learning technology (see Section 2.1), and therefore partly out of the scope of this review. It is however important to briefly consider how the use of symbols may affect the learning experience, and interaction with learners who use them. For example, a study by Checkley et al. (2010) highlighted the difficulties of expressing complex ideas using VOCAs, such as using them to give an opinion of technologies such as the VOCAs themselves.

There is much anecdotal evidence to suggest symbols can aid literacy (e.g. CHANGE, 2012), and some case studies showing how they can boost confidence and independence (e.g. Pampoulou & Detheridge, 2007). However, experimental studies show a more complex picture. A small study by Chen et al. (2009) suggested that symbols were more effective for autism than for other learning difficulties. A study by Zentel et al. (2007) suggested that while symbols can be beneficial, they only had a benefit over written text when also presented alongside audio. Another study by Poncelas & Murphy (2007) demonstrates that symbols do not necessarily have an obvious 'intuitive' meaning, and can only aid understanding for people who are familiar with the symbols and trained in their use, as for any other language. This suggests that while symbols may be useful for interaction, they should be used with care, and like any language they need to be learned in order to be useful.

4.6 *Virtual reality*

While fully immersive virtual environments remain prohibitively expensive for most schools or homes, desktop-based virtual environments or 3D worlds (e.g. Second Life²⁶, World of Warcraft²⁷ etc.) are more commonplace and have attracted a great deal of attention as environments to support education in general (e.g. Kirriemuir, 2008), so it is to be expected that opportunities may arise using these environments. In theory, they could potentially offer benefits to some learners with special needs, through the ability to present material in an interactive multimodal manner. For example, it is worth noting that Parsons & Mitchell

²³ Widgit: <http://www.widgit.com/>

²⁴ SymbolWorld: <http://www.symbolworld.org/>

²⁵ Makaton: <http://www.makaton.org/>

²⁶ Second Life: <http://secondlife.com/>

²⁷ World of Warcraft: <http://us.battle.net/wow/en/>

(2002) put forward a compelling case for the potential of virtual reality environments to support social skills training for learners with autistic spectrum disorders, based on the fact that it can combine the strengths from both the behavioural and 'theory of mind' approaches.

4.7 Augmented reality

Augmented reality technology may provide opportunities to create novel assistive technologies which blend physical real-world objects with virtual information. Gaukrodger & Lintott (2007) discuss the possibilities made available by the technology, for example proposing that benefits may particularly be gained for rehabilitation tools, by assigning engaging game-based actions to repetitive physiotherapy tasks that must be performed. Farr (2010) also talks about augmented reality technologies offering possibilities for autistic children, by providing more information about the world which may help them to make sense of the social context they are in – for example giving information showing the state of other individuals in the environment, or information about the environment itself. A level of augmented reality can be achieved through modern smart-phones using vision recognition software and a phone camera, or through game technologies such as the Microsoft Kinect²⁸, so it is possible that more education innovations will emerge in this domain in the near future.

4.8 Robotics

Robotics have been researched quite widely for their use in aiding rehabilitation, but they may also have uses in education as virtual tutors, companions or other interactive characters (e.g. Saerbeck et al., 2010). Cook et al. (2002) describe the importance of physical play for early learning, and describe the design of a system where children with physical impairments can engage in play activities through the use of a robotic arm that can be controlled by switches – this allows for 3D manipulations to be explored that are not possible using 2D computer environments. More simple robotics kits are already in widespread use in education, such as the popular Lego Mindstorms²⁹, which are normally used to teach concepts of computer programming and engineering. Dautenhahn also describes the AURORA project, which explores the use of socially expressive robots as electronic 'pets' for young people with autism (e.g. Dautenhahn, 1999). In this context, Dautenhahn suggests that robots have advantages over human interaction for this user group due to their predictability and reliability. Wainer et al. (2010) also explore the use of a robotics class as a means to encourage collaboration between school children with autistic-spectrum disorders, claiming that the nature of the technology was an effective way to leverage the existing interests of the children, resulting in a more effective intervention than social skills classes. This suggests that there are potentials to the use of robotics for

²⁸ Microsoft Kinect: <http://www.xbox.com/kinect>

²⁹ LEGO Mindstorms: <http://mindstorms.lego.com/>

education that should be explored as these technologies become more widespread and affordable in the future.

