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Personalised Learning Materials Based on Dyslexia types: Ontological Approach

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Abstract

In recent years, e-learning systems have played an increasingly important role in higher education and, in particular, in enhancing learning experiences for individuals who have learning difficulties. However, it appears that many of the people involved in the development and implementation of e-learning tools overlook the needs of dyslexic students. As such, these students lack access to the resources on offer to other students and this leads to a disability divide. In order for educational initiatives to be effective, learning experiences need to be tailored to the individual needs of each student and the materials and tools employed should be aligned with the student's needs, capabilities and learning objectives.

The objective of this research was to propose an ontology that will facilitate the development of learning methods and technologies that are aligned with dyslexia types and symptoms. The paper commences with a discussion of domain ontology and examines how learning objectives that take into consideration a student's capabilities and needs can be matched with appropriate assistive technology in order to deliver effective e-learning experiences and educational resources that can be consistently employed. The ontology employed within this study was developed using Ontology Web Language (OWL), an information processing system that allows applications to handle both the content and the presentation of the information available on the web. Two characteristics were employed within this research to describe each resource: dyslexia type and the features of assistive technologies that were deemed to be most appropriate for educational experiences targeted at each dyslexia type.

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Keywords: Dyslexia; Personalisation; E-learning; Ontology; Assistive Technologies (ATs);

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1. Introduction

In recent years, an increasing focus has been placed on the role technology can play in enhancing teaching and learning experiences. E-learning has become a fundamental tool for progressing student's knowledge, understanding and skills, and the web, in particular, has become a common educational tool in the classroom setting. Although the technologies that are currently available have had a positive impact on teacher's abilities to deliver the curriculum, students who have disabilities are often overlooked in the development and provision of these tools and, as such, they do not benefit from the same learning experiences as those without disabilities. This is particularly the case with students who have dyslexia. According to Beacham and Alty,[1] the e-learning materials that are commonly employed were developed with the needs and capabilities of non-dyslexic learners in mind. They claim that this results in an, 'inability to provide accessibility and convenience for all learners'. They add that e-learning materials in their current form act as a hindrance to dyslexic student's learning as opposed to an aid, because the resources do not take into consideration the individual learning approaches that these students exhibit and, therefore, present students with dyslexia with further challenges and disadvantages.

This paper commences by defining the nature of the problem that was the subject of the research before progressing to provide a brief overview of the existing literature that is available on this subject. Section 4 examines dyslexia and the learning styles that are suitable for students who have dyslexia. Section 5 provides a brief overview of the concept of ontology and then progresses to examine one method by which an ontology for learners with dyslexia can be developed and implemented. Section 6 presents a conclusion and recommendations for future research.

2. Problem Definition

Woodfine et al.[2] discussed how many of the text-based synchronous activities that are commonly employed within the classroom setting, such as web conferencing and instant messenger, can serve to disadvantage students who have conditions like dyslexia. These disadvantages are not merely related to aspects of ease of access and design, they also encompass the lack of consideration of the process by which individuals who have dyslexia learn and acquire knowledge. According to Thomson and Watkins,[3] many of the e-learning tools that are currently in use in the classroom setting present the same problems to dyslexic learners as more traditional paper-based approaches.

In their research, Fichten et al.[4] placed a particular emphasis on the way in which disabled students interact with e-learning tools. Their findings revealed that over 50% of disabled students require access to assistive technology to aid the progression of their writing and reading skills and that such technologies can be extremely useful in progressing learning outcomes. For example, technological tools that perform automatic spell checks or provide text-to-speech functionality can help dyslexic students to express themselves while minimising errors. However, according to Unterfrauner and Weiermair-Märki,[5] much of the assistive technology that has proven to be beneficial for such students is currently incompatible with the e-learning systems that have evolved in recent years. Furthermore, Alsobhi et al.[6] argue that the e-learning platforms that are currently available fail to provide the functionality and methodology required to vary approaches according to learner's needs. It is generally accepted that further research is required to identify how assistive technologies and e-learning capabilities can be combined to generate effective tools that assist dyslexic students to learn and develop the skills they need.

