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A proposal for a unified framework for the design of technologies for people with learning difficulties

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ABSTRACT

BACKGROUND: Existing generic technology design principles and guidelines are considered not to be sensitive enough to meet the needs of people with learning difficulties.
OBJECTIVE: To propose a unified design framework that can inform the design of technologies for people with learning difficulties
METHODS: A literature search was undertaken and the resulting papers were analysed and coded in order to identify common ideas or recommendations that could be clustered into design principles.
RESULTS: Four main categories of design principles were identified: learning support, accessibility, usability and agency. A conceptual framework incorporating diversity, difference and digital inclusion offers a way to understand the consequences of applying or not applying some or all of the principles.
CONCLUSIONS: A unified framework for the design of technologies for people with learning difficulties has the potential to fill the gap that more generic design guidelines cannot fill with regards to meeting the very specific needs of people with learning difficulties.

Keywords: learning difficulties, design principles, accessibility, usability, learning support, agency

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1. INTRODUCTION

This paper will present the results of a comprehensive review of the literature in the field of technologies and learning difficulties [see papers 1-45] in order to identify and synthesise common design principles and propose a unified design framework that might inform the design of future technologies for people with learning difficulties. Learning difficulties is just one of an array of labels that are ascribed to people who have diverse access needs associated with perception, memory, cognition and communication and the design of technologies that may help to enhance their access to and inclusion into society (e.g. learning disabilities, intellectual disabilities, intellectual impairment and cognitive impairment [46]). In using the term 'people with learning difficulties' this paper adopts the language advocated by self-advocates such as Simons [47] and self-advocacy groups such as People First [48]. They request that labelled individuals are recognised as people before anything else, and that we use the term 'learning difficulties' to remind others that they can learn for the whole of their lives like everyone else. For the purposes of this paper technology is defined broadly to mean mainstream technologies and applications such as mobile technologies, virtual and augmented reality; games and software as well as more specialised devices such as haptic devices.

The stimulus for the literature review presented in this paper is a current Horizon 2020 funded project called ARCHES (Accessible Resources for Cultural Heritage EcoSystems) which involves heritage and technology partners across Europe. Working in the context of museums, art galleries and heritage sites, the overarching objective of the ARCHES project is to create more inclusive cultural environments for people with differences and difficulties associated with perception, memory, cognition and communication (commonly ascribed labels would include learning difficulties, sensory impairment and hearing impairment). This will be achieved through the development of innovative applications, functionalities and experiences based on the reuse and redevelopment of digital resources. Related to this global aim is an objective to develop and evaluate the use of mainstream technologies to enable inclusion of people with such disabilities as museums visitors and consumers of art. Between 2017 and 2019, the ARCHES project will develop online resources, software applications and multisensory technologies to enable people with differences and difficulties associated with perception, memory, cognition and communication to access cultural heritage sites.

The underpinning approach to the design and development of technologies within the ARCHES project is a participatory one, in which 50 to 100 participants (including people with learning difficulties) from England, Spain and Austria will work collaboratively with the technology companies over the whole life-span of the project. In this sense, the design will be very much led by user needs and feedback. Despite this, we felt that it may still be helpful to conduct a literature review focused on design principles for people with learning difficulties, so that the technology developers in the project would have an underpinning context and knowledge-base to help them interpret and understand the conversations they were having with participants with learning difficulties [Separate reviews have been undertaken for hearing and visual impairment and these will be reported elsewhere). Furthermore, we argue that the outcomes of the literature review can also usefully inform the wider technology design and development community. Our argument is underpinned by a growing acknowledgement that existing and commonly cited design guidelines such as the Usability guidelines proposed by Nielson [49] and the

Accessibility guidelines developed by WC3 [50] are not sensitive enough to the needs of people with learning difficulties, leading those in the field to conclude that:

> *Although thin, the current evidence base indicates that the accessibility needs, requirements, and preferences of people with cognitive disabilities are diverse. This ought to be reflected in accessibility guidelines and standards.* [51]

1.1 Current attempts to address the deficiencies of generic design guidelines

The community response to the perceived gap between generic guidelines and the needs of people with learning difficulties has been varied and eclectic. Less common approaches have involve simply drawing on personal experience [52] or analysing disability classifications [53]. Lloyd *et al.* report on a project called LATCH-ON which supported the use of computers by young adults with learning difficulties [52].They explain how they have used their experience of working on the project for six years to develop a check-list for evaluating the design of software. This checklist suggests a range of aspects that technology developers can attend to including: instructions are clear easy to understand and age appropriate; help messages are easy to access; appropriate screen formatting; feedback is appropriate and relevant; multiple levels of mastery and appropriate cues and prompts to responses. Dekelever *et al.* analysed classifications of intellectual and developmental disabilities and the extent to which mobile software design addresses the usability and accessibility requirements suggested by these classifications. They make a number of design recommendations in relation to navigation and graphic design; text requirements and personalisation including: user input should be minimized; the user interface should have consistent and simple structure; the mobile application should be equipped to identify and prevent errors; in order to reduce the cognitive load and a better understanding, related images can be used; the menu of the mobile device should be adjustable so it can adapt to the needs of users and the number of functions should be limited in order to avoid cognitive overload [53].