4.9 Considering technology: summary and discussion

From this section, it can be seen that there are a wide variety of technological solutions available that can support learners with special needs, ranging from traditional desktop computers to more cutting-edge technologies. Multi-purpose portable devices such as smart-phones and tablet computers may offer opportunities through the use of a mainstream device which is customisable through the addition of a wide variety of available software or 'apps'. Future solutions may involve more along the lines of ubiquitous computing, or technologies which are embedded in an everyday environment, or along the alternative dimension of virtual or augmented reality.

However, it is worth noting that not all the technologies discussed here may be currently widely available or affordable, and there is also a need to promote affordable solutions, or those that use existing technology which is currently in place in educational institutions. It is also important to note that not all of the studies described here take the extra step of comparing the technological solution with existing solutions, and there is often a need to consider carefully if technology can provide a benefit over non-technological solutions.

5. Considering use in different educational contexts.

Use of assistive technologies can vary greatly across different educational contexts.

Naturally, the needs of the learners will vary greatly, with more of a focus on remedial technologies in the early years, with compensatory technologies being introduced later as there is a need to 'keep up' with peers, and for this reason compensatory technologies may prove more attractive and effective for adults (Raskind, 1994). Moving into further and higher education, the focus shifts into supporting independent learning. As well as this, one particular issue that affects use of assistive technologies is the issue of provision, as this changes greatly between educational institutions, and so this will also be addressed in the following sections.

5.1 Pre-school

With technologies being introduced to children earlier and earlier, there is now a need to consider pre-school as one possible place where children may first be exposed to assistive technologies to aid early learning. With children at a very early stage in their development at this point, one question to ask is what technologies are most appropriate for this age group.

It is worth noting that 'pre-school' varies in ages between countries – for example in the UK Year 1 is at age 5, but many schools also have a Reception class at the school (age 4) or even Nursery (age 3). In Finland, pre-school is until age 7, while in the USA kindergarten is until the age of 6. Some learning difficulties are not normally identified this early, for example dyslexia is usually only diagnosed after literacy education has failed. However, diagnoses of some conditions are getting earlier, for example with some researchers working to identify signs of autism in pre-school children, from around the first birthday – an article on the topic notes that “very few studies have found clear predictors as early as six months of age” (Charman, 2012). Studies of this age group are often done by addressing 'at risk' children, for example where there are other family members with a similar diagnosis, such as the work being conducted by the BASIS group (BASIS Network, 2012).

However, there is a need to consider this age group in the context of assistive technologies, as some problems are best addressed as early as possible, such as literacy (e.g. Floyd et al., 2008; Shamir et al., 2012) and particularly if an additional language needs to be learned such as sign language (Parton et al., 2010). Issues such as low self-confidence and difficulties with social interaction with peers can also be assessed at this young age (e.g. Bart et al., 2011), which may help to target early interventions. Most technologies aimed at this age group therefore seem to take the form of games and other 'fun' activities, such as

those to support inclusion and social skills. For example, the UMSIC project is an example of a music-making game aiming to support inclusion and collaboration for preschool children at risk of marginalisation, such as those with learning difficulties such as ADHD (e.g. Paananen & Myllykoski, 2009).

There is therefore a growing body of literature addressing assistive technologies for the preschool age group (Edyburn, 2003; Edyburn, 2004), although some researchers feel that some areas of preschool education are not given enough attention (Floyd et al., 2008). Perhaps one issue is the difficulty of technology provision before children enter the school system, and the question of who would pay for systems to be introduced.

