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Technology for inclusion

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ABSTRACT

There is increasing recognition of the value of inclusive education and the role of universal design for learning in supporting it. However, moves towards inclusion are taking place at different rates in different countries. Technology has considerable, but largely unused potential to support inclusive education of disabled people and other minority groups. In particular it can provide multiple means of presenting, representing and expressing learning and through AT enable disabled learners to overcome barriers they would otherwise experience to participating in the curriculum. It also has the potential to increase enjoyment and motivation. There is increasing evidence of the value of ICT and AT in supporting and improving the education of disabled people. Distance education has potential to increase educational access, but should not be at the expense of making institutional education accessible. However, not all the initiatives consider the needs of disabled people. Differentiated learning supported by technology has considerable potential, but is rarely used, largely due to lack of appropriate teacher education and other resources. The lack of schools and other educational infrastructure and poverty raise particular challenges to the introduction of technology mediated UCL in the low (and medium) income countries. However, the barriers worldwide are similar and include lack of funding and other resources, lack of available technologies and specialists and lack of teacher education.

1. INTRODUCTION

Inclusive education has been recognised as a human right in the Convention of the Rights of Persons with Disabilities (https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html). Many countries have incorporated the principles of the Education for All movement (UNESCO, 2000) into their policies and legislation. However, although access to education is improving, universal primary education was still only 91% in 2015, and rates of tertiary education in many of the low and middle income countries are very low. Disadvantaged groups worldwide generally have less access to education than the majority population

Many disabled people, in particular, still experience numerous barriers to education, including learning environments which are not fully accessible (WHO, 2011), limited legal recognition of their right to education (Forlin & Lian, 2008), limited financial support (Hernandez, 2006) and negative attitudes and low expectations (McGrew & Evans, 2004; OPM, 2014). There are an estimated 200 million disabled children in the world (UN, 2009), as well as millions of disabled adults. However, this could be an underestimate due to differences in definitions and limited diagnosis facilities in many countries. Female access to education is still lower than male, with probably even lower access for disabled girls and women. About two thirds of majority world countries have gender parity in primary education (Galatsidas and Sheehy, 2015), with probably less equity at higher levels. Globally 186 million children have not completed primary school. 95% of children in the middle east and north Africa are out of school. Access to tertiary education for disabled people varies greatly at 0.56% in India, 1% in South Africa, over 5% in

Australia and 11% in Canada and the USA (Kanwar and Cheng, 2017). Disabled children are the most significant and the most marginalised group globally with regards to education (Oralbekova et al., 2016).

Obtaining a postsecondary education qualification has been shown to significantly increase the likelihood of obtaining a job e.g. (Hutcheon and Wolbring, 2012) and the correlation may be even stronger for disabled people (Burgstahler, 2003). Disabled students are underrepresented in further and higher education (Konur, 2006) and obtain poorer degree results despite comparable entry qualifications (Fuller et al., 2004). This results in reduced opportunities for personal development and qualifications and together with attitudinal and other barriers (Daone and Scott, 2003; Roberts et al., 2004) leads to significantly reduced employment (Barnes et al., 1998; Szeto, 2014).

Although there have been moves from special to more inclusive education in many countries, they are taking place at variable rates in different countries. The extent of real inclusion is also variable. In some cases, poor access to education for the population as a whole means that the issue is inclusion of disabled people in education. This is a particular issue in rural communities in sub-Saharan Africa and South Asia (Alkire et al., 2014). As will be discussed in greater details in subsequent sections, technology has considerable potential to support increased educational opportunities (Foley and Ferri, 2012) and inclusive learning, but needs to be used with appropriate pedagogies. The term e-inclusion relates to the use of digital technologies to support and scaffold learning to maximise the learning experiences of all learners (Pellerin, 2013). E-inclusion is aligned with the principles of universal design (UDL), a framework for inclusive education, which is presented in the following section.

Definitions and additional information about the technologies of interest is provided in Appendix 1. However, in general terms they are 'high tech' information and communication technologies and include computers, laptops, smartphones and other mobile devices and the software used on them, as well as other electronic devices and software, including videos, videoconferencing and digital recorders. A glossary of terms is presented in Appendix 2.

The information presented in this report has been obtained from a combination of literature searches and requests to expert informants for information, with the latter identified from a combination of my contacts and the literature. Most of these responses were provided on a short online questionnaire.

The report is organised as follows. Section 2 - 5 discuss different ways in which technology is used to support inclusive education. Section 2 considers general purpose 'high tech' technologies, whereas section 3 discusses assistive technology i.e. technologies intended specifically for disabled and older people. Sections 4 and 5 consider the use of technology in distance and differentiated learning respectively. Differentiated learning involves using different approaches with different students in a class. Section 6 presents challenges in the use of technology to support inclusive learning and some potential solutions and section 7 conclusions.

2. TECHNOLOGIES FOR INCLUSIVE EDUCATION IN THE FRAMEWORK OF UNIVERSAL DESIGN FOR LEARNING

This section is divided into five subsections. Sections 2.1 and 2.2 consider inclusive education and universal design for learning, and the role of ICT in supporting them. Section 2.3 discusses the use of ICT in support of inclusive education in different countries and section 2.4 provides some examples of computer aided learning and other technologies. Section 2.5 presents a brief evaluation of the impact of ICT in supporting learning of disabled (and other minority group) learners.

2.1 Inclusive Education and Universal Design for Learning (UDL)

The value of inclusive education in mainstream schools is being increasingly recognised including through legislation. For instance 2012 Danish legislation required 97% of all learners to be included in mainstream schools (Andersen and Sorensen, 2015). There is generally a move globally to educating disabled students in mainstream schools. However, this is taking place at different rates in different countries. For instance, only a relatively small percentage of schools in Indonesia are inclusive (Sunardi et al., 2001) and studies indicate that Kazakhstan is not yet 'ready' for inclusive education. However, 24 secondary schools in the capital Almaty have 'adjustment' classrooms for students with developmental disabilities, an integrative approach to education, and a special school in Taldykorgan has been merged with a mainstream school (Zholtayeva et al., 2013).

The Second Primary Education Program is funding projects to improve inclusive education in Bangladesh and there is an appropriate legal framework, but implementation is limited. Much of the work on inclusive education is being carried out by non-governmental organisations (NGOs) with limited national coordination (Grönlund et al., 2010). Uganda has a rights based approach to education and positive discrimination in primary education for girls and disabled girls and boys. Despite some commitment to inclusive education, special schools are still considered appropriate for deaf children and those with 'severe' disabilities. Units attached to primary schools have been set up in Bushenyi district to act as resource centres for other schools. Local Deaf adults have helped teachers and parents learn sign language despite initial resistance. Community involvement has prevented these units becoming small special schools and supported the development of specialist expertise, enabling Deaf children to go to school while living with their families (Miles and Singal, 2010).

In some countries, such as Rwanda education of any type for disabled people is relatively recent. There is now a mixture of special centres/schools and inclusive schools and a small number of disabled people have graduated from Rwandan universities each year since 2011 (Karangwa, 2014).

Universal design for learning (UDL) is a curriculum framework intended to support the development of curricula which consider learner diversity (CAST, 2011) and support inclusion. It is based on universal design i.e. for all users, regardless of disability, age, gender, size, culture and other factors (Connell et al. 1997; CEN 2003). It applies universal design principles to learning with a focus on the three important pedagogical issues of inclusive means of representing information, expressing knowledge and engaging in learning (Rose and Meyer, 2002). Thus, UDL involves the provision of multiple flexible presentation

approaches to support recognition learning (what is this?); multiple, flexible means of expression for strategic learning (how am I going to do this?); and multiple flexible means of representation for effective learning (why should I learn this?) (Rose et al., 2005). A number of studies suggest that UDL is an effective teaching approach that can improve all students' learning experiences (Capp, 2017).

It has been suggested that full educational inclusion requires physical, academic and social inclusion (Qvortrup and Qvortrup, 2018). There is increasing recognition of the value of inclusive mainstream education and its benefits to all students. However, movement from special schools to mainstream schools is taking place at different rates in different countries and education in mainstream schools does not necessarily lead to social and academic inclusion. Integration has involved the provision of adaptations and resources to enable disabled students to fit in with existing curricula and learning environments. Inclusion is aligned with the social model of learning (Abbott, 2007) which considers learning to be socially situated and barriers to exist in the learning context rather than the particular student.

2.2 Information and Communication Technologies (ICT) to Support Inclusion and UDL

ICT can be used to support inclusion by providing different ways of representing information, expressing knowledge and engaging in learning, including assessment. This involves both general learning technologies and assistive technologies designed specifically for disabled people. The use of ICT in education has the further advantages of teaching ICT skills, which are becoming increasingly important and drawing on the increasing popularity and motivating effects of using ICT, particularly amongst young people.

However, ICT is a tool rather than an end in itself or a universal solution. Its successful use requires appropriate pedagogical strategies which take account of the needs of a diverse student body, appropriate teacher education and career-long learning. The technologies need to be fully accessible to disabled and other students and take account of gender and the social and cultural issues, values and sensitivities of the diverse populations that might use it (Heemskerk et al., 2005; Tondeur et al., 2016). A mathematics computer game with a young female central figure was found to be popular with girls and also enjoyed by boys (de Jean et al., 1999). Different versions of games and other learning activities and applications could be used to address different interests (Heemskerk et al., 2005) and could include central characters with different identities, such as disabled people from different cultures. This could support the inclusion of disabled learners and make learning more interesting to them. In addition, the problem context needs to be relevant and problems authentic and to produce meaningful outcomes. Disabled people frequently require standardised positions for menus and icons to enable them to locate the information. These positions should be appropriate and customisable to take account of the different directions in which languages are read (Heemskerk et al., 2005).

Head teachers have a central role in implementing new technologies and learning models in schools. Head teachers' social/medical model orientation and attitudes toward inclusive classrooms have been found to be the main predictor of effective teaching (Stanovich and Jordan, 1998). They will develop positive attitudes to inclusion amongst teachers if they have a positive view and knowledge of ICT and present student diversity as a resource (Brodin, 2010). Teachers with 'social model' perspective often teach more effectively and inclusively than 'medical model' teachers (Stanovich and Jordan, 1998),

making it important to educate teachers about the social model of disability. However, recognition of the different and sometimes conflicting needs of different groups of disabled and other students (Foley and Ferri, 2012) also makes personalisation of technology important.

ICT tools can be used to support creative and cooperative learning environments where disabled students are included in learning activities and have class or group roles or responsibilities (Obradovic et al. 2015). This includes using a portable notetaker to record group discussion (Quenneville, 2001). ICT tools can also support different thinking styles and perceptual processes (Obradovic et al., 2015). Computers with specialised software can be used to record, edit and share ideas and facilitate completing assignments on time and improve motivation. With appropriate instruction they can improve language and writing skills (Quenneville, 2001).

However, not all learning technologies are suitable for disabled learners. In addition, as far as can be determined from the published information, many of the initiatives to introduce technology into education have not specifically considered the needs of disabled students and staff. For instance, LED screens, mathematics and science multimedia content, teacher tablets and SMS (short message service) review questions together with teacher in-service training have been introduced in schools in Pakistan and are considered to have the potential to improve student achievement (and reduce costs) (Beg et al., 2019). However, there has been no indication of attention to accessibility and usability for disabled students and consequently it is likely that these technologies are unsuitable for at least some disabled people.

The lack of involvement of disabled people can result in technologies which are not fully accessible to at least some groups of disabled people and/or which are very time consuming and difficult to use. Virtual learning environments (VLEs) are frequently used, particularly by universities. However, few, if any of them are fully accessible to disabled people. For instance, a study shows that the VLEs Moodle, ATutor and Sakai are not fully accessible (Iglesias et al., 2014). Comments from one of my informants indicate that another popular system, Blackboard, is also not fully accessible. For instance the software they require to expand abbreviations is not compatible with Blackboard. While technology is by no means a universal solution, there is great value in considering it together with UDL as an integral part of the toolbox for supporting inclusive education.