More common approaches to identifying design principles for technology users with learning difficulties have been to conduct: user surveys [54,55,56]; in-depth observations of people with learning difficulties using technology [57, 58, 59] and bespoke usability and accessibility testing [60,61]. Dawe reports on the results of semi-structured interviews with twelve families about how and why they acquire and abandon assistive technologies. The results lead Dawe to suggest some design implications which include the importance of simplicity not only in technology function but in configuration, documentation, maintenance, and upgrade or replacement [54]. Williams & Hanson-Baldauf present a study designed to assess how people with learning difficulties used a web portal designed specifically for them. They noted aspects that the users struggled with, which has implications for future design work such as participant difficulty with advanced navigation skills and eye–hand coordination connected to directed cursor movement and mouse manipulation; and web content readability levels [58]. Kirijian & Myers report on a project that aimed to develop online learning modules and games for individuals with Down syndrome. The first two phases involved literature reviewing and interviews with experts. What is most interesting about this project however, is that in the third phase (usability testing), the researchers found results that contradicted those found in the earlier phases. For example, contrary to the research the researchers had completed prior to the usability study no preference for the Comics Sans Serif style font was found. They conclude that the repeated use of this font in materials designed for people with Down syndrome should perhaps be questioned. Kirijian & Myers report a number of other observations regarding Font, Colours and Buttons [60].

1.2 The need for a more unified approach to filling the gap

Whilst each of the current responses to the perceived gap between generic guidelines and the needs of people with learning difficulties offer useful information they are not widely cited, suggesting that the advice and guidance that each has produced is not widely applied or implemented. There are probably many reasons for this, but we would argue that there are two main reasons. Firstly, the potential difficulties that designers may have in finding and accessing such a dispersed set of guidance, particularly when more generic guidelines such as WC3 offer a ‘one-stop shop’, are high profile and easy to find. Secondly, the lack of an overarching conceptual framework that designers can use to understand why a principle is so important to implement. This is something that designers who have previously used accessibility and usability guidelines will be familiar with and may come to expect of any alternative design framework.

The purpose of the literature review reported in this paper therefore is to bring together a wide and varied set of papers relating to design principles for people with learning difficulties in order to identify and synthesise common design principles and explore how they may underpin a unified design framework that can inform the design of future technologies for people with learning difficulties

2. METHOD

The literature review took place between October and December 2016. The parameters of the review are laid out in Table 1. A range of databases were searched in order to reflect the multidisciplinary nature of research in the field of learning disability and technology design. A particular focus of the search was the design of technologies similar to those being developed within the Arches project. A range of keyword terms were used to search for outputs related to learning disability in order to reflect the national and disciplinary differences in labels used to categorise this group of people. The date range of the search was restricted to the last ten years in anticipation that design principles may be quite different for older out of date technologies designed and evaluated prior to 2006. In each literature database, 24 separate searches were conducted using a two level search strategy:

First level search		**Second level search**
Learning disabilities		Mobile technology
Learning difficulties	AND	Games
Intellectual impairment		Virtual reality
Cognitive impairment		Augmented reality
		Haptic device
		Software

These searches produced 75 papers which were then downloaded and recorded. The first author read all 75 papers and made recommendations regarding whether the paper should be included in the review based on the extent to which it addressed the research question. A co-researcher then read the abstracts of the papers along with the recommendations and mediated the decisions made by the first author. This two-level filtering process reduced the number of papers down to a corpus of 45. When referring to these papers in the proceeding results section we will refer to them by their allocated number, 1 to 45, as listed in the Reference Section.

<Table 1 about here>

Once the 45 papers had been identified, they were each re-read and notes were made on anything within the paper that had implications for technology design. These notes were then analysed both inductively (bottom-up, drawn from the information within the articles) and deductively (top-down, influenced by pre-published principles such as those for accessibility and usability). This dual-process was adopted in order to identify common ideas or recommendations that could be clustered together into design principles.

3. RESULTS

In presenting the results of our literature review we will begin by providing an overview of the corpus of papers found in our search in order to provide a detailed context for the review findings; particularly in relation to differences and difficulties, age range, technologies and intended purpose of technology use. Following this overview, we will then focus on using the literature found in our review to answer the question: What common principles for designing technologies for people with learning difficulties can be distilled from the literature?

3.1 Overview of the corpus

There were three different types of paper produced by the literature search. Thirty-one papers which reported the design and evaluation of new technologies. Ten papers reported the design specification of a new technology prior to evaluation by intended users [2,4,5,10,12,14,22,24,42,44]. Four papers reported the results of surveys or observational studies regarding technology use and needs of people with learning disabilities [8,29,33,36]. The 45 papers spanned research from countries in North America (United States); Central America (Mexico); South America (Brazil); Europe (Italy, France, Spain, Germany, Portugal, Finland, Lithuania, Hungary, UK); Asia (Taiwan, Japan, Sri Lanka) and the Middle East (Qatar).

All the studies included in this review involved at least one participant with a learning difficulty; for example those labelled as having 'special educational needs' or Down Syndrome' (we recognise that we have made an assumption that the term 'learning disability' would be commonly accepted as an alternative term to 'special educational needs' or 'Down Syndrome'.) In addition to this, some studies focussed entirely on Autism or ADHD and given that individuals with this diagnosis may not have intellectual impairments we could not reliably draw upon them. Other excluded studies focused on participants with other non-learning related differences such as motor impairment, dementia or schizophrenia. Six studies included people with learning difficulties who also had a sensory impairment – three were from the same EU funded project [17,20,34,38,40,41].

