UDLOntology
An ontology for education in the diversity

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Abstract. An education that values and enhances the skills and strengths of each student incorporates important advantages for learners and educators. However, the teacher is not always prepared to create educational resources that consider such a diversity of skills, especially when including disabled learners. In this context, this paper presents UDLOntology, an ontology in the domain of Education based on Universal Design for Learning principles. Its goal is to infer recommendations of educational materials that best facilitate and stimulate student learning according to their individual learning skills and strengths. UDLOntology together with the SELI course authoring platform (Smart Ecosystem for Learning and Inclusion) will guide and assist teachers and educators in building didactic resources to support and empower people with disabilities. In order to verify the adequacy of the ontology, still under development, in the inference of specific educational materials for each skill, some properties necessary for attending students with Down syndrome were specified. The main UDLOntology goal is to highlight learning skills and strengths rather than disabilities.

Keywords: Ontology, Universal Design for Learning, Down syndrome, Inclusive and equity education.

1 Introduction

Education, information, and autonomy are essential elements in and for people's freedom. Thinking and believing in the universality of education and betting on individual learning skills and strengths rather than disabilities, implies a paradigm shift and therefore a great challenge. This shift allows for talking of “education in the diversity” rather than “inclusive education”, and incorporates as well important advantages for learners and educators. From the learner’s side one advantage is to highlight and work on positive aspects by identifying learners with characteristics that empower the human being like skills and strengths. Another advantage is preserving the students’ privacy by avoiding the need to ask them to select their disabilities to determine their learning profile. From the educators' view, the main advantage is that it comes to professionalized curriculum design, content design, and assessment,

specifically for intellectually disabled learners. As mentioned by [11] strengths and skills addressing individual differences has been shown to have a positive impact on students' commitment, hope, and self-perceived academic performance. With the intention to reinforce the education in the diversity we have built the SELI Platform in the context of the Smart Ecosystem for Learning and Inclusion - SELI Project [15] [17], a course authoring tool that guides the teacher to comply with the UDL (Universal Design for Learning) principles in the creation of educational resources. To verify that an educational resource conforms to the principles of UDL, it is necessary to have a formal specification of UDL, on which one can construct a sastifactible model. Furthermore, this specification should help to classify educational resources according to their adherence to UDL principles. Below, we present our ongoing work on the development of a UDL ontology named UDLOntology as a formal specification of this model to be integrated in the future with the SELI Platform to help teachers build courses based on UDL principles.

UDLOntology allows for the inference of recommendations of educational materials that best facilitate and stimulate student learning according to their individual learning skills and strengths. Our work contributes towards building an inclusive education, especially with the goal of supporting and empowering people with learning disabilities, by focusing on using ontologies that enable us to highlight learning skills and strengths rather than disabilities. To illustrate UDLOntology and its contribution to education in the diversity, in this paper we focus on the properties needed for the appropriate educational resources for students with Down syndrome.Although the strengths of people with Down syndrome can vary greatly from person to person, as with other diagnoses of intellectual problems, one of the advantages of using ontologies as a formal model is the possibility that they can be developed in a specialized way, assisting the teacher in choice of appropriate learning resources for these students. Currently UDLOntology is under development. This paper is organized as follows: Section 2 shows the concepts and guidelines of Universal Design for Learning. Section 3 shows some related work in ontologies in the domain of disability and education. Section 4 describes the proposed UDLOntology Framework, and Section 5 presents the conclusions and future work.

2 Universal Design for Learning (UDL)

UDL framework, developed by the Center for Applied Special Technology (CAST), is a set of principles for designing learning elements that provides equal learning to all people regardless of their disabilities, age, gender, or cultural and linguistic background [2]. It is based on the neuroscience research which has identified three primary neurological networks that have a successful impact on the learning: the affective network that impacts the why of learning, the recognition network that impacts the what of learning, and the strategic network that impacts on the how of learning. Based on the three neurological networks, UDL is grounded on three principles: engagement, representation, and action and expression, as shown in Fig. 1.

In addition, each principle has three guidelines that give recommendations on how to access, build and internalize educational resources, together with 31 UDL checkpoints. The “access” row presents recommendations to increase access to the

learning goal offering options for perception and physical action. The "build" row presents recommendations to improve the language, expression, and communication. Lastly, the "internalize" row presents recommendations to empower learners through comprehension and self-monitoring. The ultimate goal of UDL is: "to develop expert learners who are, each in their own way, resourceful and knowledgeable, strategic and goal-directed, purposeful and motivated", as shown in the 4th row of Fig. 1.

