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DAEL Framework: A New Adaptive E-learning Framework for Students with Dyslexia

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Abstract
This paper reports on an extensive study conducted on the existing frameworks and relevant theories that lead to a better understanding of the requirements of an e-learning tool for people with dyslexia. The DAEL framework has been developed with respect to four different dimensions: presentation, hypermediality, acceptability and accessibility, and user experience. However, there has been no research on the different types of dyslexia and the dyslexic user's viewpoint as they affect application design. Therefore, in this paper a framework is proposed which would conform to the standards of acceptability and accessibility for dyslexic students. We hypothesise that an e-learning application, which will adopt itself according to individuals' dyslexia types, will advantage the dyslexics' individuals in their learning process.

Keywords: E-learning, Dyslexic students, Hypermediality, Acceptability, Accessibility, User Experience.

1 Introduction

The term electronic or distance education (e-learning) has become very familiar to most people. E-learning has many advantages (Rosenberg, 2001). The literature on e-learning reports on critical factors regarding the successful adoption of e-learning in many education sectors (Sun et. al. 2008). Its nature, characterised by 'no time' and 'no place' constraints, makes e-learning unique and it is increasingly part of a winning strategy for the specific needs of educational bodies, such as decongestion of overcrowded educational facilities, support for students and teachers who live at a distance from schools and universities, and in life-long education. Furthermore, it allows individuals with disabilities to do things that were difficult or impossible for them in the past. For example, chat programs allow deaf students to communicate; e-learning that has text-to-speech applications has helped blind students to read many books. Grammar and spell-check programs that are embedded in some e-learning applications allow dyslexic students to overcome their disabilities. E-learning can provide a valuable opportunity for disabled students if the learning material is more accessible (Alsobhi and Abeysinghe 2013).

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E-learning is a great tool, which has contributed to the distribution of learning materials and processes through the internet; however, there are some important points to consider before making remote data and tools available to individuals. A student's physical and cognitive abilities must be considered, as well as their cultural background. It is also important to consider the technical experience of the student and if they need any assistive technologies. To avoid the 'digital divide' phenomenon, which may result in a disadvantage to a particular group of students, it is very important to provide the widest access possible to e-learning facilities. The usability and accessibility of e-learning tools must be a priority as well as a prerequisite for the developers of e-learning applications, so that they benefit all students equally.

Educational software enables an extended segment of users to access learning resources and also supports their learning process; but it is clear that now the developers of educational software should be taking into account the fact that students learn in different ways. They should guarantee that a student's interactions with the software are natural and intuitive. This requires revision of traditional interaction theory and paradigms to provide a flexible and adaptive tool which will suit the differing needs of individuals. In order to achieve this, there should be harmony between a learner's interactions with the software and the learning process. When designing an e-learning tool, the usability features should not only be concerned with how efficient and interactive the software is, but also be appropriate for the intended learning task. In the literature, some argue (Tobing et. al. 2008) that scholars have not put enough consideration into the effects of the usability features of an educational application on its achieving its educational goals.

Accessibility is an important aspect in the modern world of computing. Its importance can be realised from various examples of legal implementations around the world. For example, the British Special Education Needs and Disability Act (SENDA) (2001) modified Part Four of the 1995 Disability Discrimination Act (DDA) and established that it is illegal for institutions to discriminate against a disabled person. By law, Higher Education Institutions (HEIs) now have to make 'reasonable adjustments' to meet the needs of disabled people (SENDA, 2001).

The importance and motivation of these standards and guidelines are discussed in this paper with respect to four dimensions: presentation; hypermediality; acceptability including accessibility; and user experience. Not many systems adhere to such guidelines for all of these dimensions. Thus, the proposed e-learning framework is aimed at changing this, and at providing dyslexic students with a system that will aid them in their educational process rather than being an extra burden on them..

2 Learners with Dyslexia in the E-environment

Tinklin, Riddell, and Wilson (2004) state that the percentage of disabled students who declared themselves as dyslexic in 1999/2000 was twice the percentage of 1995/1996. This is likely to be because of the increased encouragement to disclose dyslexia over this period. Figures from the Higher Education Statistics Agency (HESA) show that the majority of disabled students declared over that period were men; this was mainly due to the fact that males are more likely to have dyslexia than women; those with dyslexia were the largest group of disabled students (Tinklin, Riddell and Wilson, 2004). The UK offers the most substantial legislative support to dyslexic persons among all European countries, by means of the Disability Discrimination Act 1995 (DDA), the Special Educational Needs and Disability Act 2002 (SENDA) and the Disability Equality Duty 2006 (DED) (Sekovanić, Vukovac and Podbojec, 2012).