Fifteen of the studies focused on children aged 0-12 years old [articles 1 through to 15]. Three of the studies focused on adolescents, aged 13-19 [16,17,18]. Just one study focused on all three age groups [19]; two focused on adolescents and adults [20,21] and four did not specify the age of their participants [42-45]. Twenty of the studies focused on adults aged 20 or above [articles 22 through to 41].

Many of the studies report the design and evaluation of a combination of technologies, rather than a single technology [3,7,9,10,11,12,18,20,28,33,35,37,39,44]. However, in terms of which technologies were the primary or main focus of the project twelve studies focused on mobile devices such as android or smart phones, tablets and IPads [2,3,16,18, 21,22,23,24,34,35,36,40]. Twelve studies focused on games or serious games [4,5,6,7,17,19,26,27,38,41,42,45]. Nine studies in the review focused on the

Internet [1,8,12,25,30,31,32,33,44]. Three studies report the development of virtual reality applications [3,9,39]. Three of the studies focused on software [15,20,29]. Two studies focused on augmented reality [14,37].

In terms of the context or purpose of technology use that was being designed for ten studies were developing technologies to teach basic educational skills such as literacy, numeracy and colour recognition [1,2,9,14,18,23,30,31,41,45]. This was across all ages and range of technologies. Six studies focused on cognitive skills training across all ages [4,13,19,25,39,42]. Six studies described developing technologies for leisure or play purposes. [5,7,10,16,26,27]. Five studies addressed way-finding as an independent living skill. This was for adults only and on mobile devices [22,24,35,34,40]. Five articles in the review focused on using technology for vocational purposes such as short order food preparation or cleaning a hostel [17,28,29,36,37].
Three studies focused on digital literacy, three on a mix of skills training; three on general independent living skills; two on communication skills and two were rather general or vague in their intended use.

3.2 What common design principles can be distilled from the literature?

The process of deductive and inductive coding of the literature produced four main categories of design principles:

1. Learning Support (29 papers);
2. Accessibility (19 papers);
3. Usability (16 papers);
4. Agency (13 papers);

The labels given these categories (and sub-categories) are not necessarily those used by the authors themselves. The four main categories are outlined and exemplified in Tables 2-5 along with indications of which of the 45 papers referenced each principle. To be included, a principle needed to described or recommended by ten or more of the 45 papers. To be included, a sub-category of a principle needed to be described or recommended by three of more of the 45 papers (range=3-15).

3.2.1 Learning Support

Learning Support design principles essentially focus on enhancing the learning experience or making learning more likely to happen. This is the most prominent design principle that we have identified in relation to the number of sub categories and examples we have identified. (See Tables 2.1,2.2 and 2.3). Six sub-categories were identified each of which have particular pertinence for people with differences and difficulties associated with perception, memory and cognition:

1. Feedback and reinforcement
2. Associability
3. Familiarity
4. Focus
5. Facilitation
6. Appropriate challenge

<Tables 2.1, 2.2 and 2.3 about here>

The feedback and reinforcement design principles focus on helping users to succeed and avoiding where possible the potentially negative consequences of failing on a task. The design principle of Associability is pertinent as it can be difficult for people with learning difficulties to understand key concepts and establish associations between the computer world and the real world. Using icons, tasks and materials that users are familiar with can reinforce learning or memory of tasks. Many people with learning difficulties find it difficult to concentrate for long periods of time, Focus is therefore an important design principle in terms of seeking to maximise attention on a task or bring attention back to a task. Facilitation as a design principle relates to the instructions and prompts that an application or game provide a user with learning difficulties; for example, providing multi-sensory instructions, or just-in-time prompts. The final principle 'Appropriate Challenge' essentially focuses on not making the activities within an application too hard or easy and allowing opportunities for consolidation of learning, for example enabling the user to repeat an action as many times as they wish. (See Tables 2.1, 2.2 and 2.3 for more examples).

3.2.2 Accessibility

Many papers mentioned accessibility when discussing the design of their technologies and although not always explicitly mentioned. The principles they articulated could be categorised using the POUR (Perceivable, Operable, Understandable, Robust) model that underpins the World Wide Web Consortium (W3C) guidelines on accessibility [50]. However, what this review has identified is which of these principles particularly apply to designing or people with learning difficulties. The accessibility principles outlined in Table 3 reveal that '*distinguishability*' (as a sub-category of perceivability) and '*readability*' (as a sub-category of understand-ability) particularly reflect the perceptual and cognitive differences and difficulties that people with learning difficulties can experience.

In order for technologies to be 'Perceivable' they must be designed to be adaptable- presenting content in different ways and anything presented to the user must be distinguishable so that users can recognise the difference between one thing and another. For example, ensuring sufficient contrast so that it is easier to distinguish items, both visual and auditory. (See Table 3 for further examples).

People with learning difficulties do not always like completing tasks under time pressure. The default time limits on solving a problem, pre-set on many educational software or game Web sites therefore can be too short. Therefore technologies need to be 'Operable', in that they are designed to allow enough time for users with learning difficulties to complete tasks. Operability is also influenced by the extent to which users with learning difficulties are helped to navigate through a program, system or game. For example helping users to find content and know where they are by placing navigation information in the same place (usually at the top), ensuring that it is consistent and simple, using maps when appropriate, using home and back buttons and providing auditory context and orientation information. (See Table 3 for further examples).