Given the fact that the very nature of the current problem relates to the lack of adaptability that current e-learning systems demonstrate, there is a need to develop semantic web technologies that offer learning experiences that are aligned with student's needs. According to Mizoguchi and Bourdeau,[7] ontologies represent one promising method by which this can be achieved. Ontologies allow an effective information extraction process (Bergman[8]), and research by Tzouveli et al.[9] revealed that learning methods that involve ontology-based personalisation have been employed to great success in the development of learning experiences for students who have mental or physical disabilities. Ontologies not only represent a means of improving what information is presented and how it is presented, they also enhance communication. Knowledge that is represented using ontologies reflects information that machines can understand; as such, it demonstrates the ability to aid e-learning for people with a variety of learning needs in accordance with their individual profile. The effectiveness of this approach will be enhanced by filtering the information presented so that it is aligned with the user's personal learning style. For the purposes of this paper, we will examine how an ontological approach can aid the development of e-learning methods that meet the learning needs of students who suffer from dyslexia.

3. Related Work

While many e-learning applications do fail to take into consideration the needs of learners who have disabilities like dyslexia, the notion that ontologies can improve learning outcomes is not entirely new. In recent years, a number of tools have emerged that seek to automatically meet the needs of users who have dyslexia. It is worth examining some of these in detail.

The use of ontology-based software to aid the learning and development of children who exhibited reading difficulties was assessed in a study by Tzouveli et al.[9] The researchers developed an ontology-based software, called AGENT-DYSL, that was designed to enhance the learning process for children with dyslexia. The main aim of the tool was to present reading materials that were aligned with the children's learning needs and capabilities. To enhance the effectiveness of the system, the user interfaces were designed to be age appropriate while also taking into consideration the limitations of dyslexic users. AGENT-DYSL stood out from many of the existing e-learning technologies that were available at the time because it offered a personalised approach to learning. Such an approach is widely regarded as being of assistance to dyslexic children in particular because it combines various techniques, such as speech recognition, adaptive support and error profiling, to facilitate learning. However, the main disadvantages of the tool were that it was not tailored to the needs of adults and was limited to assisting children with reading dyslexia, not any other dyslexia difficulties.

Ivanova et al.[10] developed an adaptive framework that was designed to take into consideration the needs of dyslexic students in an e-learning environment. Their framework was an open agent-based structure that incorporated ontology-based learning aspects. The approach developed facilitated the management, employment, reuse and retrieval of external resources that were aligned with the needs of the user. The various agents that were incorporated into the software included experts, teachers, evaluators, dyslexic learner assistants and annotation specialists. Through combining semantic and agent-based approaches, the technology could automatically align learning experiences with the needs of the user and this improved the effectiveness of the e-learning approach. However, once again, the applicability of the model was limited to individuals with certain types of dyslexia and was not suitable for teaching adults.

An ontological approach holds great potential for the development of a system that can flexibly meet user's learning preferences and needs and this has been discussed by a number of researchers, including Gascuena et al.[11]; Gasparini et al.,[12] and Siadaty et al.[13] Gascuena et al.[11] examined the development of an ontological approach that was aligned with students' learning styles through correlating an ontology with the Felder-Silverman learning model (FSLSM).[14] Similarly, Gasparini et al.[12] developed an ontological approach to the development of learning materials that aggregated learner's knowledge, reading abilities and learning styles in the form of AdaptWeb. Finally, Siadaty et al.[13] formulated a tool that encouraged the development of an environment in which learners could collaborate to enhance learning outcomes. Through employing ontological approaches that aided and promoted personalisation, this approach provided personalised learning experiences through inferences.

Unfortunately, while these various models have proven to successful aid e-learning outcomes, they lack the ability to provide dyslexic learners with personalised learning experiences that can be used in combination with assistive technologies.