Some of the earliest examples of ICT to support learning by disabled people involved post-formal education in day and adult training centres, sometimes finally giving them access to basic education they had previously missed. However, from the available information e.g. (Clay et al., 1988) this involved providing individuals rather than groups with specific technologies.

2.3 ICT in Education in Different Countries

Technology is increasingly being used in education in many different countries. However, there are very great differences, largely determined by income, between technology availability in different countries and also in different parts of a country. There may also be greater availability at university than primary school level. This subsection provides an overview of the ICT availability in a number of different countries.

The UK and Australia are two English speaking (by the European population in the case of Australia) high income countries with good ICT availability. For instance, computers are available to all students free of charge at all levels of education, with much greater availability at university level. Colleges and universities in Australia and the UK generally provide screen readers and some other assistive technology (AT) on all computers and an AT centre with a range of ATs, ergonomic furniture and private study rooms in the library (Hersh and Mouroutsou, 2019).

Romania is an upper middle income country which uses technology widely in schools, colleges and universities. Sufficient computers are available at school level for students who pass the yearly test of digital competences. Internet access is generally via mobile phone, as in many other countries. Accessible learning software for mathematics, languages and other subjects have been developed through European projects. Georgia has been recently reclassified from an upper to lower middle income country. It has limited ICT access. Many schools lacking even a slide projector and not even all universities providing computer access. Government programmes for purchasing computers are also lacking. However, where computers are available, disabled students may be allowed to use them in exams and some computers have screen readers.

Indonesia and Nigeria are both lower middle income countries, both of which have limited ICT access. For instance, 23% of the small number of inclusive schools in Indonesia provide special equipment, media and resources for students with learning disabilities or cognitive impairments, the main groups of students in these schools, and less than 10% for students with other types of impairments (Sunardi et al., 2011). Educational technology use in Bangladesh is basic. For instance a school in Dhaka with 50% disabled children and other children recruited from poor families has limited technology, mainly audio tapes and objects to aid activities. However, it does have small classes and teachers with expertise in working with disabled students. (Grönlund et al., 2010).

Nigeria introduced a national ICT policy in 2001, including compulsory ICT use and the development of ICT curricula at all levels of education, but they have had little impact in practice (Yusuf et al., 2017) and failed to recognise the importance of AT for IT access. A further ICT initiative had inputs from a variety of stakeholders and recognised the value of AT in disabled people's education (FME, 2004), but had limited impact on AT use. There is limited ICT use in Nigerian schools (Yusuf, 2017). However, Nigeria was ranked the second worst energy supply nation in 2017 (Okator, 2018). Consequently, improvement of the energy infrastructure, preferably based on renewables, will be required to make regular widespread ICT use feasible.

2.4 Computer Aided Learning and Other Technologies

The use of ICT in education has frequently involved computer aided learning (CAL) i.e. the provision of computing devices (desktops, laptops, iPads) with different types of software to support learning.

Examples of CAL involving iPads and other tablets include by disabled students in an education support centre in Western Australia (Johnson, 2013), by learners with attention deficits in an inclusive classroom in Denmark (Andersen and Sorensen, 2015) and by students and staff in nine primary and secondary schools in the Metro Manila area in the Philippines (Lumagbas et al., 2019). The education support

centre teachers received training in using a variety of popular applications to support literacy and mathematics. They considered that all the students responded positively to tablet use and that tablets were particularly suitable for autistic students, students with ADHD and those requiring multisensory (audio and visual) input. Other advantages included the extent to which they were customisable, portable and comprehensive. Issues were those typical of any new technology i.e. cost of the hardware and lack of teacher skills (Johnson, 2013).

The Danish teachers used PCs, laptops, iPads and tablets. They found that one tool to two learners worked well, but one to three reduced involvement of disabled learners (Andersen and Sorensen, 2015). The Australian Aid programme funded 10 inch tablets for teachers and 7 inch ones for students, as well as a computer server, wireless routers and cameras for several schools in the Philippines. Free applications, Philippine courseware and Australian learning resources were downloaded onto the tablets. They were intended to be used by 11-13 year old students for English, mathematics and science. Success was mixed: concerns about loss or theft frequently prevented use outside the classroom and teachers had little knowledge as to how to use the tablets to optimise instruction in large classes (Lumagbas et al., 2019).

CAL involving laptops or PCs includes special schools in Victoria and Melbourne Australia with the Victoria school supporting integration into or from mainstream schools (Adam and Tatnall, 2008); physically disabled students in Swedish schools (Brodin, 2010); 'reference schools' in Portugal (Ramos and de Andrade, 2016), a vocational further education college in Dublin (UNESCO, 2011); a Tunisian university and several schools in Grenada (2011).

The Victoria school has students with mild to moderate intellectual disabilities from all socioeconomic backgrounds. Its 121 project provided a laptop or desktop computer for each of the students in its Transition Centre for 60 students from years 10-12. The students were given access and taught to use web 2.0 tools to create an online presence, express themselves and respond to others. Social software and networked learning activities and practices were trialled and the students are starting to use the social software for leisure activities. Access to technology helped engage the students and enable them to learn successfully. However, teacher commitment to personalised student-directed learning experiences is required (Adam and Tatnall, 2008).

Funding from Victoria University was used to give each senior student in the Melbourne school a laptop to use in class and provided PDAs and Dragon digital voice recording equipment. This was later extended to middle of the school students. Software was used to support social and networked learning activities, for instance in music classes. The roles of the principal and ICT specialist teacher were crucial, the principal in providing support, time and resources and the ICT specialist in ensuring that technology and networked activities were appropriate for the students and teachers (Adam and Tatnall, 2010).

Physically disabled students in Swedish schools have access to computers, but not for one per student. The majority of a small study sample used a regular mouse and keyboard, though a small number used adapted terminals, foot control and a joystick. As an example use of laptop with an adapted keyboard for foot typing has enabled a 15 year old student who has always attended mainstream school to be

socially integrated and obtain good grades, though better devices for writing with the feet are available. He uses the laptop at school and at home, including to email files and assignments between home and school and an assistant takes notes for him in class (Brodin, 2010).

Computers with assistive and other software and the VLE Moodle are used in the network of 41 'reference schools' in Portugal. These schools were established to educate blind and partially sighted students in regular classes in mainstream schools and had 225 visually impaired students in 2012/13. Specialist and regular education teachers work together, but there is no technology adviser. A teacher survey found teachers were proficient with computers, but specialist teachers had a greater knowledge of the tools used by visually impaired students. Most of the teachers lacked training in both ICT for visually impaired students and integrating ICT into their teaching. Unfortunately, Moodle is not fully accessible and teachers used Moodle more frequently with sighted than visually impaired students (Ramos and de Andrade, 2016) implying a potential disadvantage to visually impaired students.

The Tunisian university provides personal computers and uses Moodle. The Dublin college is using blended learning involving traditional classes with e-learning to support inclusive learning, including of disabled students and adults returning to education. Moodle is used to deliver e-learning. The approach is supported by collaboration with organisations that provide services to disabled people and a qualified disability support officer (UNESCO, 2011).

Computers with screen readers, magnifiers and special keyboards and various Braille tools were used to support the transfer of five visually impaired students from special to mainstream schools in 2004. Support was provided by the Ministry of Education. Two professionals trained to teach disabled students worked with the school teachers and a trained instructor visited the schools and assisted in training the students. After two years they took the Caribbean Secondary Education Certificate and performed very well, with four of them obtaining over 80%, the first time blind students in Grenada took and passed an exam at this level. Subsequently other disabled students were admitted Two of the students became teachers, one at his old school. The use of ICTs, a technical support unit and specially trained teachers were all crucial in the success of the initiative. This success led to the admission other disabled students to mainstream schools in Grenada (UNESCO, 2011).

Other ICT-based approaches include lecture recordings, subtitles (closed captions), and the provision of digital materials. As evidenced by comments from one of my informants and discussion in the UK University and College Union, teaching staff are generally supportive of lecture recordings made by (disabled) students for their own use, but are very concerned by lecture capture systems controlled by universities. Lecture recordings allow (disabled) students to review them in their own time, at their own pace and as often as they want. A survey of deaf people in Poland and the UK found that their preferred option was for subtitles for recorded educational materials and a combination of subtitles and sign language interpretation for lectures (Hersh, 2013a). Subtitles are also useful to non-native speakers. Digital materials provide accessibility to blind and other students with print disabilities and enable (disabled) students to review materials wherever and whenever and as often as they want.

Examples of the use of digital materials include their provision in a university in New South Wales (NSW), Australia, the provision of digital textbooks by a university in South Korea and the use of digital textbooks in the USA under the Chafee amendment. This amendment allows some disabled students to access them despite copyright legislation (Rose et al., 2005). Examples of the use of lecture recordings include by universities in NSW, England, and the Netherlands for use both in the university and at home. Examples of the use of subtitles include by a NSW university.

Telecentre and technology club examples will now be discussed. 58 community telecentres have been set up in Syria to train people to use ICT. Over a period of 2.5 years nearly half of those trained were female. Six of the training centres provide Arabic screen readers. They also provide audio libraries. The Damascus centre is designed to meet the needs of people with different impairments and has been used to train over 10,000 physically disabled people, including in the international computer driving licence, graphic design, web site design and typing to help them obtain employment. Mobile computer labs are used to bring ICT to and improve digital skills in remote rural areas (UNESCO, 2011; Eid, 2012). It is unfortunately possible that some or all of the telecentres are no longer functioning due to the conflict.

In Eastern Finland two technology clubs have been set up for 4-13 year old children with special needs and their parents. They provide a number of very short duration activities related to the children's interests and which use various senses and take the children's opinions very seriously. The main technologies are six laptops, including LEGO mindstorm NXT robots and one touchscreen. The children have made control units to control computer programs using USB game-pads or keyboards with wood, aluminium tape and/or cardboard (Kärnä et al. 2010; UNESCO, 2011).

The final example in this section is the Moscow Technical University Centre on Deafness (GUIMC) which offers specialist Bachelors and Masters programmes in computer science and engineering. ICT is used to support alternative communication in the classroom to improve access to information, The technologies and support materials provided include a smart board with associated software, internet resources, powerpoint presentations, student presentations, scanners and printers. Each GUIMC student has an individual package of resources based on evaluation of their needs. This includes individual and group hardware as well as additional support, communication and rehabilitation services such as special devices, special software, assistive listening devices and sign language translation. GUIMC students have an additional year of study (GUIMC, undated).

2.5 The Impact of ICT Use on the Education of Disabled People

There have been several studies of the impacts of ICT use on learning of disabled people. Many, though not all of them indicate positive outcomes. Brief overviews of the outcomes of a number of studies are presented in this section. They are intended to be representative, but it should be noted that no attempt was made to identify all the studies in this area. In addition, there is the possibility of publication bias i.e. the greater likelihood of studies which obtained positive outcomes being published than those with no or negative outcomes. Few of the studies identified indicated effect sizes. The studies reported below are either subject or skills specific. Some of them are for disabled learners with a particular impairment (disability) and others with several different types of impairment.

There are several studies of the impacts of different technologies on writing skills. Several studies reported in (Batorowicz et al, 2012) indicate that the use of multimedia, concept mapping/organising software and dictation (with speech recognition for college students) can improve quality and/or quantity of the writing of children (and adults) with learning difficulties. There were also indications that multimedia technologies could improve motivation. However, these studies are of low or moderate quality (Batorowicz et al, 2012). Both disabled and non-disabled students have been found to benefit from the use of online instruction in the Paragraph Writing Strategy (an approach for learning to produce structured writing) using power point media, streaming video or multimedia (powerpoint and video). Power point instruction was the most effective and led to significant improvement for both disabled and non-disabled students. However, this may have been due to greater previous familiarity with power point (Kaffar, 2006). The addition of graphical symbols (produced using symbol production software) to written text has been found to improve reading comprehension of some adults with mild and borderline learning disabilities (Jones et al., 2007). However, it should be noted that technology was used here just as a mechanism for producing the symbols.