In order to meet the requirements of the 'Understand-ability' design principle technologies and associated content must be readable and predictable. For individuals with learning difficulties, the information presented to them when using computers can be too overwhelming to handle; readability is therefore important. Examples of how readability can be enhanced include: making any text plain text (rather than images or graphics), avoiding dense blocks of text and using plain language. (See Table 3 for further examples). Predictability is also a key component of 'Understand-ability' in that users with learning difficulties tend to respond well when they can learn a pattern or sequence of actions and can struggle if this pattern is interrupted by unexpected occurrences that they are unable to problem-solve.

Predictability requires organisation to be maintained so that instructions and buttons are clearly displayed and in the same place (often at top) throughout presentations. (See Table 3 for further examples).

In order for technologies and systems to be ‘Robust’ they need to be consistent and error-free as well as usable with one or more assistive technology (i.e. input from a range of sources is catered for). (See Table 3 for further examples).

<Table 3 about here>

3.2.3 Usability

Within the computer-science and HCI fields, usability is about making technologies and applications easy for people to use, whilst Accessibility focuses on making them equally easy for disabled people to use [62]. Usability tends to have a broader definition than accessibility; encompassing issues such as the effectiveness, efficiency and satisfaction with which users can achieve their goals. Whilst many papers in the literature review mentioned design characteristics that could be associated with usability; very few referred to *all* the common usability principles such as those proposed by Nielsen Learnability, Efficiency, Memorability, Errors and Satisfaction [49]. Rather, two principles that we have called ‘Simplicity and ‘Efficiency’ emerge which appear to have particular pertinence for people with learning difficulties. The Simplicity principle focuses on reducing clutter and eliminating any unnecessary or irrelevant elements that might distract focus. For example, using clear graphics and icons, simple screen layout, consistency, contrasting colours, and large, clear navigation buttons, descriptive hyperlinks, minimizing scrolling and limiting the number of fonts (See Table 4 for more examples). The Efficiency principle is about reducing the work-load for the user for example using supportive automation to make the user’s work easier, simpler or faster or allowing changes to content quickly and easily without need for long complicated operations (See Table 4 for more examples).

Agency

A number of papers referred to design principles that we felt could be categorised as relating to agency: enabling the user with a learning difficulty to be an active agent in their own learning. Within this category, we identified a self-pacing principle related to enabling users to control the speed with which they progress through an application, including the opportunity to go back and revisit actions or items if needed. A second principle we identified related to enabling users to indicate choice and preferences (as opposed to a teacher or parent). For example, giving users the freedom to edit pictures or pictograms being used within the application or game. In their daily lives people with learning difficulties are infrequently encouraged to take the initiative, and therefore can have little personal motivation to engage with technology based tasks and activities. We therefore felt it particularly pertinent that a design principle focused on allowing the user to take the initiative and promoting proactive interactions was identified in the literature. (See Table 5 for examples).

< Table 5 about here>

4. DISCUSSION

The purpose of the literature review presented in this paper has been to distil out common design principles from the literature. In this section we will propose an overarching framework for these principles which has the potential to guide design and development practice in the field of learning difficulties and technology. In our exploration of a potential framework for design principles around which technology design and development practice can be built we will discuss how a diversity and difference dimension and a digital inclusion dimension can underpin our proposed design framework.

4.1 The case for a focus on diversity and difference

The four principles suggest that the technology developers in our review conceptualised their users in a number of ways:

- Usability design principles- user is anyone (with or without a disability);
- Accessibility design principle- user is anyone who is disabled;
- Agency- user is anyone who is disempowered or excluded;
- Learning support – user is anyone with a learning difficulty.

25 of the 45 papers referred to two or more design principles and 13 referred to three or more principles suggesting a tendency for developers to adopt a mixed design strategy. (See Table 6).

<Table 6 about here>

There could be two reasons for the developers to conceptualise their users in a range of ways and to adopt such a mixed strategy. Firstly, in recognition that their users are diverse. For example, in addition to including users with learning difficulties some studies included users with Autism and ADHD as well as participants with other non-learning related differences such as motor impairment, dementia or schizophrenia. Secondly, in recognition that people with learning difficulties have a range of needs. For example, six studies included people with learning difficulties who also had a sensory impairment [17, 20,34,38,40,41].

Adopting a mixed design strategy, that addresses a diversity of needs has some resonance with the Universal Design approach to education. Broadly speaking, universal design in educational contexts is an approach characterised by anticipating the needs of a diverse group of learners [63] in which instructors mix their strategies to ensure that the overall mix is inclusive for everyone [64]. Many researchers in the field of learning difficulties and technologies advocate the principles of Universal Design. For example, Chadwick *et al.* argue:

> *Universal design is critical in allowing people with ID to gain substantial benefits associated with being online. There are a number of principles associated with Universal design and these all affect user interface with the webpage. For example, websites should be flexible, simple and intuitive, contain perceptible information, include tolerance for error and require low physical effort* [65].