Woodfine et al. (2008) provide clear evidence that text-based synchronous activities such as chat programs and videoconferencing, which are commonly used in education, can disadvantage students with dyslexia. Dyslexics' problems with e-learning tools are beyond those of accessibility and web design. E-learning tools may benefit others by providing experience of different learning styles, but at

the same time they may put up severe barriers to students with dyslexia. E-learning materials can cause the same difficulties for adult dyslexic learners as do paper-based materials (Thomson and Watkins, 1998). However, there is a lack of literature in this field and a gap regarding any consideration of the problems of students with dyslexia in collaborative environments. This gap in the literature may be as a result of the relatively recent adoption of these technologies in education or due to lack of awareness of the problems associated with this type of disability in such environments. There are Assistive Technologies, which are readily available, and offer the potential to help students with learning difficulties such as dyslexia; however, e-learning applications are ineffective and/or failing dyslexic learners, possibly because developers have not considered the different types of dyslexia. They have simply developed generic applications, whereas what may be required are specific e-learning applications that are tailored to specific categories of dyslexic learner.

Here, a teasing out of the shortcomings of these technologies has been attempted and efforts at providing a general framework to help students with dyslexia have been made. Introducing some solutions that can be difficult to understand and interpret consistently, can involve some very complex thought. This means that there are many conflicting alternative solutions and advice. For example, there are many ways to help dyslexic students with reading difficulties, but some methods are better than others. However, there is no clear single source of advice or method to choose the best solution in a particular situation. Solutions chosen randomly, rather than in a standard framework, can also be expensive to manage and maintain. One effective way to reduce the costs of managing these issues in any organisation is by using frameworks. Frameworks can effectively reduce unnecessary random alternatives so that more things are done in the same way yielding benefits of scale.

A review revealed only a limited literature providing information on the voices and e-learning experiences of higher education students with dyslexia.

3 Relevant Theories and Suitable Attributes

Scientists use theories as a foundation to gain further scientific knowledge, as well as to accomplish goals such as inventing technology or curing disease. In the following sections we study the respective domain, which is dyslexia and e-learning, in order to gain further scientific knowledge regarding the e-learning requirements for individuals with dyslexia.

3.1 Presentation

Some scholars, such as Guardiola (2001), consider dyslexia to be a cognitive disability, and so cognitive learning theories must be studied before the design of any e-learning tool for dyslexic students. Cognitive theory says that the amount of information learned is determined by the learners' ability to process information (Craik and Tulving, 1975). Apart from the amount of effort expended by the learner in the learning process, the depth of the learner's processing (Craik and Tulving, 1975) and the structure of the existing knowledge of the learner (Ausubel, 1960) are considered as other factors for determination. This is in turn implies that when designing e-learning applications the materials must be presented according to some strategies that will enable students to process the materials efficiently. The information on the e-learning tool should be organised and presented in small paragraphs, hence facilitating brain processing. This is because dyslexics have a limited capacity in their working memory. Miller (1956) mentioned that information in the classroom should be grouped into meaningful sequences to assist those with short-term memory.

A report conducted by the Disability Rights Commission in the UK (DRC) in 2004 focused on the accessibility of the web for disabled people. The report showed that there were more than 100 Checkpoint violations per page. This demonstrates the scale of the obstacles impeding disabled people's use of websites (DRC, 2004). One of the violations that have been expressed by people with

dyslexia is the, 'unclear and confusing layout of pages'. Most of the other violations stated were related to the presentation and navigation of the webpage. This highlights the importance of the presentation of e-learning tools for students with dyslexia.

Most of the general presentation aspects of the graphical user interface are concerned with how to make the system more interactive by choosing icons and interaction styles, or by selecting different layout designs (Mayhew, 1992). This framework proposes that e-learning systems should be analysed from general and specific points of view. The presentation dimension refers to the most general point of view common to all interactive applications, while the other dimensions address the appropriateness of design with respect to dyslexic types and the purposes of the application.