4. Dyslexia and Learning Styles

According to Cassidy,[15] an individual's learning style is determined by the way in which he or she responds to a given learning opportunity. Alsobhi et al.[16] argued that dyslexia should be classified according to the difficulties that the student experiences as opposed to the type of dyslexia he or she exhibits. Ingram[17] described three different types of dyslexia: Visio-spatial, speech sound and correlating, each of which presents the learner with its own unique difficulties in terms of literacy, numeracy and memory (Alsobhi et al.[16]). The following section will examine the implications of each type of dyslexia through mapping the associated difficulties with the dimensions of the FSLSM model.

Individuals who have dyslexia are more likely to conceive ideas through feeling and mental images as opposed to sounds or words. For this reason, such learners find it hard to develop an adequate understanding of words and symbols and this can place them at a disadvantage in a standard educational setting, particularly when it comes to timed assessments. Dyslexic's preference for sensory over auditory learning experiences entails that they will learn more through conversation and discussion than they will through reading, as confirmed by research conducted by Brooks and Weeks[18] and Exley.[19] It is for this reason that the majority of assistive technologies that have been developed to aid dyslexic learners place an emphasis on translating visual messages into sensory experiences; e.g., text-to-speech readers.

Learners with speech-sound dyslexia will often stutter in situations of stress and may mispronounce multi-syllable words when speaking. As such, they generally avoid tasks that involve explaining information or discussing a concept. Dyslexics are typically reflective learners who work most effectively in isolation or in a one-to-one setting.

According to Chinn and Ashcroft,[20] dyslexic students also experience a range of mathematical difficulties because they exhibit problems with sequencing and directional confusion, among others. In a study that examined the mathematical performance of students with dyslexia, Joffe[21] found that one of the biggest problems that individuals who have this condition experience when dealing with numerical information is the inability to perform mental calculations. She attributed this to verbal labelling, and short-term memory issues. Further work in this area, as conducted by Exley,[19] found that children who suffer from dyslexia enhanced their mathematical skills when they were provided with sensory and visual-based learning experiences. As such, these individuals benefit from lessons that use flow charts and graphs to simplify and communicate complex processes or algorithms.

Students who have dyslexia typically demonstrate an excellent long-term memory for visual elements such as faces, shapes and colours. However, on the contrary, they exhibit difficulties when they attempt to recall information pertaining to events or phenomenon that they have not experienced first-hand for themselves. This preference for visual elements should be taken into consideration when planning learning experiences for dyslexic learners, and teachers, educators and those involved in research that aims to improve the effectiveness of learning interventions should provide visual learning experiences that optimise the process by which information is transferred to the long-term memory of dyslexic learners.

5. Ontology Creation

As previously discussed, the important role that ontologies can play in the development of personalised e-learning experiences has been acknowledged by many researchers. However, at present, those ontologies that have been applied to personalised e-learning are largely limited to taxonomies of user interests and there is a distinct lack of an ontological approach that effectively integrates learner preferences, assistive technologies and special needs in one ontology. This aim of this current study was to identify an approach by which this could be achieved.

5.1. Definition of Ontology

According to Noy and McGuinness,[22] ontology consists of a series of entities, referred to as classes, that describe the concepts associated with a given domain in a formal and explicit manner. It is possible for every class to have more than one parent class, and this leads to the development of a specialised or generalised hierarchy that consists of 'as-is' links. Each class also has slots and restrictions that illustrate the various features of the class modelled. The slots themselves also have a type that determines how many values can be allowed. This type can be a string, number, Boolean or other class. In addition, many instances of a given class are possible. Each of these instances corresponds to objects in the domain. As such, a concrete value exists for each instance of each class. A knowledge base is the ontology and the individual instances of each class.