We would argue however, that the design framework suggested by our review is distinctly different to universal design in one key regard- it does not ignore difference. If designers of technologies for people with learning difficulties followed the advice from Chadwick et al. they would employ the usability principle as identified in this review (simple and intuitive, tolerance for error, low physical effort) and the accessibility principle (perceptible information) as identified in this review. They would not however employ the agency or learning support principles; suggesting that their needs as a disabled person might be met, but at the expense of their needs as a person with learning difficulties, or their needs as someone who has little control over the decisions made about their lives. Designing for diversity is important, but not at the expense of designing for specific needs, needs related to specific differences or difficulties- in this case learning difficulties. However, if a technology developer just addressed the learning support principles that we have identified in our review, there is a chance that a person with a learning difficulty would not benefit, as they might not be able to access or use the technology in order to be supported in their learning.

4.2 A case for a focus on digital inclusion

The four design principles that we have chosen to focus on in our proposal for a design framework reflect four concepts that dominate digital inclusion discourses: use, access, empowerment and participation (See Table 7).

<Table 7 about here>

Use

In the digital inclusion literature there is a growing recognition that the quality of technology usage needs to be addressed. Selwyn and Facer [66] suggest that quality of use can vary considerably depending on issues such as technology platform or level of connectivity (e.g. broadband). Other ways of conceptualising quality of technology use include ‘meaningful use’ [67] or 'smart use', where smart use is defined as making use of technologies as and when appropriate [66]. Understanding what influences use and therefore digital inclusion, is likely to involve more than understanding barriers to the acquisition of skills or competences. It is likely to involve understanding an array of factors that influence the decisions that learners make about when technology use is appropriate or meaningful in their lives. In the context of this review we would argue that the Usability design principle, addresses designing for ‘quality use’, where ‘quality use’ is understood as unimpeded use. If designers follow the two usability principles of simplicity and efficiency, users with learning difficulties are offered the path of least resistance towards the learning content and experiences. Their path to learning is not impeded by complex and inefficient user interfaces.

Access

Digital divide and digital inclusion discourses tend to embed within them an expectation or imperative that digital inclusion happens when all members of society are able to access the affordances offered by technology use [66,67]. Digital inclusion is therefore concerned with addressing inequalities, where those unable to access the affordance of technologies are, disadvantaged, marginalised in society and therefore digitally excluded. In the context of this review we would argue that the Accessibility design principle addresses the need to enable users with learning difficulties to access the content/learning experience being delivered through the technology which may then facilitate greater access to heritage and cultural sites.

Empowerment

Selwyn and Facer stress the importance of enabling individuals to make informed and empowered choices about technology use ‘whilst ensuring these individuals have ready access to the resources required to enable them to act on these choices.’ [66]. The UK government in its consultation paper on Digital Inclusion talked of technology being a ‘vehicle for empowerment, rather than a force for further exclusion’ [68]. In their consultation paper, the government link empowerment to notions of limited opportunity. For example, the consultation document proposes a Digital Inclusion Charter which has enshrined in it the principle of ‘Citizen and community empowerment’, where the most disadvantaged citizens and communities are assisted and motivated to 'achieve increased independence and opportunity through direct access to digital technology and skills'.

In this review, those papers that proposed an ‘Agency’ design principle, did so in recognition that people with learning difficulties have limited opportunities; they are infrequently encouraged to take the initiative particularly if this involves taking some kind of risk [69] and technology use may have to play therefore in promoting decision-making and initiative-taking. In the context of this review and the Arches project, we would argue that the Accessibility design principle addresses the need to ensure people with learning difficulties can exert some control over the content or experience being offered by the technology

Participation

Eynon defines the digital divide as 'the differences between those who have all the necessary digital resources to participate in current society and those who do not' [70]. Resources are understood more broadly than technological equipment. For example, van Dijk sees successful engagement with ICTs as being contingent on the following aspects of resourcing: temporal resources (time to spend on different activities in life); material resources above and beyond ICT equipment and services (e.g. income and all kinds of property); mental resources (knowledge, general social and technical skills above and beyond specific ICT skills); social resources (social network positions and relationships – e.g. in the workplace, home or community)and cultural resources (cultural assets, such as status and forms of credentials) [70].

Cook and Light also challenge us to consider whether a distinction should be made between active and passive participation; where passive participation could be viewed as being on the receiving end of e-services and active participation could be viewed as having an influence on the way technologies are used. [72]. Through active participation, citizens would be 'fully included, self-determining participants in a digital society'. Whilst a binary distinction between active and passive might be over-simplistic and open to different perceptions or interpretations, we would argue that it is still important to consider the extent to which a person with a learning difficulty is able to use their technology to participate to the ‘level’ that they desire as opposed to the ‘level’ that is afforded them by others.

In the context of this review we would argue that the ‘Learning Support’ design principle is about increasing the opportunity for people with learning difficulties to increase their mental resources (i.e. their understanding and appreciation of the assets on display within cultural and heritage sites) and in doing so, participate in an active way in the arts, rather than being passive consumers of heritage and cultural sites.

4.3 A proposal for a unified design framework

In this discussion section we have scoped the parameters of a design framework that incorporates four key design principles that we have distilled from our literature review (Tables 2,3,4,5). The outcome of this scoping exercise is a proposal for a unified design framework which has the potential to guide design and development practice in the field of learning difficulties, technology and heritage and culture. (See Table 8). We are positioning this framework as comprehensive in that it incorporates all four design principles and offers an approach to addressing a range of users (diversity), a range of needs (difference) and all the components required for full inclusion.