5.2 School system

When used within the school system, there is a need for technologies to fit in with and support the national curriculum as well as the needs of the users. The Universal Design for Learning (UDL) approach described earlier (Section 2) is worth bearing in mind as an alternative angle, taking the view that it is the curriculum, not the learners, which is disabled, suggesting that changes need to be made to a curriculum if it is not capable of supporting all learners (CAST, 2012).

As it stands however, it can be difficult for schools to adopt new technologies due to existing school policies which are already in place (C. Wright et al., 2011). The problem is compounded by the fact that there are a variety of models and strategies in place across different local authorities and no single source of information for schools or Special Education Needs Coordinators (SENCo), meaning that provision of assistive technology in schools may vary greatly according to location (Atkins Ltd, 2009). While several sources of information do exist, for example AbilityNet³⁰, AbleData³¹ or Gov.UK (formerly DirectGov)³², this relies on concerned parties finding the information they need from a number of sources. Schools may also vary greatly in the technology provision already in place within the school, for example use of a learning platform or VLE can differ greatly between schools (Jewitt et al., 2010), and this can affect how assistive technologies fit into the existing infrastructure.

One key factor in assistive technology provision at school level is the assessment system, as all pupils identified with special educational needs should have an assessment of their needs, and make an Individual Education Plan/Programme (IEP). As well as supporting the needs which are assessed, technology can also aid with monitoring performance towards the IEP, including logging and visualisation of activities and events (Hayes et al., 2010). However, the assessment process may be long, complicated, and may run the risk of isolating young people further while they go through a long process. This can be partly due to a lack of assessors, as a report on assistive technology provision in the UK noted: “of the

³⁰ AbilityNet: <http://www.abilitynet.org.uk/>

³¹ AbleData: <http://www.abledata.com/>

³² Gov.UK: <https://www.gov.uk/children-with-special-educational-needs/overview>

11 local authorities interviewed, two did not possess any in-house expertise and as a result outsource their assessments. The majority of local authorities interviewed have low levels of expertise that are mainly tailored towards learners with less complex needs. Some local authorities only had one assessor, and in one instance this assessor was part-time and served 110 schools” (Atkins Ltd, 2009).

Another serious concern is the issue of who pays for technology which is needed – officially, local authorities should be responsible, yet in practice schools and/or individuals may have to contribute, or at least feel they have to. This can be linked to issues of ownership, as this report notes: “When a school has paid for the assistive technology then that technology belongs to the school. If the technology has been funded by the local authority then it belongs to the child for as long as the child remains within that local authority area” (Atkins Ltd, 2009). The same report also notes a worrying lack of an integrated approach within schools: “commonly, when a piece of assistive technology is provided to a child, the school's SENCO, teaching assistant and the child will be provided with training for that piece of equipment by the local authority. However, other teachers are often unaware of the piece of equipment and how to use it. This is leading to instances where the technology is not been utilised effectively to its full potential. This results in wasted effort and funds in assessment and provision” (Atkins Ltd, 2009).

Towards the end of the school system, there is also a need to consider if and how technology will be used beyond schooling, in the workplace or in post-compulsory education. Around Year 9, learners with special needs are expected to make a Transition Plan (Gov.UK, 2012a), which covers plans for the future and how to live as independently as possible. This may include identifying technology which is needed, and the education department of a local authority is responsible for making sure that people receive the support and services that are listed in the Transition Plan. However, more research may be needed on the use of technology through this transition period, and whether the technologies used in school are the most appropriate for preparing young people for life beyond school.

5.3 Further and higher education

This section will consider issues relating to post-compulsory education, which may be a college or university. There is a sizeable body of literature on disabled learners in higher education: for example, Edyburn's yearly literature reviews suggest a disproportionate amount of studies are looking at postsecondary education, perhaps due to an over-reliance on opportunity samples gathered by university researchers (Edyburn 2003; Edyburn, 2004).