5.2. Ontology Creation Resources

This paper proposes an OWL-based ontology design. This type of ontology was selected for the purposes of the current research because it is closely aligned with the structure of educational content. In more recent years, the

OWL approach has been applied as a standard W3C language for the purpose of representing web-based ontologies. The Protégé[23] 5.0 framework is typically employed to edit and update contents. De Meo et al. [24] suggested that these contents should be organised into learning objects in order to create personalised learning programs that offer sufficient flexibility to meet the needs of a wide variety of learners. As such, in the ontology proposed in this paper, the fundamental components of the method are the learning objects. According to the IEEE,[25] learning objects are any digital or non-digital identity that can be employed, accessed or referenced during a technology-supported learning intervention. A learning object can be small; e.g. text, video or image, or it can be large; e.g., a full learning application or website that incorporates the smaller learning objects in various forms. Two characteristics should be taken into consideration when planning a learning object: the type of dyslexia that a student has and the features the technology will need to incorporate to deliver learning objects in a manner that is suitable for this type of dyslexia.

The *Resources* and *Concept* classes presented by Gascuena et al.[11] were adopted in this research as they were deemed to represent appropriate learning objects and resources. Metadata pertaining to the learning object was used to develop the ontology. Gascuena et al.[11] employed some elements of the Learning Object Metadata (LOM),[25] a standard for e-learning environments that was defined by the IEEE. As we were concerned with describing the characteristics of assistive technologies, an ontology was produced that was based on elements of the technical category of the Foundation for Intelligent Physical Agents (FIPA) Device Ontology. The FIPA[26] Device Ontology presents a frame-based structure that can be applied to describe devices. The purpose of this structure is to facilitate agent communication in order to allow content adaptation via a range of different devices, including iPads, PCs and PDAs. Within the realm of assistive technologies ontology, FIPA provides an ideal starting point from which modifications and additions can be implemented while taking into consideration the key aspects of assistive technologies. In terms of this paper, dyslexia-type ontology and assistive-technologies ontology represent new concepts.

6. An Overview of Ontology

This section presents an overview of the ontology of a learner who has dyslexia. It is possible to extend this ontology through inheritance by introducing additional classes and through concept instantiation. Such actions can take into consideration the requirements of a specific application or those associated with the type of disability the user exhibits.