There are a number of studies of the use of ICT in mathematics education with students with 'high incidence' disabilities, with anchored instruction the most commonly investigated approach. This involves problems situated in a real-world context presented via video on a CD-ROM (Bouck and Flanagan, 2009). Several studies, particularly by Bottge et al. e.g. (2006, 2007) have shown the effectiveness of this approach in improving problem-solving skills, contextualised problems and transfer tasks, but that students may do worse on computational assessments. This could be due to learning less factual knowledge or an inappropriate assessment method (Bouck and Flanagan, 2009), giving a need for further research. Several studies, generally involving small numbers of disabled students, have indicated the potential effectiveness of audio and video online lessons, multimedia and other computer aided instruction software in improving various mathematics skills of disabled students. However, after the first eight lessons where computer aided instruction may have had a novelty effect, teacher instruction e.g. flashcards was found to be more effective in improving automaticity of basic mathematics facts (Wilson et al., 1996).

A range of technology, including videos, multimedia and software of different types, was found to be effective in improving vocational, independence and social skills for autistic adolescents and young adults in a review of high quality studies. As in the case of touchscreen mobile devices, only a few studies involving very small numbers of autistic students, considered academic skills. They showed that video self-modelling on an i-Pad increased independent completion of mathematics story problems across six problem types and the production of correct unprompted responses in small group science instruction (Odom et al., 2015).

A pilot study of the use of a web-based virtual history museum (VHM) with three classes in a US urban middle school showed similar post-test scores for disabled, non-disabled and honours students after adjustment for pre-test differences. This indicates that the technology had enabled disabled students to learn as much as honours students. However, disabled students performed less well than the other two groups on a position paper, possibly due to poor writing skills. Students believed they had benefited from the VHM and liked its text to speech features. Disabled students had higher rates of engagement and were more willing to write than in traditional history instruction (Okolo et al., 2007).

There are indications of the effectiveness of mobile technologies, for instance, in improving task engagement and completion by disabled people, but further research is required (Cumming and Draper Rodríguez, 2017). A Swedish study of school computer use by physically disabled students aged 8-15 years found computers to be a useful tool, which was not used optimally, and that teachers lacked ICT competence (Brodin, 2010).

Motivation, enjoyment of learning and self-esteem are also important. Primary school children with learning disabilities in Slovenia considered CAL more fun than traditional approaches, but most of them only had a few computer aided classes a year (Bagon and Vodopivec, 2016). Students using laptops with a variety of software and networked learning activities in a Melbourne special school were found to have high self-esteem and engagement (Adam and Tatnall, 2010). Various ICT tools have been found to help focus learners and to reduce noise and disruption and the exclusion of disabled learners. They have increased physical and academic, but not social inclusion (Andersen and Sorensen, 2015).

3. ASSISTIVE TECHNOLOGIES (AT) FOR DISABLED LEARNERS

This section is divided into five subsections. Subsections 3.1 and 3.2 discuss the factors that affect AT use and its availability in different countries respectively. Sections 3.3 and 3.3 present AT used by visually impaired, and autistic and other disabled people respectively. Section 3.5 considers the impacts of AT use.

3.1 Assistive Technology (AT) and the Factors that Affect its Use in Education

There are various different definitions of assistive technology. The focus here will be on ICTs used by disabled and/or elderly people 'to overcome the social, infrastructural and other barriers' to independent learning, full participation in education and carrying out [learning] activities 'safely and easily' (modified from Hersh and Johnson, 2008, p. 196) and with minimal assistance. There has been some discussion of the relationship between UDL and AT e.g. (Rose et al., 2005). However, it is most useful to consider both UDL and AT as tools for accessing high quality inclusive education which enables all learners to achieve their full (learning) potential rather than aims in their own right. This makes AT a means of accessing the curriculum and achieving positive outcomes (Warger, 1998).

Students may need support and training to successfully use assistive technology, but may be unable to commit the time and effort required or not consider them worthwhile (Seale et al., 2010). While there may be tradeoffs between AT use and assistance, it is generally preferable to consider them to be complementary and, whenever feasible, to provide resources to give students a choice. Curricula and/or assessments may need to be modified to provide a learning context which supports effective AT use. Wherever possible, learners should be able to use the same technologies at home and school (Ahmad, 2015), other educational institution and/or work. A very wide range of AT is available. However, where they meet learner needs general purpose technologies have the advantages over AT (Alnahdi, 2014), of easier availability, reduced costs, less stigma and often allowing disabled learners to use the same technologies as other students.

For instance, alternative and augmentative communicative (AAC) apps on iPads and other mobile devices have the advantages over stand-alone AACs of using a mainstream 'cool' device rather than a possibly stigmatising AT. Other benefits include relatively low cost, ease of purchase and operation and device familiarity (McNaughton and Light, 2013). They therefore also overcome some of the other barriers to AT use of relatively high cost, possible difficulties in finding suppliers and the need for (extensive) training. People with minimal technical background can fairly easily develop personalised content for AACs and language intervention (Shane et al., 2012). However, more effective integration with internet and other apps is required, to avoid users needing to toggle between them (McNaughton and Light, 2013), as well as research on AACs in education, social networking and accessing information (Williams et al., 2008).

Student and staff attitudes to AT are very important. Barriers to student AT use include availability issues, high cost, training needs, eligibility issues, device abandonment (Mull and Sitlington, 2003), and concerns about stigma. For instance, a UK study of disabled university students found that some of them only used AT at home due to concerns about stigma (Seale et al., 2010). This can be a particular issue for people from ethnic minorities who may also find it difficult to tell professionals their concerns (Parette and Scherer, 2004). Stigma can be reduced by designing ATs to be small, attractive, similar to general use devices and/or challenge stereotypes (Bichard et al., 2007, Hersh, 2013b). Factors such as reliability and availability of technical support, involvement of potential users (and their families if appropriate) in decision making and ease of use, particularly the time taken to programme the device also affect AT use (Baxter et al., 2012).

'Bring your own device' is becoming more common. This has the advantages of ensuring that disabled learners can use a familiar device with AT already installed. It has the disadvantage of shifting costs to students where funding is not available. This is a problem for all disabled students, but particularly difficult in low and middle income countries (Hersh and Mouroutsou et al., 2015).

Many disabled UK university students have been found to be highly proficient and frequent technology users and use a wide range of different strategies to support effective technology use in education. They frequently used strategies for computer or information access and managing written work and preferred technologies which saved time and gave faster access to data (Seale et al., 2010). They often used both specialist ATs e.g. Kurzweil and Dragon Dictate and mainstream technologies e.g. mobile phone and digital recorders, as well as free alternatives to proprietary ATs and several ATs to manage the computing environment (Seale et al., 2010).

3.2 AT Availability in Different Countries

AT availability varies greatly both between and within countries. The main factors that affect it are income, language and urban/rural area, with most of the ATs available in English or the more dominant European languages. There are, for instance, several hundred learning technologies, including a wide range of ATs, in the UK. In countries, such as Serbia (an upper middle income country) where AT is limited, screenreaders and other AT for visually impaired people are the most common. Within countries rural students use significantly fewer AT devices than urban ones (Ault et al., 2013). There is a marked digital divide in Australia with much greater ICT access in cities and by the European population than in

rural/remote areas, particularly by disabled and indigenous students. Many assistive and learning technologies are available in English but there are no ATs in Australian indigenous languages (Hersh and Mouroutsou, 2019).

As high income English speaking countries (by the European population in the case of Australia) the UK and Australia have relatively good educational AT access. Screenreaders and possibly some additional AT are available on the computers in most UK colleges and universities. Many Australian and UK universities and colleges have an AT centre in the library, with a range of AT, ergonomic furniture and private study rooms. Most Australian universities make free short or long terms loans to students of laptops and other equipment and some AT, such as DAISY readers and talking calculators, and let students upload WYNN screenreader and Dragon speech to text conversion software to their computers (Hersh and Mouroutsou et al., 2015). In some countries, including Australia and the UK computers are available at all levels of education with greater availability at university than school level. In France, a high income country with a slightly less widely spoken language, computer and white board magnifiers are available and cameras connected to a tablet enable zooming in on a white board. Braille notetakers, computers with screen readers (JAWS) and interactive tactile maps on tablets are also available. However, there may be delays in the production of Braille/tactile images.

However, there are also limitations on AT access in high income English-speaking countries. In Ireland a very small percentage of the special education budget is used for AT, access to educational AT requires diagnosis, can easily miss students and does not allow a trial period. Transfer of AT between institutions does not always take place (Bouck et al., 2012). AT access in the USA may be impairment-dependent. For instnace, US students with learning, cognitive, emotional and behavioural impairments and ADHD have been found to have limited AT in school and post-school (Bouck et al., 2012).

Italy and South Korea are two very different high income countries with lower incomes that Australia and the UK and less dominant languages than English. In Italy schools are required to provide AT-equipped computers for disabled students, though there does not seem to be a standard setup. In South Korea modified keyboards, mouse emulators, screen magnifiers and screen readers are available in special education schools, but only for specific students in mainstream schools. Additional AT can be supplied on request to mainstream and special schools (Hersh and Mouroutsou et al., 2015). Estonian became a high income country in 2006 with a very much minority language. An Estonian text-to-speech converter and Thunder screen reader are available free of charge, as well as Estonian learning technologies, mainly e-learning platforms, and online dictionaries and handbooks e.g. an Estonian dictionary of grammar and some English-language technologies (Hersh and Mouroutsou, 2019).

Romania is an upper middle income country with a language spoken by a moderately limited number of people. Braille materials are only available in special schools. Robobraille is a free software available in Romanian which produces accessible document formats e.g. MP3, Braille and e-book. It was developed by a project. Digital recorders are also available.

Georgia and Nigeria are both lower middle income countries, though per capita income (GDP) in Georgia is nearly twice that in Nigeria. In Georgia blind and partially sighted children mainly use a slate and stylus

to write and there is limited availability of Braille displays, CCTVs and magnifiers. In Nigeria there is limited use of AT hardware, including large key keyboards, mouse alternatives and induction loops; and software, such as screen-readers, magnifiers, print to Braille converters, Braille to speech synthesizers, speech to text converters, memory/organisation devices and voice-over on electronic devices (Adebisi et al., 2015; Bosick et al., 2008; Osatuyi, 2003; Yusuf et al, 2012). The main groups that use AT in education are hearing impaired people and people with a learning disability (Ajuwon and Chitiyo, 2016; Adebisi et al., 2015). Nigerian teachers lack familiarity with both computers and AT (Yusuf, 2005), but mobile phones are frequently used to support learning and communication (Idowu et al., 2003), as in many other low income countries. They may therefore have the potential to support AT use, for instance in the form of apps.

3.3 AT Use by Blind People

ATs for blind people are amongst the most widely available. Screen readers, such as Jaws, followed by screen magnifiers are probably the most commonly used AT by blind people. Other AT used by blind people includes refreshable Braille displays, Braille notetakers, Read&Write Gold, a flexible toolbar which supports access to reference books and journal articles, Supernova, the Smart Brailler and mathematics software. The Smart Brailler provides standard print output and auditory feedback (Michaelson et al., 2015). Teachers with minimal Braille knowledge can use the free software Braille Easy to produce Braille mathematics representations from computer text. They can use the free software Monet with a Braille printer to produce tactile graphics of printed versions of graphs, charts and other figures (Bernardo and Rust, 2018). AT use by visually impaired people needs to be complemented by accessible materials, including accessible websites (Ashraf et al., 2017). Customised and optimised user interfaces for mobile devices and applications can increase inclusion of visually impaired people (Buzzi et al., 2012). Software, such as LaTex, BlindMath, LAMBDA and LeanMath use access overlays and hotkey techniques to improve e-accessibility (Ashraf et al., 2017).