Until 2001, educational institutions in the UK were exempt from parts of the Disabilities Discrimination Act (DDA). When the Special Educational Needs and Disabilities Act (SENDA) came into effect in 2001, it introduced the requirement that all learning environments and learning materials needed to undergo “reasonable adjustments” to ensure

provision for all students (Woodfine et al., 2008). This in particular affected university courses, where use of online learning materials in a variety of formats can be more common, as well as the need for support for distance learning and independent study. Because of the requirements introduced in SENDA, which are now covered by the Equality Act of 2010, there is a need to provide materials in a format which is suitable for students with varying needs, working without support (Beacham & Alty, 2006; Alty et al., 2006). While guidelines and procedures exist for this (see for example Section 3.2), there is however a difficulty of adapting all university pedagogies (or, since higher education involves teaching to adults, andragogies) to suit all learners, particularly when they rely on aspects which may be difficult for some learners, such as group-work or fast-paced text environments (e.g. Woodfine et al., 2008).

UK students in full-time or part-time further and higher education can receive assistance through the Disabled Students Allowance (DSA), which can include funding for assistive technologies. The support to be given is decided by an initial assessment, so that solutions aim to be as personalised and individual as possible. More information about the workings of the DSA can be found through the Gov.UK website (Gov.UK, 2012a). However, perhaps due to the varying levels of provision in the school system, many learners come into post-secondary education not having used assistive technologies before, and not being aware of what is available (Day & Edwards, 1996). Also, since use of technological support is determined by individual assessments, a further difficulty is also created for lecturers and tutors, since all their learners may be using different systems, some of which may be unfamiliar to the tutors. This perhaps lends further support for moving towards a UDL approach (see Section 2) where possible, with the eventual aim that more learners are using the same or similar systems.

There is also a need to consider the social aspects of postsecondary education for learners with special needs. For example, for some learners, leaving home and parents can be very stressful and there is a need to address issues of anxiety (Mohammedali et al., 2011). At this stage of education, there is also an increased focus on independent learning, meaning that there is a need to provide more support for working alone than may have been needed while at school. Support networks can be helpful for this, including for groups who are not normally expected to be sociable such as those with autistic spectrum disorders (MacLeod, 2010). Most universities also have a disability support service, and the JISC TechDis³³ website also exists which aims to give advice specifically on assistive technologies for higher education.

5.4 Independent adult learning

One other area of learning which should also be considered is that of independent or self-directed adult learning. This is an area which is often overlooked, and does not seem to be given much attention in the research literature, particularly for learners with special

³³ JISC TechDis: <http://www.jisctechdis.ac.uk>

educational needs. It is also important to consider a person's opportunities for lifelong learning as part of their personal development (Watkins, 2011). However, there are a growing number of online educational resources designed for independent learning, or 'MOOCs' (Massively Online Open Courses), for example iTunes U³⁴, the Khan Academy³⁵, Udacity³⁶, Coursera³⁷, EdX³⁸, and many more. While these resources may provide opportunities for people who struggled with mainstream education or wish to learn new topics at their own pace, it may be difficult to get support for this type of learning. This type of informal, self-directed learning also requires a great deal of personal motivation, which may be difficult for adults with some special educational needs, particularly if they did not have a positive educational experience while in the school system.

One problem for individuals engaging in self-directed learning is that they would not qualify for a DSA loan to support their learning, so all technology support will have to be sourced by the learner or a helper, and also often self-funded. Adult colleges are also expected to make 'reasonable adjustments' to support learners' needs, in accordance with SENDA, but without DSA assessments then provision of technology may be less extensive and personalised than in higher education. There is also a noted gap in funding for ICT for disabled people who are not currently in education or employment (Nath, 2012). There may therefore be a greater reliance on public information sources, for example AbleData³⁹, EmpTech⁴⁰, the BDA's national helplines⁴¹ and so on, and also on free or highly affordable software as far as possible. Some sources of information are also more aimed at school-aged learners, and do not consider the specific needs that adults have, such as a need for technological support which provides rapid benefits across a wide range of contexts (Raskind, 1994). While there are a great deal of resources available for adults, particularly when searching online, it may be difficult to find the information that is needed, particularly if a learner is struggling with literacy or concentration for example, and many people may simply not realise that solutions are available. This is therefore an area of research which requires much more study in the future in order to enable this group of learners more effectively.