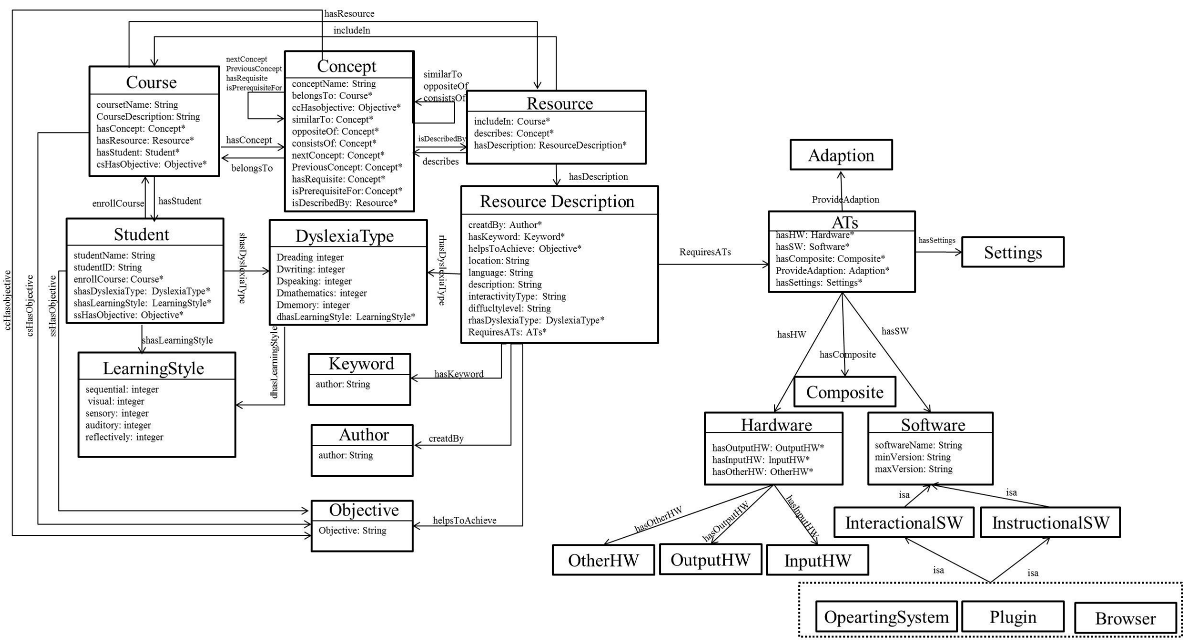

Fig. 1. General layout of the proposed ontology

Figure 1 presents a broad overview of the domain ontology outlined in this paper. The *Course* class denoted the subject to be taught during the learning experience. For example, an individual class of the *Course* class could be 'mathematics'. The *Course* class incorporates five properties; *courseName* and *courseDescription* describe the name and an overview of the course content respectively. The *hasObjective* property refers to the objective of the course, and *hasConcept* and *hasResource* are the concepts and resources that are provided during the course.

6.1. Dyslexia Type Ontology

For The techniques of Felder and Silverman's[14] Learning Style Model (FSLSM) were employed to produce the dyslexia type ontology. This method attempts to determine a student's learning style by answering multiple questions. In order to provide a means by which student's learning styles could be taken into consideration in the e-learning application, we attempted to match each form of dyslexia to the dimensions of the FSLSM. Such an approach has been successfully employed in a variety of adaptive environments; for example, in the work of Capuano et al.[27] and Shi et al.[28] The *DyslexiaType* class of the ontology reflects the types of dyslexia difficulties that should be included in the learning objects, and it incorporates five properties that correspond to the five types of dyslexia. The *DyslexiaType* and *LearningStyle* classes are connected via the *hasLearningStyle* property object. Furthermore, the five properties of the FSLSM—reflective, visual, sensory, sequential, and auditory—constitute the dimensions of the *LearningStyle* class.

6.2. Ontology of Assistive Technologies

The *AssistiveTechnologies* class (see Fig. 2) encompasses those technologies that have the potential to improve learning outcomes for students who have learning disabilities. This class is not limited to students with dyslexia; it can be effectively applied to a wide range of disabilities. A fundamental requirement of providing learning objects in a form that meets the learning styles of students with dyslexia is the use of appropriate technological offerings. As such, the *Hardware* and *Software* classes are required as part of the *Composite* class. This allows the offering to incorporate both hardware and software. The *Hardware* Class incorporates three subclasses: *InputHardware*, *OtherHardware* and *OutputHardware*. *InputHardware*, and *OutputHardware* classes represent the input and output systems that the students will employ, and the *OtherHardware* class is further divided into additional contains subclasses: Memory, Processor and Graphics.

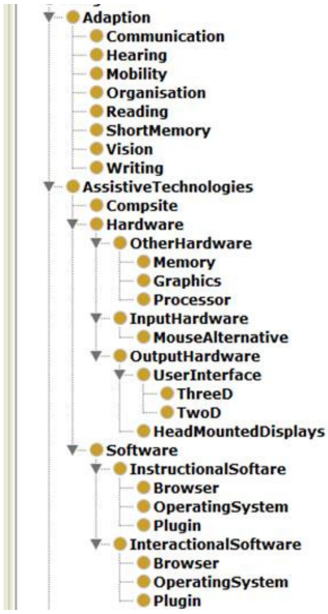

Fig. 2. Class *Adaption* and *AssistiveTechnologies* with their subclasses in Protégé

The assistive technologies involved in the ontology each incorporate flexible settings that can be altered in accordance with the learning needs of the student who is using the system. The way in which these settings are fixed and adapted is determined in the *AssistiveTechnologies* class, which incorporates the Setting and Adaption classes via the *hasSettings* and *provideAdaption* object properties.