3.2 Hypermediality

The first appearance of the term 'hypermediality' was in Nelson (1965). It is extended from the terms hypertext and hyperlinks (Brusilovsky, 1996). Hypertext is where graphics, audio, video and plain text are used in designing webpages. These two terms intertwine to create a non-linear medium of information, which is hypermediality. One of the e-learning characteristics of today is hypermediality. Hypermediality facilitates in-depth study and provides deeper insights for taught courses for students. However, research on hypermedia has pointed to two problems, which are cognitive overload and loss in hyperspace (Ardito et al. 2006). This reflects that one of the key distinguishing features in considering hypermedia applications is the notion of navigation, which must be designed (Schwabe, Rossi and Barbosa, 1996).

Referring to dual-coding theory, Paivio (1996) reported that information received in different modes, such as textual and visual, will be better processed than that presented in a single mode, such as text only. Multi-modes would help individuals with dyslexic 'visuospatial difficulties', and those who have difficulties with short-term memory use. Using different modes for delivering information helps dyslexic students to spot their own mistakes, because they are often not good at this skill. Dual-coded information is processed in different parts of the brain. This is in turn will result in more information coding or manipulating. Unlike other cognitive theories, dual-coding theory offers an explanation for both reading and writing (Paivio, 1996); it also facilitates processing and transfers to the long-term memory. Presenting information in different modes also accommodates individual differences in processing, such as dyslexia. This paper highlights that dyslexia has many forms and barely two individuals share the same symptoms; hence the 'one-size-fits-all' approach to developing e-learning applications is problematic (Beacham and Alty, 2006). Findings from previous studies eg. (Cobb, 1997) state that poorly designed e-learning tools may increase the difficulties for students with dyslexia. He raised a concern regarding the representation of information, and whether information was represented using media for all sensory forms including touch. Alternatively, different e-learning tools can be designed for different learning tasks.

3.3 Acceptability and Accessibility

User acceptance is an important primary measure of system success (DeLone, and McLean, 1992). Acceptability is considered to be a new term for adequacy with respect to satisfying the user's needs or complying with requirements or standards. In other words, acceptability refers to the accessibility needs of users (Maguire and Bevan, 2002). There are various models and theories explaining and measuring users' acceptability and predicting the level of user intentions to use a system. One of them is the Technology Acceptance Model (TAM) proposed by Davis (1989). The model provides an adequate foundation for evaluating a student's preparation and readiness before adopting an e-learning system. Usefulness and ease of use convey the level of acceptance for the service or application. These two variables are considered as the base for TAM. Similar attributes could prove to be useful for designing e-learning tool for students with dyslexia. This paper forms a conceptual model based

on pedagogic theory, learning, and individuals with special needs due to dyslexia. This conceptual model has been chosen as the model that directs the identification of attributes. Identifying these attributes will make a user's experience acceptable and accessible.

3.4 User Experiences

There is a correlation and overlap between usability and user experience. They both relate to how well a product or service is designed. However, usability focuses on the ease of use of the products and on how the users achieve their goals with minimum fuss and without errors. Whereas user experience focuses on making people happier by involving a more emotional dimension in the application, such as desire, joy and meaning. This reflects Nielsen's (2000) user experience theory, which was based on cognitive science. In a similar context, Norman's (2002) theory focuses on emotional design and users' feelings before, during and after using any system.

In most of the existing e-learning systems, usability features that are commonly discussed are included. On the other hand, other features such as conventions, user diversity and customisations are not addressed. This is because most of the common systems are developed for just one group of people (i.e. 'non-disabled'), but eventually they tend to fail in accessibility and usability areas for different group of people. Therefore, the term 'user experience' is relatively newer than other domains, such as human computer interaction and usability. This dimension focused on what users need, on what activities they would perform and on how the application manages with them.

From the perspective of dyslexic students, e-learning materials tend to be primarily developed for non-dyslexics. Hence, this increases 'the inability to provide accessibility and convenience for all learners' (Beacham and Atly, 2006). This will make dyslexic students struggle because they spend even more time and effort learning than they currently do using traditional approaches (Beacham and Atly, 2006). User experience is a very significant factor in measuring the quality of websites or systems' interaction with the user. User experience must be considered before developing any e-learning application. One of the keys to developing a successful e-learning tool is to involve prospective students, as stated by Smith (2002). He involved a group of dyslexic students in his design of a Virtual Learning Environment Interface and claimed that such an involvement supports the wider deployment of user testing.

4 The Proposed Framework

The proposed framework (see Figure 1) attempts to improve the educational process with the objectives of improving presentation, acceptability and accessibility, as well as user experiences, especially for students with dyslexia. The core of the four dimensions and the 26 attributes are based on the researched theories in the respective domain, as discussed above. Some of the reasons behind dividing according to these criteria are to enable a robust comparison of the frameworks and applications' features, advantages and disadvantages. This would ultimately lead to the development of the proposed framework.