This and the following two paragraphs give examples of AT use in universities. A university in England has provided Supernova since 2000. It has screen magnification, speech output for use with headphones and loudspeakers and Braille output for use with a Braille display on its computing network (Supernova, 2014). This enables blind and print disabled users to obtain Orpheus speech synthesiser output on any campus machine with a sound card and automatically access the many applications available to other students.

A university in Poland provides computers with internet access and AT, including optical character recognition (OCR), screenreaders (Jaws and NVDA) scanners, screen magnification (Lunar and Zoom Text) and CCTV and magnifiers in its main and subject libraries. Since 2010 several Polish universities have provided disabled students access to a digital online library, including study material provided by the university, and technical books. There is also a library of 'talking' books which has a Braille printer and a Braille notetaker. A technical university in Poland provides an environmental information system using small devices with sensors and loudspeakers installed at 30 points which provide information which can be activated using a free app on a smartphone or tablet. When approaching a device information about the building and getting around it is read out using the loudspeaker. All information is available in Polish and English. The system also provides contact information and will read out the canteen menu when passing the canteen.

In a public university in Mato Grosso state, the accessibility committee has not received any requests for assistance in accessing technology, presumably due to the low numbers of disabled students. A university in the Brazilian state of Parana provides blind students with laptops with screenreaders and aims to identify and meet the needs of other disabled students.

This and the next paragraph provide examples of AT use in schools. The screen reader Jaws and windows accessibility options are regularly used in Portuguese reference schools. Refreshable Braille displays, Braille embossers, scanners, electronic calculators, electronic pocket magnifiers and closed circuit television systems are also available (Ramos and de Andrade, 2016). In Georgia, Braille displays, CCTVs and magnifiers are available to a limited extent, but blind and partially sighted children mainly use a slate and stylus to write.

Tactile graphics have been developed by teachers at a school for visually impaired students in Brazil for use in mathematics and science classes. The school has equipment and technicians able to do this on a large scale, but low cost materials are also used to facilitate reproduction by other teachers. The resulting graphics are used to support class discussion and/or answering questions (Bernardo and Rust, 2018). A primary school in Mato Grosso state has provided optional special assistance once a week, including very creative use of low tech AT created by the teachers from low cost materials, but does not have mid or high tech AT.

3.4. AT Use by Autistic and Other Disabled People

Relatively few accommodations have been developed for autistic students (Kimball and Smith, 2007) and they may feel unsupported. Timers, computer software, online learning environments and PDAs (personal digital assistants) have been found to be effective on their own, but provision of a single mobile device with multiple applications would probably have advantages in mainstream education (Southall, 2013). A voice output communication aid called Proxtalker which stores vocabulary on sound tags and retrieves it with the device's radio frequency identification (RFID) technology has been used at least on an individual basis (ACE Centre, 2019) and could probably be beneficial on a larger scale.

Autistic students, students with dementia and students with low levels of literacy are using touch screen technology with about 50 symbols in a special education college in North East England to support learning in areas including vocational learning e.g. horticulture and travel, and daily living skills. The skills to be learnt are divided into a sequence of instructions. The approach is suitable for any topic that can be presented as a sequence of instructions (Hersh, 2014). A smartphone application has been developed to support training in the identification and use of PECS communication cards by autistic students and students with cognitive impairments in special schools in Brazil (Manrique et al., 2016).

Text highlighting and supportive captions for digital instructional materials have been found to be useful for hearing impaired students (McInerney et al, 1999). Microphone and receiver systems linked to the student's hearing aid have been used in several institutions, including universities in

Tunisia and Scotland. A hard of hearing student using this system supported by the lecturer being careful to always speak facing the class and giving pointers on communicating to hard of hearing students to lab technicians and demonstrators obtained very high marks in an engineering class at the Scottish university.

3.5 Impacts of AT Use

AT use enables many disabled students to study and to do so effectively. Without a variety of assistive input and output devices many disabled people would not be able to access computers and other ICTs. Children as young as 18 months can learn to use switch interface devices (Campbell et al., 2006), giving them access to learning and interaction options. Physically disabled people with impairments that affect hand or arm movement can use a range of input devices, such as large keyboards, eye, head or foot control systems, joysticks, single switches, sip and puff devices and switch adapted mice, frequently together with onscreen keyboards. This gives them access to computers, a wide range of information online and a means of producing easily legible output. This can also give them access to AACs in the form of mobile apps, if required.

Blind and partially sighted people use screen readers, screen magnifiers and less frequently Braille displays to gain access to what is on the screen of many ICT devices. Many screen readers can also provide access to feedback about what is being typed and computer operations. However, effective use of screen readers requires the software being used, including websites, to be appropriately designed to be compatible with them. Access to ICTs gives blind and partially sighted people access to a wide range of information in electronic format, enables them to edit documents and produce output that can be read by other people. This overcomes many of the barriers they would otherwise experience in accessing information and learning materials. Studies show that the use of AT by visually impaired students can promote expectations of success and assist them in developing skills (Bin Tuwaym and Berry, 2018).

Teachers have been found to consider that AT use leads to improved interaction, better preparation of materials, improved reading and writing and better educational outcomes (Wynne et al., 2016). A study of AT use by young people in education in Ireland found positive impacts on academic orientation (70%), enjoyment (79%), self-esteem (82%), optimism (85%) and subjective well-being (81%) (Wynne et al., 2016).

Having AT in school has been found to improve rates of graduation, paid employment and postsecondary education and reduce the likelihood of earning less than the minimum wage (Bouck et al., 2015). Although this should not be the main motivation for its use, AT is cost effective and can lead to savings e.g. (Enable Ireland, 2016).

The use of touchscreen mobile devices in communication, self-prompting and leisure has been found to be (very) effective with people with developmental disabilities in a number of studies reported in (Stephenson and Limbrick, 2015). However all the studies were very small scale and involved related groups of researchers. Eight of the communication studies involved Proloquo2go and only limited skills based on requesting were taught (Stephenson and Limbrick, 2015), showing the importance of not artificially limiting the aims of the instruction provided. Learners mastered the limited skills to varying extents, but did not show any spontaneous communication, showing a need for more research on

teaching spontaneous communication. Despite the availability of numerous educational apps, there were few studies on teaching academic skills and they only provided suggestive evidence (Stephenson and Limbrick, 2015). It should also be noted that Proloquo2go is an AT communication device, but that touchscreen mobile devices can be either AT or ICT learning devices.

A meta-analysis of the impact of AT use (Alper and Raharinirina, 2006) found that several different ATs had positive impacts on various literacy skills. For instance, ROBOwriter was found to improve writing performance and holistic quality, spelling and grammar, but not essay length of 7-13 year olds with learning difficulties. Other studies have found positive impacts on mathematics skills. For instance, students with specific learning difficulties in the USA have been found to perform better than controls when using an e-text application which converted mathematics to speech using Math ML (Wynne et al., 2016).

A five months trial with an application on a mobile device which allowed users to input vocabulary words and link words with pictures in special needs classes in two Toronto area schools found that it increased confidence, ease of learning, social interaction and peer-assisted learning. This was despite difficulties in using the device, including difficult to understand voices, manipulation problems due to the small size and difficulties in keeping it charged and storing it (Campigotto et al, 2013). A study involving 12 children of an iPad app for monitoring and improving classroom behaviour for children with ADHD found that it improved student self-awareness and regulation. However, students evaluated their behaviours more highly than teachers did (Schuck et al., 2016).

4. TECHNOLOGIES FOR SUPPORTING DISTANCE EDUCATION FOR DIFFERENT GROUPS

4.1 Distance Education and its Advantages and Disadvantages

Distance education takes place away from a particular school or other educational institution. The earliest versions involved text-based correspondence courses. More recently, ICT, particularly the internet, has been used to enable students to study away from an educational institution, frequently at their own pace. Distance education can be divided into the following three main categories: (i) provided by a distance learning educational organisation; (ii) blended learning, including online materials; and (iii) online courses provided by traditional educational organisations. Online learning is increasing, including in the minority world countries, with 30% of US students taking at least one online course (Kanwar and Cheng, 2017).

Whichever technologies are used, appropriate pedagogical models will be required to facilitate different styles of learning and teaching and blend with other approaches (Traxler and Dearden, 2005). Majority world (developing) countries would probably benefit from learning from and improving on rather than directly following the approaches already used elsewhere. Teachers should be involved in preparing exercises on mobile devices, personalising them for disabled students and guiding students carrying them out at times and places of their choice (Fernández-López et al., 2013). There may also be a need for additional support for disabled students, for instance to familiarise them with the topic and online

system. This has been found to facilitate instruction for students with learning disabilities (Englert et al., 2007).

Relevant universal instructional design principles for distance education include equitable and flexible use, simple and intuitive use, perceptible information, tolerance for error, low physical and technical effort and providing a community of learners and support and an instructional climate (Elias, 2010). Suggestions for implementing these principles include (Elias, 2011) simple content format packaged in small chunks, using cloud computing file storage and allowing learners rather than teachers to illustrate and animate courses. Further suggestions covered using open source software, available SMS readers and mobile specific AT. Other suggestions were encouraging multiple methods of communication, sending students regular reminders, quizzes and questions and receiving learner-generated content.

All approaches to teaching and learning have advantages and disadvantages. Distance learning has the potential to open up education to disabled people and other minority groups by providing more flexible access and overcoming the constraints of time and place. It can also provide differentiated learning through options for personalisation to take account of the learner's needs. Distance and blended learning can potentially provide access to a wide range of multimedia online resources and difficult to access materials such as rare specialists and native speakers of uncommon languages (Mikolajewska and Mikolajewski, 2011). However, distance learning should not be at the expense of making institution-based and other forms of education more accessible. It also needs to be adequately resourced, so that all teaching materials are high quality and appropriate teaching support is available, preferably with the same staff:student ratios as for institutional learning. In addition, distance learning should involve the development of communities of learners to enable students to support, learn from and motivate each other and avoid isolation.

4.2 Distance Education using SMS and Mobile Devices

In remote rural areas of, for instance, sub-Saharan Africa and refugee camps in the Middle East and North Africa there are few, if any, schools. This can make distance education, using whatever technologies and resources are available, the main or even the only type of education in some areas.

The technologies used to support distance education generally depend on cost and availability. Where it is available, the internet is popular and has a number of advantages. Although not able to provide access to the same range of resources as the internet, SMS on smart and mobile phones has the advantages of low cost, speed, accuracy, user familiarity, multimedia delivery and creation options and local availability of resources, expertise, systems and technology (Elias, 2011; Motlik, 2008; Traxler and Dearden, 2005). However, while SMS can expand educational access, the small screen and controls and difficulties in customisation make mobile phones difficult or impossible to use for some disabled people. Web based course materials may need to be divided into small pages to be easily read on small mobile screens (Whattanarong, 2005) and this may have implications, positive and negative, for disabled learners. Other challenges of learning with mobile handheld devices include variable device features, relatively slow download speed and limited internet access and memory (Elias, 2011), though performance is improving.

SMSs on mobile devices are already being used to support education in a number of different ways. The University of the Philippines Open University has formal SMS based mobile courses in English, mathematics and sciences and students are generally happy to set aside credits to learn by SMS (Ramos et al., 2006). In Mongolia SMS-based English units have been developed for waiters and bank tellers and 94% of them are willing to use SMS to learn English (Batchuluun, 2007).

Mobile phone based education has potential for the more than 13 million children in the Middle East and North Africa (MENA), including 2.3 million in Sudan, out of school due to conflict (Stubbé et al., 2016, UNICEF, 2015). Internationally, 76% of primary school age refugees and only 36% of secondary age refugees are in school (Dryden-Peersen and Adelman, 2016). ICT access in the Arab countries is relatively good and mobile phone access is particularly high, including in refugee camps, with 86% of young people in Zaatari refugee camp owning mobiles, generally smartphones, and 83% having SIM cards (Maitland and Xu, 2005). WhatsApp and Google are the most popular apps/engines (Fisher and Yafi, 2018).