The *Software* class is classified in two separate forms: *InstructionalSoftware* and *InteractionalSoftware*. The *InstructionalSoftware* class describes computer software that does not immediately interact with the system; for example, a program that displays photographs or plays sounds to support learning activities. The *InteractionalSoftware* class describes programs that the learner directly interacts with as he or she learns; for example, educational games or online tests. Both forms of the software class can incorporate the software types of *Browser, OperatingSystem* and *Plugins.*

It is important the system that is developed offers personalised learning experiences that can be reused. As such, the *Setting* class (see Fig. 3) is required as a separate entity to the *AssistiveTechnologies* class. The *Setting* class allows the user to select options that are aligned with his or her learning needs and capabilities and semantically captures the various settings that are available within the technology. The *Setting* class incorporates four semantic classes: *AudioSettings*, *PersonalSettings*, *CommunicationSettings* and *VisualSettings* (Figure 1). The semantic classes can be further split into the subcategories of the *AssistiveTechnologies* class via the *hasSettings* object property.

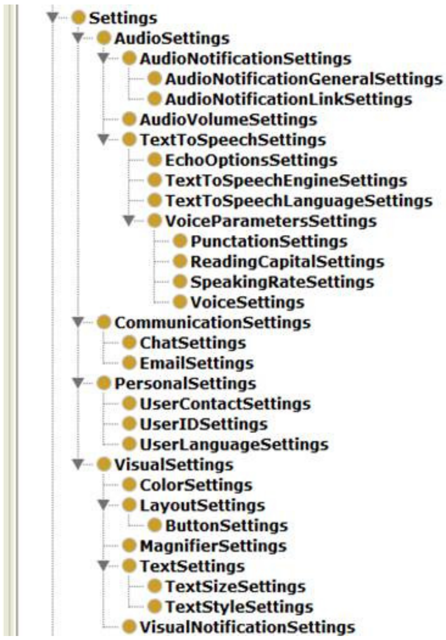

Fig. 3. Class Settings with its subclasses in Protégé

The *Adaption* class (see Fig. 2) is also a semantic class. The purpose of this class is to provide a range of adaptation options that allow the software to be tailored to the nature of the user's disability. As such, the *Adaption* class categorises the various adaption solutions and applications that are available into semantic classes. For instance, the first semantic level of *Adaption* class classifies the adaption solutions into eight generic classes: *Reading*, *Writing*, *Communication*, *Hearing*, *Vision*, *Mobility*, *ShortMemory*, and *Organisation*. The deeper into the ontology one progresses, the more refined these classes become and the more the software is adapted.

7. Conclusion

This paper examined the use of a domain ontology to develop assistive learning technologies that can be aligned with the needs and capabilities of learners with dyslexia. Two fundamental aspects were of interest: the learning styles that people with dyslexia exhibit, and how assistive technologies can be adapted to align with these learning behaviours. Through taking dyslexia type into consideration when developing the learning objects, it was possible to develop an e-learning system that is capable of aligning the resources presented with the student's learning needs and capabilities. In order to achieve this, it was necessary to create a link between the *Adaption* class and the *AssistiveTechnologies* class. This provides the levels of adaptation required to ensure that the e-learning software integrates the assistive technologies needed to deliver learning experiences that are appropriate to the student's needs. The *Setting* class was separate from the *AssistiveTechnologies* class. This ensures that the proposed ontology can be reused and employed with a wide variety of users and audiences. The proposed ontology can be used for a variety of purposes and may be extended to individuals who exhibit general usability problems because the difficulties associated with dyslexia are also commonly experienced by individuals who have other special needs (Evett and Brown[29]). Furthermore, dyslexia symptoms can vary (Dixon[30]).

For future work, we aim to create a tool for enabling the delivery of the courses taught in our University from the ontology proposed in this paper. This should not present us with too much work, as we have designed the system architecture already in Alsobhi et al.[31] In order to enhance the level of adaptability the subject matter to be taught is decomposed into theory, exercises and test questionnaires.

The ontology described in this paper was evaluated in accordance with the needs of students who suffer from dyslexia and the validity of the system was assessed through two evaluation tests. The first involved observing students who have dyslexia and the second phase constituted a heuristic evaluation that was performed by educational experts. The process of evaluation and the outcome will be described in a later paper.

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