The four dimensions with 26 attributes have been identified after conducting an extensive study on the available theories in the respective domain. These dimensions and attributes have been used to design the proposed framework, the Dyslexia Adaptive E-Learning (DAEL). Table 1 summarises the elements of the DAEL framework. The framework will facilitate the structuring of the attributes, which are based on the researched theories of the four dimensions. In the literature, most of the existing frameworks (Baguma and Lubega, 2008) tend to provide general solutions, either by enabling features or providing instructions. To the best of our knowledge, no such framework previously existed to cater for the needs of dyslexics. Furthermore, there is no system that responds to their feedback and personalises itself in accordance with the learner's preferences. This e-learning system,

called the Adaptive Learning System (ALS) system, tailors its learning content according to a student's dyslexia type (Alsobhi et al. 2014).

Dimension	Attribute	Label
Presentation	Personalisation	A
	Clarity	B
	Adequacy	C
	Self-descriptiveness	D
	Memorability	E
	Simplicity	F
	Helpfulness	G
	Learnability	H
	Mapping	I
Hypermediality	Technology Variety	J
	Media Channels Variety	K
Acceptability and Accessibility	Accommodate different learning styles	L
	Scaffolding	M
	Incremental Feedback	N
	Constructivist Learning	O
	Linearity	P
User Experiences	User Disability Type	Q
	Controllability	R
	Aesthetics	S
	Attitude	T
	Consistency	U
	Multiple Language Support	V
	Effectiveness	W
	Efficiency	X
	Robustness	Y
	Constraints	Z

Table 1: The chosen dimensions and attributes for the framework design based on the relevant theories in the respective domain.

5 Linking the Technology Acceptance Model and the DAEL Framework

Since user acceptance is an important primary measure of system success, many researchers have adopted the Technology Acceptance Model (TAM) framework (Davis, 1989) in their research. The TAM framework has helped many organisations in providing a useful analytical framework, which allowed them to have a clear understanding before the adoption and assimilation of different types of IT innovation. Igbaria and Iivari (1995) state that the contribution made by the TAM framework can be considered to be significant due to its simplicity and ease of use.

Many researchers have developed frameworks in different information technology domains based on the TAM framework. Since one of the focal points of this research is e-learning acceptance, a major focus will be on the framework by Squire and Preece (1996). They proposed a framework based on the TAM framework. It provides an adequate foundation to evaluate students' preparation and readiness for the AEL system.

The proposed framework concerns not only the students' 'learning part', but also helps teachers when dealing with dyslexic students i.e. the 'teaching part'. In addition, it provides clear standards and guidelines for developers in understanding the requirements and then designing e-learning systems. The framework will facilitate the structuring and understanding of the attributes that are based on the researched theories of the four dimensions, hence, helping e-learning developers from the early stages and even before making any plan or design. This framework established the functional

or technical requirements the design must meet. Moreover, it considers the needs and constraints imposed by students with dyslexia, policies and the environment.

New themes have been added to categorise the attributes in Table 1 and to incorporate them within the framework. The themes have been allocated on the basis of the factors within the TAM framework.

5.1 Perceived ease of use (A-I)

The degree to which a person believes that using the technology is free of effort is what Davis defines as the perceived ease of use in his model (Davis 1989). When designing e-learning applications the materials must be presented according to some strategies that will enable students to process the materials easily.

The process of learning can be made easier if self-descriptiveness is present, i.e. the system describes itself in a very simple way. However, self-descriptiveness would not be efficient if it is not coupled with the logical flow of functions and clarity. The combination of such attributes makes the learning process easier; therefore, these can be grouped under a single theme of 'ease of use'. The attribute of 'helpfulness' provides aid to the user to interact with the system in the most convenient manner. The learnability and memorability of functions, as well as services in the system, allow the student to interact with the system at a faster pace. Such attributes facilitate ease of ease with the system; hence, these can be grouped under the single theme of 'ease of use'.

This is what defines the presentation dimension in this research. The perceived ease of use concept of the Davis Model is equivalent to the presentation dimension in the DAEL framework (Davis 1989).