<Table 8 about here>

Developers designing technology for people with learning difficulties can design for diversity and difference by designing for the specific needs of people with learning as well as designing for a range of other user needs. They can do this by adopting the 'Learning Support' design principle (Tables 2.1, 2.2 and 2.3) and one or more of the other three design principles (Tables 3, 4, 5). However, people with learning difficulties will only be afforded optimal inclusion (i.e. full participation) through their use of technologies if all four design principles are employed. A person with a learning difficulty will not be able learn something from the content or experience being offered by the technology and in doing so, participate in an active way if they cannot use the technology, access the information on offer through the technology or be an active agent in their own learning.

5. CONCLUSION

The study reported in this paper is the first in the field to combine a comprehensive review of the literature with a conceptualisation of difference, diversity and digital inclusion in order to propose a unified framework for the design of technologies for people with learning difficulties. This study pushes the design field forward by suggesting a way to fill the gap that generic design guidelines do not fill regarding meeting the needs of people with learning difficulties. It does so, by both exemplifying the generic guidelines by describing how they can be applied in a learning difficulty content; providing additional principles not found in the generic design guidelines that address the very specific needs of people with learning difficulties and suggesting the implications for the inclusion or exclusion of adults with learning difficulties if some or all of the design principles are not addressed.

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Table 1: The parameters of the literature review

Date range	2010-2016
Language(s)	English
Literature Databases	CiteSeerX Association for Computing Machinery Digital Library IEEE Explore SCOPUS
Journal databases	SpringerLink Science Direct Journals Elsevier Proquest dissertations
Types of publication	Journal articles and conference papers
Inclusion criteria	Papers must be evaluative as well as descriptive- enabling lessons to be drawn from the results or experiences
	Must involve learning disabilities
	Must involve one of the following technologies: General Software Serious games Virtual reality- avatars Augmented reality Haptic devices Mobile technologies
Keyword terms	Learning disabilities Learning difficulties Intellectual impairment Cognitive impairment Mobile technology Games Virtual reality Augmented reality Haptic device software

Table 2.1: Learning support design principles: Feedback and Reinforcement

Category	Sub category	Examples	Papers
Feedback and Reinforcement	**Multi-sensory**	When users make a selection (right or wrong) after a prompt, they are given a learning reinforcer: an audio clip saying the name of the selection. When users follow prompts correctly, they are given two positive reinforcers: an audio clip saying “Good Job!” or “That’s right!” and a picture of something they might like.	3,6,7,13,17,31
		Students with impairments often have communication difficulties at both vocabulary and comprehension levels so sounds are also used to give reinforcement to the user about his actions. These sounds could be also recorded or synthesized using text-to-speech	
		The system also includes an interactive interface with audio and video feedback to enhance students’ motivation, interest, and perseverance to engage in training sessions.	
		Reinforce positive feedback, by means of laughs, applause, dancing, etc., and not only by spoken words.	
	Emotional and encouraging	Feedback should be emotional: e.g. appearing sad for negative feedback, and laughing and dancing for positive feedback	7,17
		The style is friendly and encouraging with positive messages also in case of failure.	
	Avoid negative feedback-the system should help users learn from their mistakes and not punish them.	Give positive messages on failure	3,14,17,31
		When users do not follow a prompt correctly during an activity, give them various attempts and hints on how to follow prompts correctly along with learning reinforcers which also help users learn the correct response. On the last attempt, give users no other choice but to follow the prompt correctly and learn the correct response.	
		The screen visual/audio contents should offer positive reinforcement to a successful action, and have no reaction in case of failure.	
		Only correct actions are available at each moment of the game.	
		Only objects related with the next correct action are selectable at each moment of the game in order to provide an error-free play.	
	Informative	Leave users in do doubt of correct answer: Users may not really know whether they have completed a task or not-This may explains why they so frequently but unnecessarily persist with tasks. Therefore, more attention should be paid by game developers to ensure children understand the game.	7,30,31
		Display progress information: Users should know which round they are on out of the total number of rounds in an activity	