Mobile technologies can provide personalised learning which includes excluded rural learners, but requires student-centred approaches, collaborative learning and constructivist pedagogies (Madden, 2014). Teachers need to be empowered, including through appropriate high quality training, and have access to mobile technologies (Schmitt, 2015).

4.3 Mobile and Other Learning Kits

Various e-learning approaches are being used to try to educate the millions of out-of-school children. Girls, poor children, ethnic and linguistic minorities (Stubbé et al., 2016) and disabled children experience particular education access problems

A number of projects are developing mobile learning, curricula, content and infrastructure (Lewis and Thacker, 2016). For instance, the United Nations refugee agency, the UNHCR (Lewis and Thacker, 2016) has developed a sturdy portable multimedia toolkit which takes 20 minutes to set up. A typical kit has four laptops, 50 e-Readers, 5000 e-books, 250 paperbacks, MOOCs, Khan academy, TV board and video games and provides a customised library and media centre with internet access. It has been deployed in Jordan (http://innovation.unhcr.org/about-us/). However, this and other projects should consider the needs of disabled learners, including accessibility and access to AT.

The Rumie tablets are low cost very power efficient tablets loaded with high quality learning resources which can be used to support education in areas without schools. They have been used in 13 countries with positive results. Each tablet provides a full library for the cost of a book and can also monitor student progress. Completion of educational exercises leads to the reward of playing time on preinstalled games. The LearnSyria version includes Syrian e-textbooks, video lessons, offline Arabic encyclopaedia, dictionaries and tools and apps for supporting learning languages, science, mathematics, geography etc. (https://www.rumie.org/learnsyria/faq.html)

E-learning Sudan is a computer/tablet game for learning mathematics that can be used by Sudanese children in their (remote) villages without a teacher. Slightly older children explain each mathematical

concept and how to approach problems in Modern Standard Arabic on short videos. Children can learn at their own pace and repeat material and the technology supports progress monitoring. Pilot tests with children in remote areas of Sudan who had not been to school previously found the game was effective in teaching basic mathematics concepts. The second six months pilot of the game included focus groups with parents and children (Stubbé et al., 2016). Initiatives of this type are very valuable in expanding education to excluded groups. However, no attention seems to have been given to making the Runie tablets or e-learning Sudan accessible to disabled children.

4.4 Distance Universities and Tertiary Education

This section starts with discussion of distance learning in two very different universities in the UK. The UK Open University has been particularly successful in attracting disabled students (Kanwar and Cheng, 2017) and has 24,500 disabled students out of a total of 135,000. Its approach is based on a combination of UDL and reasonable adjustments. Technology and UDL work closely together with technology providing multiple modes of representation. However, providing multiple modes of action and expression is more difficult and the standard assessment is varied rather than multiple options being available. The OU uses a mixture of blended and online learning, organised into modules managed by module teams. Online content is provided by a version of the virtual learning environment Moodle which has been significantly modified to make it accessible and usable. Accessibility and usability testing is carried out by experts and (disabled) users. Each unit has an accessibility champion, who coordinates accessibility issues, answers questions and provides training. However, accessibility features are designed for students with single sensory impairments and not for deafblind students with minimal sight and hearing or for students using eyeblink technology, and they will require assistance. The OU will fund support not available through the Disabled Students' Allowance if the student has a relevant diagnosis.

Content is interspersed with activities and personalisable to some extent. An online tool is able to convert material into different formats, but it not able to produce figure descriptions and has difficulty with complicated tables. A resource centre is also able to produce accessible formats. Various formats are available to make printed texts, audio/visual content, interactive activities, and other online resources accessible. There is a lending scheme for specialist equipment and software. Students work individually, but collaboration is important. However, autistic students, students with anxiety and some other disabled students can engage in other activities instead. Collaboration takes place through teleconferencing systems and an online platform which is about 90% keyboard and screen reader accessible. Live captioning is provided for deaf students.

The University of the Highlands and Islands was set up in 1993 to serve a geographically dispersed, mainly rural population, with a relatively high proportion of bilingual Gaelic-English speakers (Haddad and Jurich, 2002). Its online learning degrees use videoconferencing and a virtual learning environment and provide an online learning community on a student social platform for resident and online students and a 24 hour helpdesk (https://www.uhi.ac.uk/en/studying-at-uhi/online-learning/online-learning-tools/.) A variety of AT is available through loan or purchase via the Disabled Students' Allowance. Disabled students can also receive an individual support plan (https://www.uhi.ac.uk/en/students/support/disability-matters/).

This and the following two paragraphs discuss distance learning in three universities in Africa, one in South Africa and two in Tanzania. Of them, only the University of South Africa definitely has a reasonable number of disabled students, though less that 1% of the total of 350,000 students. In South Africa both institutions and individual students are increasingly mixing distance and contact learning (DoE, 1996) and several contact institutions also offer distance education (Badat, 2005). However, distance higher education has not been particularly successful in attracting Black students and meeting the continuing education needs of mature and working students (Badat, 2005). The University of South Africa had 2500 disabled students in 2011 and has a resource centre which provides texts in Braille and sign language services (Kanwar and Cheng, 2017).

The Open University of Tanzania, the main distance higher education provider in Tanzania, has growing numbers and percentage of women, but low graduation rates. In 2009 it had 50 blind, partially sighted and print disabled students. They used audiotapes or cassettes, with the addition of tone indexing, bleeps or graphics and had initial training on using the audio tape systems and navigating the pages, in addition to the training and services available to all students.

The University of Dar es Salaam has a good ICT infrastructure at its main campus and uses Blackboard and WebCT platforms. A virtual campus with collaborative learner-centred ICT-mediated distance education was set up in 1998. Since 2002 workshops have been organised to provide staff with the prerequisite skills to design and deliver online courses. Enrolment and completion rates, particularly of women are an issue of concern. It is unfortunately difficult to find information about the inclusion of disabled students. The ability to pay where there are fees has also been identified as a barrier (Komba, 2009).

The remaining three paragraphs provide brief information about distance learning in several different countries, as well as access to tertiary education for previously excluded groups. A university in New South Wales, Australia uses closed captioning with podcasts, video casts and screen casts. A university in Tunisia uses speech recognition and text-audio conversion software to make distance learning material accessible. Online courses are used with students in rural areas in Tunisia, including with the idaformation platform. Several universities in Brazil use the virtual learning environment Moodle, which is not fully accessible to disabled people.

The South Korean government promoted the opening of online universities in the early 2000s. It has a public national online university with 240,000 students and 19 private ones with about 96,000 students. Disabled students are a significant minority of online university students, leading to support from the institutions. Accessible materials are provided through government websites for special needs education and a government run broadcasting station for education.

When appropriate ICT is available, it can increase access to tertiary education for excluded groups. This includes women with family responsibilities, secondary school graduates not admitted to African universities (only 3.3% of the population are), learners in remote rural areas, small towns and refugees camps distant from a tertiary institution, and marginalised or poor communities (van Brakel and Chisenga, 2003)

4.5 School, Remote and Refugee Distance Education

The increasing availability of online environments in schools is leading to the increasing use of distance school-level education. For instance, over half a million US students were taking courses delivered by virtual schools in 2005 (Zandberg and Lewis, 2008). SchoolNet was set up in South Africa to support linking schools to the internet (Herselman, 2003). Open and distance learning courses at the Institute of Education in Tanzania, a popular secondary school and vocational institution, have very low completion rates and enrolment of women (Komba, 2009).

Distance learning has been used in sub-Saharan Africa for decades (van Brakel and Chisenga, 2003). Lower costs favour print and radio over computers and television in schools there and interactive radio instruction has been successful, particularly in primary schools. At secondary school level, computer use has tended to be supplementary to the curriculum and computers and internet use to increase quality have been limited to pilot programmes (Van Brakel and Chisenga, 2003).

Technology can be used to enable school participation by learners unable to travel there. For instance, the Bednet system in Belgium enables learners at home or in hospital due to long term/chronic illness to participate in the classroom. There were 158 Bednet learners in 2009-2010 and the aim is to increase this to 500 to meet the estimated need. The Bednet system has an easy to use interface and a broadband internet connection between the class and the learner's room. It mirrors the learner's classroom environment on their laptop and gives access to IT learning resources and video conferencing and remote access to printers and scanners at both the school and the learner's site to exchange documents, assignments and exercises. The webcam gives the learner visual contact with classmates and the teacher. They can take pictures of the blackboard with a digital camera. Classmates of the Bednet learner operate the school site using training and a simple manual. They and the Bednet learner can access a helpdesk if necessary. The system can be used outside classes for social interaction (UNESCO, 2011).

Despite initiatives such as Bednet, less attention has been given to online instruction for disabled than non-disabled students and there is limited research on online school education for disabled and at-risk students. It has been suggested that virtual schools have numerous benefits for disabled learners. For instance, they can provide individualised instruction to meet their needs, flexible schedules and location and increase accessibility for students unable to attend traditional schools (Rose and Blomeyer, 2007). However, (largescale) moves to online learning would reduce pressure to make traditional schools accessible and could result in some of the benefits of interaction between disabled and non-disabled students being lost (Vasquez and Straub, 2012).

Online training courses have been produced in Romania for people with physical disabilities and from rural areas. Online courses are used in both blended and distance learning. A blended learning centre was set up in 2017 to support home schooling.

In China the established network of public libraries has been used to improve access to the internet. Despite various challenges, rural libraries are used more than urban ones (Minges et al., 2014). Cybercafes and telecentres have also been suggested (Chinapah and Odero, 2015), but may not be accessible to all disabled people.

4.6 Prison Education

Education for prisoners raises various challenges, including a varied population, generally with limited previous education and sometimes minimal reading and writing skills, a variety of problems, sentences of different lengths and increasing numbers of non-native speakers (Greenberg et al., 2007; Hammerschick, 2010). There are also concerns about security and prisons are not a flexible environment. ICT can involve more prisoners, offer a wider range of subjects, including short courses, and provide more options for personalisation (Hammerschick, 2010).

Several European countries (Hammerschick, 2010) and US states provide e-learning, generally with very restricted and controlled access to the internet due to security concerns. However, this could be managed by using learning management systems to restrict access to outside sites (Chappell and Shippen, 2013). A variety of technologies are in use in the USA, but some are dated. A 2003-4 US survey showed that distance education using video or satellite technology was available in half the prisons (Chappell and Shippen, 2013). It is difficult to obtain information about specific measures to make prison education accessible to disabled prisoners and it seems unlikely that this has been done on a large-scale basis.

5. TECHNOLOGIES FOR DIFFERENTIATED LEARNING FOR DIFFERENT GROUPS

5.1 Differentiated Learning (DL) and UDL

Differentiated learning (DL) involves students having the same learning goals and learning similar things. However, a variety of approaches are used to take account of students' learning styles and how they learn, including degree of difficulty, working arrangements and support, and express this learning (Tomlinson, 1999, Tucker, undated). DL frequently involves small working groups, regular assessment and students sharing what they have learnt with classmates (Tucker, undated). It requires solid curricula and instruction, student engagement and students to develop understanding, not just acquire knowledge (Tomlinson, 1999).

DL should meet all students' needs, maximise their learning capacities and grade level attainment, raise expectations and provide varying levels of support from teachers (Lawrence-Brown, 2004; Mahoney and Hall, 2017). It can also provide opportunities for disabled students to learn at higher levels than in special education and give students an enriched more advanced curriculum in some subjects and support in others (Lawrence-Brown, 2004). It is as much about providing exciting an enriching learning opportunities for the 'better' students, as for students requiring additional support.