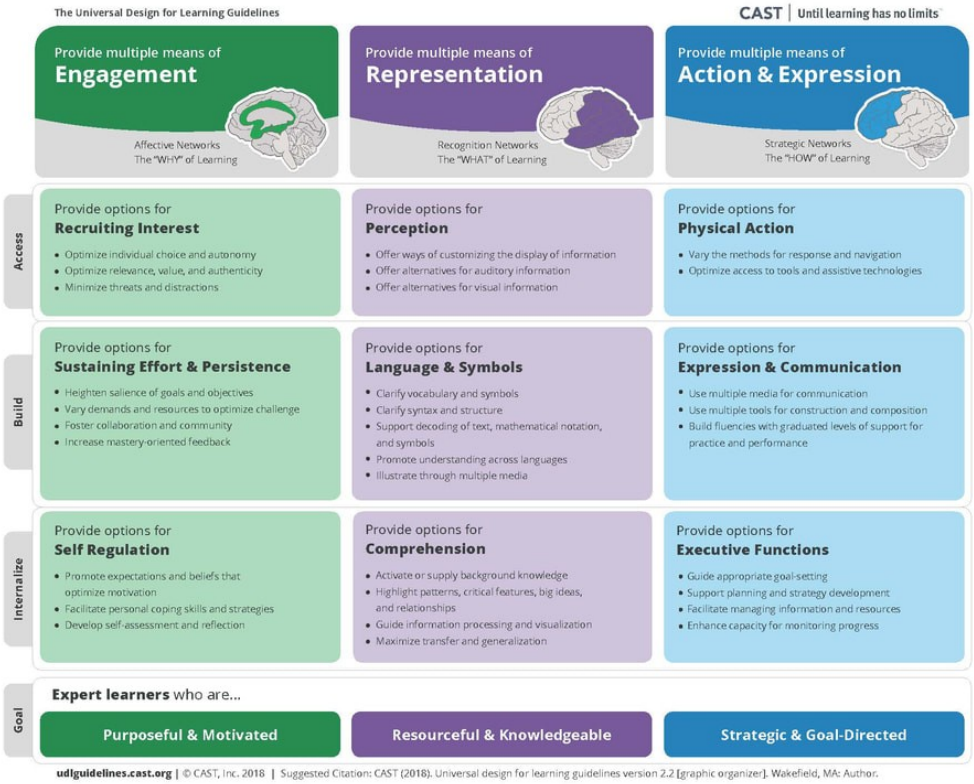

Fig. 1. UDL Guidelines Graphic Organizer (Image obtained from http://www.deaccessproject.org/universal-design-for-learning/udl-guidelines-2-2-2/).

3 Related Work

In this section we present some related work on ontologies in the domain of disabilities and education. Ontologies in the domin of disability are presented in [10] and [19]. They can be used to describe different types of disabilities, to specify user capabilities and needs, and to map user preferences to assistive. Ontologies in education were developed and used for different purposes. OntoEdu, presented in [5], is based on education grid system for e-learning. This ontology is divided in two parts: activity ontology that describes the activities and operations of education and relations and material ontology that describes the educational content organization. There are

others that describe students' characteristics with the intention of adapting content or activities that best suit the student when interacting with virtual learning environments. The work proposed in [13], models students' characteristics such as behavior, objective learning preferences, the learning style and the academic performance. However, the model proposed by this author aims at the student's profile to be used in Intelligent Tutoring System. In [4] the authors present an ontology designed for accessible OpenCourseWare and built on the accessibility concepts of IMS Learning Global Consortium and the vocabulary structure of the ACCESSIBLE ontology [1]. It was developed with the purpose to map learners´ needs and preferences to digital resources characteristics and adaptations to support learners disabilities. As mentioned in [12] work, ontologies are flexible tools and contribute to the modeling of UDL guides by means of mapping multiple means of representation for educational resources. In addition, [12] states "AccessibleOCW is an ontology that can be taken as a starting point to be extended, reused, or combined with other ontologies to achieve a complete UDL". However there is no work up to now that models UDL guidelines allowing the inference of recommendations based on learners learning skills and strength, allowing for tailoring of educational resource content, a key point especially for people with intellectual difficulties.

4 UDL Ontology

To delimit the scope of this work, we decided to analyze the representation UDL' principle for learners with Down syndrome, within the learning disabilities group according to the International Classification of Functioning, Disability and Health (ICF) [10]. The next subsection presents Down syndrome learning characteristics, abilities, and strength as a starting point to identify how UDL guidelines provide options for addressing representation of learning elements.

4.1 Down Syndrome learning abilities and strengths

People with Down syndrome share some areas of strength and learning cognitive characteristics. Some of their areas of strength are strong visual awareness and visual learning skills, ability to learn and use sign, gesture and visual support, ability to learn and use the written word, ability to learn from pictorial, concrete and practical materials, and routine. As for cognitive learning aspects perception, attention, memory, and reading are the ones we mentioned in this work. From the perception aspect, they have better ability to capture information through visual perception. Consequently, it is recommended to provide alternative visual options such as images, videos, and pictures for better comprehension. From an attentional perspective, they have difficulty fixing attention and focusing it. They also are easily distracted interfering with the learning process. Some of learning recommendations are to keep the working framework and digital resources simple, and to avoid as many distracting stimuli as possible. Another important recommendation is to provide clear and precise instructions, that require short attention time. Regarding memory, they have difficulties to effectively retain, evoke, connect, and transmit different information. As mentioned in perception, it is important to rely on alternative input channels to improve memory. When referring to literacy they have difficulty handling various information, complex vocabulary, and concepts [18].