5.2 Perceived usefulness (L-P)

Perceived ease of use has direct influence on perceived usefulness. Davis (1989) defined perceived usefulness as how a particular system enhances a person's performance, which is learning performance in the present research. There are many studies proving that perceived ease of use and perceived usefulness are fundamental factors in determining user acceptance and a user's intention to use a system again. For example, a study by Ngai, Poon, and Chan (2007) showed that acceptance of WebCT is determined by its ease of use, which directly affects its usage. Based on this we adopted perceived usefulness as hypermediality as well as acceptability and accessibility.

The attributes of these two dimensions provide the student with different modes through which the learning process can be improved and facilitated. For example, scaffolding notifies the factors that should be learned to improve the functioning of the system. Constructivist learning attributes exist in the system in order to teach the student the most appropriate way to use the system. Accommodating to the learner's style will help the student to overcome the limitations commonly witnessed in system operations, as they are designed for a specific set of students. Incremental feedback will facilitate the constant improvement of the system, thus making the learning process easier for students.

5.3 System adaptability (Q-Z)

The user experience dimension has a significant positive relationship with the other dimensions. The effect of the user experience dimension should be considered to be a critical issue in understanding the user acceptance of DAEL. In the future, this will determine the importance and usefulness of integrating user experience into any e-learning system.

The consideration of different types of students has existed at minimal levels in prevailing systems, such as adapting to User Disability Type; this is considered to be the novelty of this research. The provision of such attributes within the system promotes controllability, as students will be more confident and comfortable with selecting settings of their choice.

The content of a system bears great relevance to the building of any system, as commendable functions will not prove to be effective for students if the content is not placed in a logical flow. Another important aspect of the content is its tone (attitude), which should encourage students to utilise the system for different services.

The presence of performance measures is vital for the evaluation of any system and service. The most common forms of performance measure include effectiveness, efficiency and robustness. The effectiveness of the functions of any system depends on the level of interactivity and convenience they offered. Multiple language support enables students to interact with the system with ease, as they are able to understand all the available functions and services in their own language.

5.4 Constructing the DAEL Framework

The DAEL framework has been developed with the aim of allowing the conceptualisation and development of an adaptive e-learning system that facilitates 'ease of use' and 'usefulness'. This adaptive e-learning system will also facilitate accessibility and usability for all kinds of students with dyslexia.

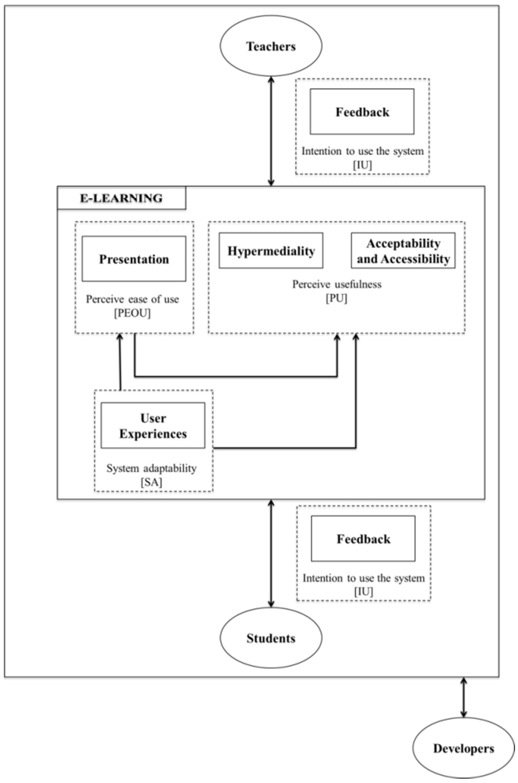

Figure 1: The DAEL framework dimensions linked with the TAM framework.

6 Conclusion

An extensive study of existing frameworks and relevant theories enabled an understanding of the requirements of adaptive e-learning for students with dyslexia from four different perspectives: presentation, hypermediality, accessibility and acceptability, and user experience. There is no e-

learning system currently known that adapts itself according to type of dyslexia. Therefore, this paper proposed the DAEL Framework, which would conform to the standards of acceptability and accessibility for different dyslexia types. An expert evaluation has been designed to measure experts' agreement patterns concerning the components of the DAEL Framework. Experts ascertain whether there are some attributes missed and rate the level of importance and conflict associated with each attribute towards the four dimensions. As a future extension of this paper, an expert evaluation will be designed to measure experts' agreement patterns regarding the dimensions of the frameworks. Experts' evaluation will determine whether there are some attributes need to be added. It also will rate the level of the importance and conflict associated with each attribute towards these four dimensions. The expert evaluation's steps as well as their results will be presented in details later.

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