Table 2.2: Learning support design principles: Associability, Familiarity, Focus

Category	Sub category	Examples	Papers
Associability	**Where possible use images of the real thing rather than abstract representations of the object**	Provide context sensitive in situ instructions	3,8,10,12,14,16,21,31, 41
		The use of concrete material enables students to establish relationships between the experienced situations and the abstraction of the studied concepts.	
		The representation of money amounts through images of bills and coins	
Familiarity	**Build in familiarisation tasks**	Unfamiliarity with the icons can cause problems, therefore provide participants with hints about the possible location or shape of icon(s).	17,36
		A familiarization task is set up to train selection and navigation in the same environment	
	Make use of familiar situated material	Only use very familiar icons	3,11,32,45
		Use pictures of things users like as positive reinforcers.	
		The learning experience should make use of contents users like and are familiar with, e.g., music, videos, stories, voices of relatives, or images of known environments or situations. This makes learning more "situated" and is a means for consolidation, as discussed below.	
Focus	**Maximise attention on the task**	Most users with learning difficulties have limited capability of concentration, therefore, each activity should be designed to be relatively short (3-5 minutes)	3,5,13,14,17,37
		Screen just contains a single task at a time	
		Actions are implemented at different levels of detail. If the focus of the exercise is on the order of the actions and not on how they are done, a single click or touch is sufficient to do them. However, if the focus is put on how to do the action, then the action is broken into a sequence of steps, each one launched through a new interaction.	
		By removing physically demanding interaction tasks, such as moving a pointer quickly over a large screen area, the user can focus on the intellectually challenging parts of the game. Therefore automating some elements of gameplay can enable participation	
		Capture attention: Stimuli should act as behaviour-eliciting agents that attract attention, stimulate action and promote engagement.	
	Bring attention back to the task	If the user starts to look somewhere else rather than at the mobile screen, the front camera of the mobile detects this activity and vibrates the phone to bring the user attention back to the screen.	18,19,20
		The basic and essential information is complemented with motivation or call attention messages (voice), such as "Congratulations,' "it goes like this" or "be more attentive".	
		Remind user of the task: Problems with working memory can impair the understanding of screen information and recall of the current task context. This should be accounted for in design, for example by using simplified screen layouts and system initiatives to remind of and help recapture the task context and provide visible systems status information.	

Table 2.3: Learning support design principles: Facilitation, Appropriate Challenge

Category	Sub category	Examples	Papers
Facilitation	**Instructions- multisensory**	Instructions are provided always verbally, with a simple and clear style optionally complemented with a written message to reinforce reading skills of users that have them. In addition, in addition iconic images of the objects to be collected are shown at a side of the screen to reinforce the verbal and written messages.	14,17,37
		Provide voice instructions in order to improve the understanding of children, especially those who cannot read.	
		To teach participants to acquire the target response, the prompts were presented in a combination of sound and picture cues	
	Prompts	Just in time prompts- By bringing context awareness to handheld prompting devices and reducing cognitive load; people with cognitive impairments can have the prompting experiences in easier and more comfortable ways.	3,28,35
Appropriate Challenge	**No prior knowledge needed**	Do not rely on the acquisition of specific competencies before interaction and engagement can occur.	26,27,42
	Scaffolding	Ensure a balance between success and challenge. E.g. Systems for new route learning using location based services can be appropriately structured to heavily scaffold the planning of new routes and the first instances of traveling these new routes and then be programmed to offer less intervention as the user develops the confidence and skills to ultimately travel these routes independently	11,25,40
		The proposed tasks should be “sufficiently” challenging, without being discouragingly hard or boringly easy; they should progress through increasing levels of difficulty as the experiences unfold.	
	Consolidation	Create new challenges but also include moments of consolidation	11,16,18
		Evaluate the learning by asking questions about the content and automatically force-rewinds to the location where the concept was explained if the user answers incorrectly.	
		Allowing those with learning difficulties to repeatedly listen to an item independently or view a video several times.	
		Most disabled children have limited long term memory and experience the difficulty of retaining a learned concept or skill from one session to the next one. It is necessary to design activities that on the one end introduce novelty and create new challenges, and on the other end include moments in which children repeat and consolidate what they have previously understood.	

Table 3: Accessibility related design principles

Category	Sub category	Examples	Papers (see Table 2)
Perceivable	**Adaptable**	Provide text equivalents for non-text content, including auditory and visual components, so that it can be changed into other forms people need, such as Braille, speech, symbols, other languages including sign language. Provide audio with text.	19,20,40, 45
		Adjustable display image size should be offered, with appropriate labelling for icons, with combined use of pictures and audio prompts for navigation, and in general multisensory presentation of feedback information.	
	Distinguishable	Never convey information by colour alone. Ensure sufficient contrast so that it is easier to distinguish items, both visual and auditory.	3,31,34,38,40,41
		Highlight with colour-blind-friendly colours (yellow), use a high-contrast colour-scheme (white on black), use practical fonts (e.g., easily readable), use good quality images and make choices (i.e., the numbers, shapes, colours, and images of objects) sufficiently large to make them accessible to users with visual and motor impairments.	
		Labels should be situated above their fields so that blind people to find the right element. In the style-definition text and background colours, padding, text-size and contrast are described.	
Operable	**Allow enough time**	The system ensures that if users are distracted by other activities, they are informed that the system is still waiting for their interaction before terminating the session.	31,38,40,41,45
		Games should be interactive, flexible and should be in an appropriate speed, since users with learning difficulties can be very slow in their performance and responding.	
	Navigable	Employ visual cues to help users with navigation through the system.	17,32,34,38,40
		A minimum size of at least 9mm for all clickable elements should be given. Also an empty area surrounding these elements is very important. The buttons should be placed where everyone can reach them easily.	
		Place navigation information in the same place (usually at the top) and ensuring that it is consistent and simple, using maps when appropriate, using home and back buttons, providing context and orientation information	
		Navigation is disabled when it is not necessary, In other tasks, navigation is automatic- using a single click.	
Understandable	**Readable**	Not too much text (information).	3,8,32,38,40,41,45
		Language used is as simple as possible, with short sentences and max. 70 characters pro line.	
		Make any text plain text (rather than images or graphics), no dense blocks of text, plain English.	
	Predictable	Consistent, simple screen layout.	20,34,38,40,41
		Maintain organisation - instructions, buttons, clearly displayed and in the same place (often at top)	
		The input features should remain consistent throughout the application.	
Robust	**Error-free**	Checkboxes and radio buttons make it possible that the text inputs for users are reduced and thereby also the error rate is lowered. If textual input is really necessary, a suitable keyboard layout is essential.	34,36,38,40,41
		Use fall-backs.	
	Compatible	Aim for compatibility with assistive technologies - e.g., screen-readers, text-to-speech, zoom features.	5,7,15,26,27,33,40,42,44
		Creating middleware that translates the input from access devices such as eye gaze into mouse and keyboard strokes that the games can process.	