5.5 Considering use in different educational contexts: summary and discussion

This section has highlighted that while there may be a great deal of assistive technology available through the education system, provision varies greatly between different stages of education, as well as often by location or financial factors. Provision may also require

³⁴ iTunes U: <http://www.apple.com/education/itunes-u/>

³⁵ Khan Academy: <http://www.khanacademy.org/>

³⁶ Udacity: <http://www.udacity.com/>

³⁷ Coursera: <https://www.coursera.org/>

³⁸ EdX: <https://www.edx.org/>

³⁹ AbleData: <http://www.abledata.com/>

⁴⁰ EmpTech: <http://www.emptech.info/>

⁴¹ BDA Helplines: <http://www.bdadyslexia.org.uk/about-dyslexia/national-helpline.html>

assessment or diagnosis of a disability, which can be problematic, and provision for non-diagnosed learners with difficulties may not be available or advertised (for example this might involve going to a section of a webpage called ‘services for disabled students’ which might not be obvious if you do not have a diagnosed disability). In some cases this argues somewhat for the UDL approach (supported and enabled through appropriate technology use), and ensuring that curricula are accessible for all learners.

This disparity between different settings is problematic – for example, the UNESCO report on innovative practice in educational technology for disabled people which was previously quoted makes the recommendation that “the availability of ICT for people with disabilities must be viewed within a continuum of educational opportunities across lifelong learning. ICTs that support an individual person’s learning must be available to them in any formal or informal learning situation they wish to engage in” (Watkins, 2011). There is therefore a need to take a wider view of what is needed for a person’s lifelong education and wellbeing, as well as meeting their current educational and social needs.

6. Summary and conclusions

Perhaps the main finding from this review is that there is a huge body of research on the topic of technology to support learners with special educational needs, spanning a wide variety of sources and academic disciplines. This however does mean that there are often conflicting views of assistive technologies, as well as a lack of consensus on even seemingly simple matters such as definitions and research ethics. As is the case for many fields, there is a need to encourage interdisciplinary work and more communication between disciplines.

Because of this, it can be difficult for researchers and for users to find relevant information or the support that they need, although in many cases a wide variety of technology can be available which could benefit learners, either through a formal system of provision following an assessment, or free to download. The situation is made more difficult for learners due to an uneven spread of support across different impairments and different stages of education, and reports suggest that provision is also not equal across all parts of the country (Atkins Ltd, 2009). Researchers repeatedly argue for a holistic approach, taking the user, the technology and the context of use into consideration, and also considering the implications for future use and lifelong learning. This includes considering implications for informal or self-directed learning outside of traditional educational institutions.

From looking at the research literature from the point of view of the learner's needs, some user-groups have been studied extensively, meaning that there can be some helpful guidance as to approaches and solutions that may be beneficial. In particular, learners with high-functioning autistic spectrum disorders, and those with labelled literacy difficulties such as dyslexia seem to have been given a greater degree of attention by researchers and campaigners, particularly when compared to other learning difficulties such as low-functioning autistic spectrum disorders, dyscalculia, dyspraxia, cognitive disabilities or more complex difficulties. Physical disabilities such as visual, hearing and mobility impairments have been well addressed from an accessibility angle, but as discussed in Section 2.1, access to information does not necessarily imply access to learning (D.H. Rose & Meyer, 2002), and there can also be more scope for work addressing social issues for these learners, such as independence, inclusion and self-confidence. There is a need for researchers to understand the needs and capabilities of learners with special educational needs in order to support them effectively, including designing appropriate research studies that can elicit responses from participants in an appropriate manner. However, there is also perhaps a need for researchers focussed on a particular impairment to also consider how their findings may also apply to other learners – for example, it has been noted that interventions for dyslexia may also benefit learners with other literacy difficulties (Elliott & Gibbs, 2009), and guidelines on interface design for specific groups often overlap with the needs of other learners (see Section 3.9) including those with no identified special needs, who can still also benefit from good user-aware design.