DL frequently involves small working groups and students sharing what they have learnt with classmates (Tucker, undated). The use of flexible groupings can facilitate students working with diverse others and should allow disabled students to be the helper as often as the person assisted (Broderick et al., 2005). Personalised learning which takes account of interests and abilities could be obtained by combining DL with lessons and projects which take account of student needs and a focus on learning rather than didactic teaching (Ferguson, 2008).

Differentiation and UDL should have a proactive focus towards preventing learning problems rather than reacting to them. This includes ongoing assessment of student needs for technology, instruction and other supports (Basham et al., 2010). However, care should be taken so that students do not feel under pressure due to continuous assessment of performance and needs. Participation in differentiated, as other, classrooms will frequently require access to AT, including AACs and modified content (Broderick et al., 2005) and can, for instance, support oral presentation of content (Lawrence-Brown, 2004).

Good teaching of any type requires well-trained teachers with good understanding of the underlying pedagogies. DL is particularly demanding of teachers and requires a range of skills, particularly when technology is used to support it. Unfortunately, many teachers lack this training. For instance, a study of secondary school teachers in South Africa found that they were generally not trained to create effective DL strategies and generally wanted more in-service training and support. The overwhelming majority noted the lack of curriculum flexibility and additional time to meet diverse learning needs (de Jager, 2013). Unfortunately the survey did not mention the use of technology to support differentiated instruction. Research with teachers in France found that the use of DL was rare and that many teachers did not accept its value.

5.2 Using AT and ICT to Support DL

Assistive and other learning technologies have considerable potential to support DL, since they provide different ways of learning, for instance using different types of (multi)media, as well as expressing what has been learnt. However, there is both limited discussion of the use of technology to support DL in the literature and examples of its use in practice.

Suggestions have been made of a number of technologies which can support DL, including with disabled learners. Unfortunately not all the websites are fully accessible. Storybird, Bookshare and Newselea provide access to reading materials at various levels and on different topics. Bookshare is an accessible online library for people with print disabilities and Newsela provides nonfiction articles on various topics. Students can choose the reading level and answer a quiz to provide feedback on their comprehension. QR codes are readable by mobile phone and can be used to provide information about assignments, meanings of vocabulary words and assessment directions and questions to allow individual assessments (Mahoney and Hall, 2017). Unfortunately Storybird is not fully accessible. These materials are available in English, though they are probably similar websites in other languages. However, care will still be required to ensure appropriate use of technology, lesson planning and class inclusion.

Other technologies which have potential for supporting differentiated learning include (mobile) digital games (Hersh and Leporini, 2012, 2018), virtual worlds (Stendal, 2012), augmented reality (Akçayir and

Akçayir, 2017) and problem based learning with real world problems presented in video format (Bouck and Flanagan, 2009). A combination of subtitles, audio description and traditional text-based presentations can be used to improve accessibility for all students. (Mobile) digital games and virtual reality have particular potential due to their versatility, their great familiarity to young people and findings that they can contribute to children's social skill and academic development and academic achievement (Crompton et al., 2018). The familiarity of young people with these technologies, mobile/smart phones and tablets (Prensky, 2001) make approaches of this type particularly appropriate. In addition digital games are popular with all ages not just young people (Hersh and Leporini, 2019).

5.3 Examples of Technology-Supported DL

There is potential in using multiple apps or other technologies on one device to support DL. This could allow different students to carry out different activities to achieve the same learning goals and express the learning outcomes in different ways. However, it has been difficult to obtain information about this type of DL. More generally technology-based DL has the further advantages of supporting development of ICT skills by disabled and other learners. These skills are valuable in employment, education, as well as obtaining information more generally. Technology also facilitates giving different students different learning materials to provide an authentic motivating experience which takes account of their learning level preferences (Heemskerk et al., 2005).

A few examples of the use of technology to support individualised and/or differentiated learning will now be provided. A US study used the Lexia Core 5 Reading technology-based program to provide DL to students based on four groups. The groups were assigned by two reading assessment tools based on performance. Students with difficulties in decoding or comprehension improved over a period of six months, whereas those with difficulties in both areas did not and would probably require more teacher input (Baron et al., 2019). However, the approach was not full DL, as the best readers were not included. It was also unclear how the approach was designed to improve the performance of 'typical' readers performing at grade level and no information was provided as to whether any of the 'poor' readers had learning or other disabilities.

An example of an at least partially differentiated learning approach involved the introduction of four to six iPods and two iPads per class to two elementary schools in a rural suburb in Canada and their use in early French immersion teaching. In addition, all the classrooms had an interactive whiteboard and laptops and iPads were shared between classes on a wheeled cart (Pellerin, 2013). The technology enabled teachers to shift from a teacher-centred to a more learner-centred approach with more individualised and guided practice. This included work with one student or a small group while other students worked on other activities. Evidence of progress was obtained from digital recordings from iPods and iPads and used to assess individual students' needs. The multimedia and digital features provided support for students with specific learning needs or difficulties, including through multiple representations of content.

A wikispace for American Deaf history has been developed by teachers at a secondary school for deaf students in Massachusetts, USA. The resulting shared online space has been used to encourage student engagement and support DL. Students and teachers can compile digital resources in a shared space involving a learning management system. American Sign Language (ASL) lectures and student projects

in ASL on video can be embedded in the learning management system, which can also be viewed at home (von Bitter and Turley, 2016). The system could be used with hearing as well as deaf learners. It has the advantage of giving access to resources from a Deaf perspective, which may be particularly valuable to other disabled and non-disabled learners. Analogous approaches could be used to provide access to resources from the perspective of other disability or minority groups.

An example of individualised learning is the use of Microsoft Photostory by an adult and community learning tutor in England to engage a learner with ADHD while the other learners were engaged in glass painting. He used a digital camera and laptop to produce a photostory of the others' work and needed little support after an initial explanation (NIACE, undated p.9).

6. EDUCATION SYSTEM CHALLENGES IN THE ROLLING OUT OF TECHNOLOGY FOR INCLUSIVE EDUCATION

6.1 Challenges due to Lack of Funding, Other Resources, Training and Support for Inclusive Education

To some extent most countries are affected by similar barriers to the introduction of technology for inclusive education. These include lack of funding and other resources, lack of information about learning and assistive technologies, lack of training in the effective use of learning technologies, DL and teaching diverse classes, including disabled people. When learning and other ICT initiatives are introduced, there is frequently a lack of consideration of the needs of disabled learners. For instance, in two secondary school multimedia laboratory projects in Cameroon laboratories were installed on the first floor of a building without a lift, preventing computer access by wheelchair users (Nganji, 2008). Another important challenge is the lack of awareness of how technology can contribute to inclusive education, so that UDL and technology are sometimes considered separately.

These issues are compounded by the large numbers of children out of school and the lack of school buildings and modern infrastructure in many of the majority world countries, particularly in sub-Saharan Africa and the Middle East and North Africa. Rural schools e.g. in South Africa are often in very isolated areas. They lack computers and telephones and experienced and skilled teachers and sometimes do not have adequate buildings and stationery. Children may also need to walk long distances to them (Herselman, 2003). This is a drain on their time and energy which can affect their learning.

While support for inclusive education is increasing worldwide, it is still not universal and progress to inclusion, even where it is supported, is not always fast. In some countries, such as Kazakhstan, there is a degree of nervousness about the introduction of inclusive education (Zholtayeva et al., 2013). In many majority world countries the focus is still on identifying disabled children and ensuring they go to school. For instance, in Tanzania only an estimated 1% of disabled children go to school (Grönland et al., 2010). Being disabled is still stigmatised (Hersh, 2013b) in many countries worldwide. This can result, for instance in Ghana, in disabled children receiving less attention than other children and being taught by untrained teachers (Hooker, 2007).

Highly qualified and motivated teachers are crucial to the successful introduction and use of assistive and other learning technologies to support inclusive education in the context of UDL. For instance, teacher training and professional development are the most cited factors for the successful integration of laptops in majority world countries (Lumagbas et al., 2018). A particular challenge involves matching up technology and pedagogical approaches, while recognising that providing materials in various formats improves accessibility (Kinelev et al., 2005). This needs resources to be focused on training teachers to use ICT and AT effectively (Lumagbas et al., 2018) to support inclusion based on UDL principles, including in differentiated learning. However, many teachers have not had training involving ICT (Kinelev et al., 2005) and may have less ICT experience than their students (Prensky, 2001). As well as a challenge this is an opportunity for (confident) teachers to learn from their students and thereby boost their confidence and self-esteem and potentially their ability and motivation to learn.

6.2 Challenges in Accessing AT and ICT

Despite its benefits many postsecondary students have difficulties in obtaining AT (Lang et al., 2014). Ensuring AT is used effectively can be challenging and ineffective and inefficient use act as barriers to inclusion (Grönland et al., 2010 Singal, 2008). Barriers to the effective use of AT include lack of funding, time and specialists, lack of student and teacher knowledge, institutional barriers and lack of collaboration between the relevant parties Students lack knowledge on what is available and how to obtain, maintain and use devices and teachers lack knowledge on how to effectively integrate AT into teaching and support learners using it. Institutional barriers include negative attitudes, complex processes for distributing AT and limited training of disability service staff or too few of them (Lang et al., 2014; Messinger-Willman and Marino, 2010). While lack of funding is a problem in all countries, limited funding for ICT and education is a major problem in the majority world countries. In some countries there is a lack of basic IT, including hearing aids and Braille materials. Donated equipment has been abandoned due to lack of instruction manuals and training support (Hooker, 2007).

Answering these challenges will require motivation at all levels and greater prioritisation and funding from national governments and overseas development initiatives. It will also require collaboration between teachers and AT specialists, effective coordination and establishing and maintaining expertise (Grönlund et al., 2010; Quenneville, 2001). Developing expertise will require creating AT professional development plans, providing time for teachers to share AT strategies at meetings, releasing teachers and funding them to attend AT training and professional development, including online and making links with other professionals, including university special education departments (Messinger-Willman and Marino, 2010).

Access to computers and the internet in schools is very varied. For instance by 2010 96% of schools in Chile had access to computers and 92% to the internet, with the figures for South Africa 38% and 25.8% respectively (Howie, 2010). However, even where computers and the internet are available, they may be totally insufficient for the number of students, leading to limited access. Challenges to educational ICT use in Nigeria include minimal ICT infrastructure, internet connectivity and learning materials, as well as electricity supply problems. Teachers and students lack familiarity with AT, computer skills and technical competence and have negative attitudes to technology. Measures to overcome these challenges should include the provision of ICT and AT, training staff to use ICT with disabled students, the provision of equipment and financial resources (Obiadazie, 2014).

Lack of knowledge may lead to poor rural communities using expensive proprietary software they cannot afford and being unaware of the potential of open source software. Another challenge is the provision of educational materials and technologies in local languages to make them comprehensible to the whole local population, particularly rural/tribal people and women. Stereotypical gender perceptions of ICT as male may act as a barrier to ICT education and access by women and girls (Dlodlo, 2009).

The limited number of computing devices in many schools, particularly in rural and majority world countries, results in challenges of how to use them most effectively and tradeoffs between the number of students able to use them and the length of time for which they can use them. In some cases concerns about loss or damage to tablets have resulted in them not being used outside the classroom. This has significantly reduced the benefits of having portable devices. Insurance might be a solution to these concerns (Lumagbas et al., 2018).

6.3 Challenges Relating to Diversity, Including the Needs of Disabled Learners

The lack of research on technology and student diversity (Palma-Rivas, 2000) can act as a barrier to the use of ICT in inclusive education. Technology needs to be used appropriately to ensure quality teaching (Florini, 1990) and its impact on disabled or other minority group students carefully considered. Particular attention is required to ensure that all learning materials are compatible and accessible with assistive technologies. Designing for accessibility and diversity leads to a need for flexible learning environments and content, links, presentation and navigation which can be personalised to meet diverse student needs (Nganji et al., 2015). Organising and presenting content in different ways is helpful for a variety of minority group students (Palma-Rivas, 2000).