Table 4: Usability related design principles

Category	Examples	Papers
Simplicity	Avoid unnecessary buttons, sounds, and distracting objects	11,14,19,20,28,29,31,38,40,41,45
	Regarding the interaction between the user and the game develop simple and clearly organized interfaces. Every input by the user corresponds to actions duly identified on the screen	
	Use clear graphics and icons, simple screen layout, consistency, contrasting colours, and large, clear navigation buttons, descriptive hyperlinks, minimizing scrolling and limiting number of font	
	Customization should be so simple that inexperienced users e.g., teachers, educators, therapists can autonomously achieve it.	
Efficiency	Allow changes to content quickly and easily without need for long complicated operations.	5,13,17,18,20,32
	One click/touch interaction: the game can be played with a mouse, based on one-button click and mouse movement or on a touch screen. Clicks or single touches are interpreted as selections. Camera rotation is handled either with mouse movements or with touches in a navigation widget that frames the scenario. Actions are generally launched with a single click or a mouse or finger movement.	
	Allowing users to provide input by just tapping the screen (no dragging or swiping) to make them accessible to users with motor disabilities.	
	The interface uses as few elements as possible.	
	Mobile device uses tilt in four directions for response to questions, since touch, as a modality on mobile devices requires fine motor skills.	
	For input, the sequences of actions should be simplified and available choices limited when practical, and direct selection techniques favoured to support simple, time-independent actions.	

Table 5: Agency Design Principle

Category	Examples	Papers
Self-pacing	Allow users to control the speed at which they move through the game or app	18,23,38,39,40,41
	Allow users to go back - essential for all users, and especially those who may have organisational, information processing and/or memory difficulties	
	During this process, users are always allowed to switch back and forth between cameras as many times as needed to complete the task. On completion of all correct name associations, the user advances to the next phase.	
Enable users to indicate choice and preferences	Freedom to choose and edits pictures or pictograms being used within the app/game	16,17,35,40
	A layered approach to information access is adopted with the first layer comprising a label, the second a mobile-web enabled screen and the third choices of text, pictures, video and audio	
	Users can define their choices in the profiles. For example, users who are blind or with low vision may choose to avoid taking stairways in a wayfinding app, although they may be capable of doing so.	
	Allow User Control - allow for user customisation based on user preference; for example, some users may wish to slow things down, or to use keyboard access	
Promote proactive interactions- allow the user to take the initiative	Allow exploration: e.g. By selecting different buttons or options, the user can explore the learning environment and discover content or experiences for themselves. This process is open ended, and the user can take as long as he/she needs to explore.	13,39,27
	There is no cognitive barrier to becoming engaged with an activity. Such behaviour is exploratory, as it allows people to develop an understanding of the system through action, observation, and reaction. Designing for autonomy support ensures that experiences provide choice, minimize pressure to perform in specified ways, and encourage initiation	

Number of principles	Papers	Totals
All four principles	17, 40, 41	3
Three principles	5, 13, 18, 19, 20, 27, 31, 32, 38, 45	10
Two principles	3, 7, 8, 11, 14, 16, 21, 26, 28, 35, 36, 42	12
One principle	6, 10, 12, 15, 23, 30, 29, 30, 33, 34, 37, 39, 44	13

Table 6: Number of principles referenced by a paper

Design Principles	Digital inclusion concept	Exemplification in the context of learning difficulties and the ARCHES project
Designing for usability	USE	Ensuring people with learning difficulties can easily use the technology- use is unimpeded
Designing for accessibility	ACCESS	Ensuring people with learning difficulties can easily access the content or experience being offered by the technology and reducing barriers to meaningful engagement with the content or experience
Designing for agency	EMPOWERMENT	Ensuring people with learning difficulties can exert some control over the content or experience being offered by the technology
Designing for Learning Support	PARTICIPATION	Ensuring people with learning difficulties can learn something from the content or experience being offered by the technology and in doing so, participate in an active way in the arts, rather than being passive consumers of heritage and cultural sites.

Table 7: The role of technology design principles in promoting inclusion of people with learning difficulties in heritage and cultural sites

Diversity & Difference/Digital Inclusion	USE	ACCESS	EMPOWERMENT	PARTICIPATION
Designing for anyone –disabled or non-disabled	Usability design principles			
Designing for anyone who is disabled	Usability design principles	Accessibility Design principles		
Designing for anyone who is disempowered or excluded	Usability design principles	Accessibility Design principles	Agency design principles	
Designing for anyone with a learning difficulty	Usability design principles	Accessibility Design principles	Agency design principles	Learning Support Design Principles

Table 8: A comprehensive framework for the design of technologies for people with learning difficulties