Considering assistive learning technologies from the technological point of view, it seems that there are many new technologies which could offer novel solutions and support which could benefit learners with special educational needs. However, realistically many of these devices are not likely to be in widespread use in schools at present, such as tabletop or tangible technologies, or even tablets and smart-phones. While this research is still valuable as these technologies may offer benefits in the future, there is perhaps a need in the meantime to promote free or affordable solutions, including those that make use of technology already available in schools or homes: this may be particularly helpful as a means of easily trying out new technologies, which has been noted to reduce technology abandonment. In considering the social impact of technology, there is also a conflict between appropriately supporting individual users' specific needs, and in increasing exclusion through the use of non-mainstream technologies, which suggests that designers of mainstream technologies should strive towards universal usability as far as possible, and educators should consider aspects of a UDL approach which does not disadvantage learners with special needs. At present, for some users, it seems that smart-phones and mobile technologies may perhaps offer some of the most immediate benefits through the opportunity for interfaces that are both mainstream and personalised, and which can be used across many contexts. There is however also a need to consider when technology is not the best solution, moving away from an overly deterministic approach, and allowing the learners to drive societal change.

In looking at assistive learning technologies from the perspective of a learner's educational context, the problem of inequality of provision becomes apparent, and while some learners may receive extensive and appropriate support, others may struggle to get the help that they need within a complicated and often inconsistent system. The overload of information available may also exacerbate this, as mentioned previously. One particular direction for research that is needed is in exploring the 'gaps' in the system, such as transitions between educational systems (for example from school to further or higher education), or in supporting informal and self-directed lifelong learning in the workplace or for personal development.

In general, it seems that research from the academic community is lacking in longitudinal studies of the effectiveness and impact of technology on learning, and often fails to consider the wider context of use. This includes involving parents and teachers in studies, and considering how to promote teachers' positive attitudes towards assistive technologies, which has been suggested to be important in ensuring interventions are successful (Watkins, 2011). Research is also often technology-focussed, or at best focussed on academic performance, rather than exploring social issues such as confidence and independence, and the effectiveness of solutions in addressing these. There is also a worrying suggestion from some researchers that there is little consistency or academic rigour across the whole field (e.g. Gersten et al., 2005; Gersten & Edyburn, 2007), perhaps due to the span of research backgrounds that contribute to the field.

In conclusion, this review has highlighted a number of benefits of technology to education and to supporting learners with special educational needs, which could further help to enable access to the education that they are entitled to. However, while research is leading to improved awareness of users' needs, and a greater understanding of the capabilities and possibilities of the technologies available, this review has also identified areas in need of more research in the future. In particular, the impact of technology on emotional wellbeing and positive educational experiences as well as academic achievement could be addressed in greater detail: while there has been a strong drive in the research on inclusion and social engagement, other topics such as independence and self-confidence should also be explored further. From a provision standpoint, given the possible overload of information available, it would be helpful to explore in more detail how learners or carers currently search for and find information about assistive technologies, particularly for learners who are outside an assessment system; research could then explore what would be the most effective way to disseminate information and advice. Finally, there seems to be a clear need for more longitudinal research, exploring the long-term effects of technology on education and wellbeing, and from a lifelong-learning perspective the impact on a person's whole education through compulsory education and beyond. While longitudinal and interdisciplinary research remains challenging for researchers, this may provide the most valuable method for discovering how best to give all learners the support that they need, and which will provide the most appropriate methods for delivering the education that is their right to receive.

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