Unfortunately, educational ICT projects do not necessarily take account of the needs of disabled people and disabled students are not necessarily considered in curriculum and educational policy changes. For instance, analysis of the New National Curriculum in Cyprus indicates that, despite its language of diversity and human rights, it fails to take account of the needs and rights of disabled children in inclusive education (Symeonidou and Mavrou, 2014). Costs are likely to be high and availability of technologies for disabled people low in countries such as those of sub-Saharan Africa where most technologies need to be imported. A number of countries, including Tunisia, lack investment in ICT for disabled students. It is limited to a few institutions or considered the student's responsibility.

6.4 Answering Challenges: Teacher Education

Lack of teacher knowledge can be resolved by high quality pre- and in-service teacher education. Various studies have found that teachers' attitudes and beliefs have a very significant impact on successful ICT use in education. For instance, teachers with positive attitudes but less ICT knowledge found it easier to integrate ICT into their teaching and those with negative attitudes were less skilled in computer use (Khan et al., 2012). Therefore, this education should be presented in ways that encourage teachers to reflect on and change their attitudes. There is some evidence from Sri Lanka that introducing ATs to meet the requirements of disabled learners can 'automatically' lead to pedagogical change to greater individualisation (Andersson, 2008ab). However, there is value in reinforcing changed practices through training. For instance, the African Braille Centre provided a Kenyan primary school with Braillers and

trained a teacher as a Braille expert to support several schools to counter negative attitudes to new technologies and ways of teaching and facilitate their implementation (Grönland et al., 2010).

In Kazakhstan there is a training course for primary school teachers on applying ICT when working with disabled children. The course lasts 36 hours and involves active teaching methods in lectures, seminars and practical classes. Lecture topics are intended to provide both theoretical knowledge on inclusive education and practical skills in using ICT in an inclusive environment. It is divided into four modules covering using ICT in inclusive education, teacher readiness to work in inclusive education in Kazakhstan, AT in inclusive education and distance learning for disabled children, and software for creating interactive exercises and developing ICTs for disabled children. Project materials include web sites, videos, online educational media and links to networks of educational communities (Oralbekova et al., 2016). However, training on applying ICT with disabled learners seems to be an exception and information about other training programmes does not mention working with disabled learners or the use of AT.

In some countries training has been provided to groups of teachers as part of a project or other initiative, but may not have been repeated. For instance, teachers in several Kenyan secondary schools received a five day training course on the integration of ICT into the curriculum. Peer learning and sharing ideas and experiences was facilitated by organisation into subject working groups across schools. Trainers trained teachers in ICT skills and helped them brainstorm. Each team presented ICT integrated lessons to the whole group and received feedback. The schools also received 14,500 euros for ICT equipment (Tondeur et al., 2010).

ICT training can involve teaching content based approaches i.e. teaching about ICT and/or using ICT as the delivery mechanism. Content based approaches have been used in Singapore and Canada. In Singapore this includes a 30 hour foundation and 26 hour elective course in pre-service teacher training. Teachers found the foundation course provided useful pedagogical strategies, but insufficient time for proficiency. A bilingual Canadian resource has been developed to help school administrators integrate ICT into the school through sharing successful cases and practical ideas (Jung, 2005).

Examples of ICT delivery mechanisms in teaching include courses in the US, Korea and the LearnLink project in several different countries. The US Virtual High School has two graduate level online teacher training courses which use the internet as the main delivery method. They focus on ICT pedagogy integration in an online learning environment. The LearnLink project has implemented computer-mediated professional development programmes in several countries. For instance, in Guatemala culturally appropriate Mayan language materials have been developed and equipment and multimedia computer labs have been installed in several teacher training schools. Korea's EduNet provides a variety of training materials for individual and online teacher training (Jung, 2005).

In Sri Lanka there has been a move from teacher education about ICT to promoting ICT use across the school to support learning and teaching (Edirisinghe, 2007). A new national school programme, including the use of ICT across the curriculum was piloted in 2012. It involved 20 final year English teacher trainees working intensively with mentor teachers in an intensive school internship. There are early indications of

the effectiveness of the approach and it will probably be applied to the 3000 teachers graduating in Sri Lanka each year (Tondeur et al., 2016).

However, none of these examples considered training in the use of AT or ICT with disabled learners. Inclusive education requires ongoing professional development of teachers. Networking at local and national level between the different stakeholders is also important and can support ongoing professional development. However, existing networks in countries such as Bangladesh and Tanzania are small and separated from each other. They need to be developed into country-wide networks (Grönlund et al., 2010) and also used while this development is taking place.

6.5 Answering Challenges: Lack of Equipment

Access to appropriate technology is clearly a prerequisite for using it in education. A number of different projects and initiatives have been set up both to distribute refurbished computers and electronic equipment and provide new and used equipment to majority world countries.

Access to ICT is a problem for poorer and disadvantaged groups in the high income countries. Solutions include refurbishing and reusing old/unwanted computers. For instnace, in the USA an unorganised network of nonprofit and for-profit organisations acquires used computers and cleans, refurbishes and updates them. An estimated 6.8 million used computers were provided over the period 2006-2010 to disadvantaged schools, community organisations and individuals. The US government has also donated refurbished computers and electronic equipment to schools and nonprofit educational organisations (Jayakar et al., 2015).

Rwanda is an example of a low income country which has obtained computers from a variety of sources. The Ministry of Education's collaboration with a US NGO supplied used computers to primary schools in the early 2000s. The Ministry provided 10 computers to 400 secondary schools. The New Partnership for Africa's Development e-school initiative is a project involving 20 African countries in building ICT capacity in Africa. It equipped six Rwandan secondary schools with 20 computers each, internet connectivity, projectors, laptops and interactive whiteboards, as well as ICT skills training packages, subject specific materials and support. The supply of ICT was facilitated by two large ICT firms. The One Laptop per Child initiative has provided 6000 laptops to primary schools, free to public schools and at a cost of $220 to private schools (Rubagiza et al., 2011). There is not space to discuss the One Laptop per Child initiative, other than to note that it was an excellent idea which was unsuccessful for a variety of reasons.

A number of countries, including Australia (Jayakar et al., 2015) and the UK, give hearing and speech impaired people access to telephone services through telephone relay services. An operator converts text output of a textphone to speech input for a standard telephone and vice versa. In Australia a large telecommunications operator has supplied a variety of standard and adapted telephones to disabled people since 1981. Other providers are required to offer equivalent equipment for disabled people at the same price as standard handsets. However, the initiatives have been criticised for not providing mobile telephones and internet access (Jayakar et al., 2015).

There would also be benefits in local software companies working with teachers to produce educational software in local languages (Khan et al., 2012).

6.6 Answering Challenges: Lack of Funding

Approaches to resolving the problems of lack of funding have included projects, obtaining donor support, private public partnerships, scholarships, provision of resources and academic staff and reducing or removing ICT taxes.

Different countries have different and in some cases multiple mechanisms for funding ICT and AT for educational use. In Serbia the main source of funding for AT is from NGOs through projects. Project funding has also been important in Romania. For instance the development of learning materials for visually impaired students and a Romanian version of the Robobraille software for converting documents to accessible formats took place as part of an Erasmus project. In Korea assistive technology support centres provide assistive technology directly rather than funding. In Australia central and/or state government provides direct payments to schools and universities for support for disabled students. University students in Estonia, Poland and the UK can obtain funding for ICT and AT from the PRIMUS Programme, Student II Programme of the National Rehabilitation Fund and the Disabled Students' Allowance respectively. Direct payments are made to students in Slovakia (Hersh and Mouroutsou et al., 2015).

In addition to attracting fee paying students, many of the high income countries have supported education in lower income countries by providing scholarships or sending academic staff and instructional and research materials. There are generally considerable benefits to the donor countries (Sanyal and Johnstone, 2011). For instance, the US Fulbright English Teaching Assistant Programs place assistance in schools in various countries globally to supplement English language instruction and provide a native speaker (https://us.fulbrightonline.org/about/types-of-awards/english-teaching-assistant-awards). The EU Erasmus Mundus Programme provides a number of scholarships for students from majority world countries on masters and doctoral programmes (https://worldscholarshipforum.com/erasmus-mundus-scholarships-countries-20172018-apply-now/).

The term public private partnerships is generally used to cover both partnerships involving community organisations and other NGOs and those involving for profit companies. While partnerships can cover various activities, the focus is generally on core education services, including teaching and school management (Verger, 2012). They are one of the more controversial funding sources, particularly when for-profit organisations are involved.

Partnership particularly with for-profit organisations may require governments to provide a complex set of support services and procedures which can be excessively demanding of human and material resources for many majority world countries. Although budgetary constraints are used to justify the partnerships, incentives to provide education to the 'neediest' populations can increase costs. In addition, the main cost reductions may be through by-passing public employment regulations and reducing teachers' salaries (Verger, 2012). This is unlikely to lead to highly qualified teachers with appropriate expertise. For-profit (higher) education has been frequently criticised for recruitment of

unqualified students, lack of staff professionalism and excessive profit for owners and managers (Sanyal and Johnstone, 2011).

Partnerships involving community and other NGOs include the School for Life (SFL) which has provided education for out-of-school children in Northern Ghana using an intensive nine-month programme with a focus on basic numeracy and literacy in the local language. The programme was very successful in mainstreaming students into public schools. It was initiated by the local traditional council and NGOs in and with links to Denmark. However, SFL had no formal financial arrangements with the state, making the partneship fragile (Akyeampong, 2009).

Inclusive education projects in Rwandan schools are generally 'dominated' by NGOs. Successful initiatives in Rwanda have involved a common perspective with Rwandan leads and open and mutually-supportive collaboration involving civil society agencies, public services and local community members and leaders. Partnerships with parents, local educators and other local actors were critical for success (Karangwa, 2014).

7. CONCLUSION

Technology has considerable potential to support inclusive education for the whole population, including disabled people. Using ICT in education is also a means of overcoming the digital divide and enabling disabled people and other minority groups to develop essential ICT skills. It can support universal design for learning principles by providing multiple means of participating in all aspects of learning and assessment and providing options for personalisation to support accessibility, interests and learning approaches, and make learning more exciting and enjoyable. ICT could have an important role in supporting differentiated learning, but has only been applied in this way to a relatively limited extent, particularly in inclusive classrooms involving disabled learners.

However, successful introduction and use of ICT in inclusive education requires it to be integrated with appropriate pedagogical approaches and used by well-trained teachers. It is also a tool/strategy rather than a universal solution.

While there are a number of valuable initiatives, the full potential for assistive and other technologies in education is far from being met. In addition UDL and technology are frequently considered separately rather than technology being seen as a tool for implementing UDL principles. There are initiative in many countries to introduce technology, either in general or in education, as well as initiatives to use technology to expand education to excluded groups, such as refugees and young people affected by conflict and in remote rural areas. However, these initiatives have rarely considered disabled people and are therefore unlikely to be accessible to them or otherwise meet their needs.

Online education is becoming increasingly popular in both distance and blended learning. While it can provide access to disabled learners and learners in rural areas who might otherwise be excluded, it should not be a reason not making both distance and institution learning accessible. SMS and mobile/smart phones are increasingly being used to access education in the lower and middle income countries.

Particular challenges are experienced in the low (and middle) income countries, particularly sub-Saharan Africa, including low school attendance and lack of school buildings and other infrastructure. However, there are to some extent similar barriers to using technologies to support inclusive education world-wide. They include lack of financial and other resources, lack of trained teachers and lack of time for curriculum planning.

However the potential for transformation and creating exciting futures is illustrated by a quote from a blind teacher in Grenada whose education in a mainstream school was supported with assistive and other technologies. 'I was the student who had no chance in the world and today I am employed as a teacher' (UNESCO, 2011).

RECOMMENDATIONS

1. Prioritise the use of technology to support inclusive education including disabled learners based on UDL principles as a global development goal and in the provision of development assistance
2. Research and develop measures and a toolkit to ensure that all measures to introduce and encourage the use of ICT, particularly in education, appropriately take account of the needs of disabled people.
3. Research on ICT accessibility barriers for disabled staff and recommendations for making all ICT used in educational institutions fully accessible and usable by them.
4. Set up an international repository of accessible learning materials and reusable ATs.
5. Develop repositories of training materials in different languages on using AT and ICT in education andthe learning/teaching of different groups of disabled people and ensure that all teachers have access to paid-for training in working time.
6. Develop guidelines/recommendations for the use of SMS and mobile devices in learning which are fully accessible and usable by disabled learners and teachers.
7. International research leading to recommendations on good practice in differentiated learning.

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APPENDICES

Appendix 1: Learning and Assistive Technologies

This appendix will start with some definitions. However, it should be noted that there is not yet general agreement on the terms and their definitions (Robyler & Doering, 2013) and that there is some overlap between the different categories. In simple terms educational technologies are used to support learning by both disabled and non-disabled people, as well as teaching and assessment. In an educational context assistive technologies are technologies used by disabled and older people to access educational technologies, overcome barriers to learning and participate in aspects of learning not required by non-disabled people. Learning technologies cover both educational and assistive technologies.

More formally, the term educational technology will be used to denote the *'processes, tools, equipment, devices and systems used to support and facilitate learning, teaching and assessment'* whereas learning technology will cover *'both educational technologies and the assistive technologies used to, for instance, access educational technologies and/or learning materials, participate in learning activities and/or overcome barriers to learning'* (Hersh, 2017).

Assistive technology is defined here as *'technologies, equipment, devices, apparatus, services, systems, processes and environmental modifications used by disabled and/or older people to overcome the social, infrastructural and other barriers to (learning) independence, full participation in society and carrying out (learning) activities safely and easily'* (Hersh and Johnson, 2008, p. 196).

However, the division between AT and other forms of technology is sometimes understood differently by different people and there are examples in the literature of technology being classified as AT which I would not classify as AT.

Learning, assistive (and other) technologies can be divided into hardware and software. Hardware consists of physical devices and their components which can be seen and touched. Software consists of programs, routines and symbolic languages which control hardware. Unlike software it does not have physical components.

Overview of some of the main types of first learning and then assistive technologies will now be presented. Definitions or explanations are given where terms may be unfamiliar to some readers. It should also be noted that many learning and assistive technologies are multi-purpose and not used only in an educational context.

Different types of hardware used in learning technologies include:

- Desktop computers (PCs)
- Laptops

- Smart/mobile phones
- Tablets, including iPads
- Multipurpose pocket computers and media players, including iPods
- MP3 and other media players
- PDA (personal digital assistant): mobile computing device, largely replaced by smartphone.
- TV/radio
- CD/DVD
- USB (universal serial bus): this includes memory devices and cable connections based on an industry standard.

Learning technology software includes:

- Apps on mobile devices
- E-learning platforms
- Videoconferencing software
- Virtual learning environments (VLEs): VLEs provide a range of online tools to allow communication between teachers and students and between students. They enable (multimedia) learning materials to be posted and learning and assessment activities to be carried out.
- Web-based technologies
- Websites, including web 2.0 that emphasises user-generated content, usability, and interoperability for end users.

Assistive devices include:

Input technologies

- Big key or other alternative keyboard: there are both hardware versions and overlays that can be stuck on standard keyboards to give e.g. larger letters or different text and background colours.
- Braille keyboard: generally ten keys, eight for data entry of Latin based alphabets, computer data and function keys, and two space bars. A number of keys are pressed simultaneously for each letter or symbol (chording). They often have an editing mode. Chording keyboards are probably easier to learn, faster to use and more accurate than standard keyboards.
- Eye, head and foot control systems: there are various different options for controlling computer input with different parts of the body. They include a pointer on the user's head, and devices that interpret the user's eye movements to place the mouse pointer. They are frequently used together with online keyboards.
- Joystick: a stick that pivots on a base and uses its angle or direction to e.g. move the cursor.

- Mouse emulation: other inputs such as standard keyput and single or multiple switch scanning are used for mouse operations.
- On-screen keyboard
- Single switch entry devices: they can be used by any part of the body that the user has consistent control of. They are generally used to scan and choose letters, numbers, symbols and graphics.
- Sip and puff mouth controlled joystick: joystick movements are controlled by the user sipping or puffing into the joystick, similarly to drinking from a straw.
- Speech input/dictation software: speech input is used to type the text and control the computer, including some mouse actions. The most commonly used software is Dragon Naturally Speaking for Windows or Mac.

Output Devices:

- Refreshable Braille display: output text from a computer screen is read using Braille cells. 80 cells are required for a whole computer screen, but displays may consist of e.g. 20 or 40 cells. The cells 'refresh' with new text as the user reads down (and along) the screen.
- Screen magnification software: enable users to control the size of text and or graphics on the screen, generally increasing them
- Screen reader: software used by blind and partially sighted people to read the computer screen, what they type, device controls etc e.g. JAWS NVDA, Voiceover for Mac. Modern screen readers frequently have a choice of voices for their output.

Text input improvement software

- Abbreviation expansion: this reduces the amount of typing by using number of letter codes for commonly used expressions.
- Efficient text entry interface: e.g. Dasher which uses natural pointing gestures rather than typing.
- Spelling and grammar check software
- Word prediction: this reduces the amount of typing by trying to predict what comes next. The user selects the right word, sometimes by number, from a list of words to based on what was previously been typed.

Assistive listening systems:

- All these systems improve sound clarity and reduce background noise.
- Audio induction loops: one or more loops of cable are placed round a room or building. The signal is transmitted to and received by the telecoil in the user's hearing aids, so the system can only be used by people who wear hearing aids.

- FM (frequency modulated) microphone and receiver systems: the speaker speaks into a microphone and the listener receives the sound through tiny earpieces/ear level receivers.
- Infrared (IR) listening systems: the user wears an IR receiver which is used together with IR transmitter(s). The system can be used to amplify audio devices e.g. TV or radio, conversations or the sound in cinemas, theatres etc. The same type of system with additional channels is used for simultaneous translation.

AACs (Alternative and Augmentative Communication Systems)

- AACs are communication systems used to replace speech either on a regular or occasional basis. There are stand-alone versions and apps that can be used on mobile or other devices. There are both high and low tech versions.
- PECS (picture exchange communication system): AAC with 'object' and 'action' pictures. Its main use is asking for objects. It can be used for very simple communication e.g. 'I see a tiger' or to respond to 'what do you want?' questions, but nothing more complicated.
- Proloquo2go: very flexible AAC app that can be used on mobile devices. It uses symbols with a large core vocabulary and options to add addiotional symbols, photos etc. There is a choice of 100 natural sounding voices in various languages, including children's voices for output.

Other AT for deaf and hard of hearing people

- Sign language-text conversion software: the software recognises the input sign language and converts it to text. In the other direction text can be converted to sign language. Current systems are still very limited.
- Subtitles (closed captions): verbatim or edited (and sometimes simplified) text versions of the speech content of a television programme or other audiovisual presentation. They generally provide some information about background sounds.

Other AT for blind and partially sighted people

- 3D printer: produces a three dimensional model from a design on a computer. 3D printers can be used to produce tactile diagrams and Braille.
- Braille: a system of reading and writing for blind and deafblind people. It uses a rectangular cell of two columns of three raised dots to represent each letter or other symbol. It is read with the finger tip of the index finger.
- Braille embosser: the embossers print Braille documents by producing raised dots for the cells that represent each letter. They generally use thicker than normal Braille paper.
- Close circuit television (CCTV): can be used to produce magnified images with various text and background colours for partially sighted people.
- DAISY (Digital Accessible Information SYstem): a standard for producing files of talking books. DAISY books can be listened to on DAISY players, computers with DAISY playback software, mobile phones, and MP3 players.

- Scanner with optical character recognition (OCR): scanners produce digital versions of text and graphics. OCR converts the scanned images of text to editable text files which can be read with screen readers or Braille displays. Scanners with OCR enable blind people to read printed material.
- Tactile diagrams: maps, diagrams and drawings etc which are raised above the paper surface and can be felt. They also use different textures. Tactile graphics should have a lot less information than visual ones to be understood easily. Tactile diagrams can be produced on computers or produced by hand.

Appendix 2: Glossary

- Accessibility: system inputs and outputs have characteristics which enable particular (groups of) users to access and use all the facilities of the system.
- Blended learning: a combination of online learning and traditional classroom-based learning.
- Computer aided learning (CAL): learning involving computers, mobile phones or other mobile devices.
- Customisation or personalisation: modification of a system to take into account the characteristics of users.
- E-learning: use of computers or other electronic technologies, electronic resources and the internet in learning. Some definitions consider e-learning to be any learning involving formal teaching and electronic resources. Others consider it to be equivalent to online learning.
- Inclusive education/school: education of all learners in age appropriate mainstream classes in mainstream schools with social as well as academic inclusion and the provision of appropriate support and aids. The school should adapting curricula, methods and procedures to become more responsive/
- Integrated education/school: an intermediate stage between segregation and inclusion involving education in mainstream schools in inclusive or special classes, but without adaptations by the school and under the assumption that the disabled student will make changes to fit in.
- Low, low-middle, high-middle and high income countries: classifications of countries based on a particular measure of the national income per person.
- Mainstream school: inclusive school which is part of the main public education system.
- Majority and minority world countries: the term majority world refers to the countries which form the majority of the world's population in a neutral way rather than using terms such as 'developing countries'. Minority world countries are the other countries.
- Medical and social models of disability: in simple terms the medical model is a deficit based approach which focuses on the individual's impairments as a source of disadvantage. The social model considers disadvantage to result from infrastractural, environmental, social and attitudinal barriers and the societal responsibility to remove these barriers.
- Open source software: the source code is made available to members of the public who are permitted to view, copy, alter and share it and there is no licence fee. In some cases there may

be licence conditions e.g. sharing the modified source code free of charge. Open source licences promote collaboration and sharing.

- Special education/school: separate education/school for disabled (and some other) students.
- Stakeholder: a person, group or organization who has an interest or 'stake' in a particular issue.
- Stand-alone device: self-contained device which does not require any other devices to function.
- Telecentre: a public building with computer, other digital equipment and internet access which can be used by members of the public e.g. to access or improve skills or for use as an office.
- Universal design or design for all: design to be appropriate for all users, regardless of disability, age, gender, size, culture and other factors
- Universal design for learning (UDL): application of universal design principles to learning with a focus on inclusive means of representing information, expressing knowledge and engaging in learning.
- Usability: the ability of the system to carry out the intended function(s) or achieve specified goals effectively, efficiently and with satisfaction when used by particular (groups of) users in their particular context

Appendix 3: Additional Information on Prison Education in Europe and USA

Swedish prison education involves blended learning, including distance learning with a central ICT network. Each prison has a learning centre with one to six teachers. About 140 courses, including Swedish for immigrants and basic and upper secondary adult education, are available to all prisoners and all of the about 120 teachers work with both local and distance education students. Each student has an individual education plan, studies at their own pace and continues their courses if transferred to another prison. Phone and an intranet with forums for meetings of a single student and teacher enable contact between students and distant teachers. All lessons and distance learning take place in the prison learning centres, where contact between local students is encouraged, and at computer work stations. Open internet access is rarely allowed and has to be supervised all the time (Hammerschick, 2010).

There are several US examples of partnerships with colleges and universities. A Florida university has been involved in developing the Ashland Career Online High School and has made high school diplomas and a variety of career certificates available to prisoners through the Online High School. This can lead to postsecondary studies at the university. The Federal Bureau of Prisons time-delayed closed system gives prisoners access to the electronic law library and email (Chappell and Shippen, 2013).