They literally understand what they read, making it difficult for them to understand metaphors and double meaning sentences. They also have difficulties in abstraction and conceptualization, making it difficult for them to access complex knowledge. The following communications resources are recommended: Easy Read stands out, as a tool for reading comprehension that facilitates access to information, and Augmentative and Alternative Communication Systems (AAC) to facilitate the understanding of texts and environments.

4.2 How UDL addresses learning abilities

To identify which UDL guidelines can better address people with Down Syndrome abilities we consider the following questions: 1) For perception perspective: What are the sense through which the learners in study can better process or perceive the information?, 2) For attentional perspective: How is the context that better stimulates their attention at the time of learning? , 3) For memory perspective: Which techniques are better suited to improve memory? , 4) For literacy perspective: What are the characteristics of the contents for a better abstraction and conceptualization of concepts and ideas for learners in study?

To answer the above questions, we refer to the UDL Guidelines Graphic Organizer as presented in Fig. 1 and Down syndrome learning characteristics, abilities, and strengths presented in sub-section 4.1. To answer the first question *What are the sense through which the learners in study can better process or perceive the information*?, we see from subsection 4.1 that their strength is on capturing the information through visual perception. As stated in [3], "to ensure access to learning it is important that key information is equally perceptible to all learners by providing the same information through different modalities". Such multiple representations ensure that information is easier to access and comprehend for many ways of perceptions. As per the learners in study they have better ability to capture information through visual perception as mentioned before. Therefore, alternative options such as images, videos, and pictures are recommended for a better comprehension. See Table 1 for recommendations as Checkpoints. Checkpoint 1.3 is an adequate recommendation. As per the first question, to answer the second question *How is the context that better stimulates their attention at the time of learning?* visual alternatives for sound is recommended. In this case, checkpoint 1.2 is the adequate recommendation. For the third question W*hich techniques better suit to improve memory*? information transmitted solely through sound is not recommended for learners who need more time to process information, or who have memory difficulties. So as per the first question, it is also recommended to provide visual alternatives whenever feasible. Lastly, to answer the fourth question W*hat are the characteristics of the contents for a better abstraction and conceptualization of concepts and ideas?*, educators can address it by applying UDL Guideline [2], more specifically the recommendation: "Clarify syntax, instructions and vocabulary, and Illustrate through multiple media". Checkpoint 2.1, 2.2 and 2.5 are adequate alternatives.

4.3 UDLOtology for Down Syndrome

In this section we present the process we went through to design UDLOntology. We first identified a potential group of important concepts. To prepare this first group of terms, we applied the "brainstorming" technique, the consultation of documentary sources on learning skills for people with intellectual disabilities, and the study of the UDL Guidelines. Once this first group of terms was obtained, a short natural language description was added to each term to clarify concepts, identify possible synonyms and verify for equivalent terms in other ontologies. We then went through a conceptualization process where we improved the list by adding and removing some terms, we identified the main concepts of the model, and we organized them in groups. We identified the following main concepts: *UDLLearner*, *LearningAbility, UDLGuideline, UDLCheckPoint, AccessMode, ContentAdaptation,* and *EducationalResource*. *LearningAbility* represents the learning abilities a learner can have. *UDLGuideline* models the UDL guidelines as explained in Section 2.

Table 1. Relation between Down syndrome learning abilities and UDL Guidelines.

Learning aspects	Strength & Abilites	Learning abilites	UDL Guideline	UDL Guideline checkpoint
Perception	They have better ability to capture information through visual perception	Visual Multimedia media ilustrations	1: Perception Offer visual means of representation to sound and voice.	1.2: Share information in more ways than sound and voice alone
Attention	They better work within simple framework and minimum stimuli. They are strong at clear and consice instructions	Clear syntax instructions and vocabulary	1: same as perception 2: Language & Symbols Clarify vocabulary and symbols	1.2: same as perception 2.1 : Construct meaning from words, symbols, and numbers using different representations
Memory	They have better ability to capture information through visual perception	Visual Multimedia media ilustrations	1: Same as perception	1.2 same as perception
Literacy	Provide alternative representations that clarify the syntactic or structural relationships between elements of meaning. Recommended communications resources : Easy Read and AAC	Clear syntax instructions and vocabulary	2: Language & Symbols Clarify syntax and structure Ilustrate through multiple medias	2.1 : Same as memory 2.2 : Make the patterns and properties of systems like grammar, musical notation, taxonomies, and equations explicit. 2.5 : Make learning come alive with simulations, graphics, activities, and videos

Checkpoint defines UDL guidelines recommendations for learning abilities. *AccessMode* is the sense through witch a resource can be percived. Once the main concepts were identified, we identified and defined binary relations among the main concepts. We came up with the following object properties: *hasLearningAbility* links *UDLLearner to LearningAbility, matchUDLGuideline* links *LearningAbility to UDLGuideline, has_UDLGuideline* links *UDLGuideline to UDLCheckPoint, UDLCP_hasContentAdapt* links *UDLCheckPoint to ContentAdaptation,* and *UDLCP_hasAccessMode* links *UDLCheckPoint to AccessMode* as is depicted in Fig. 2.

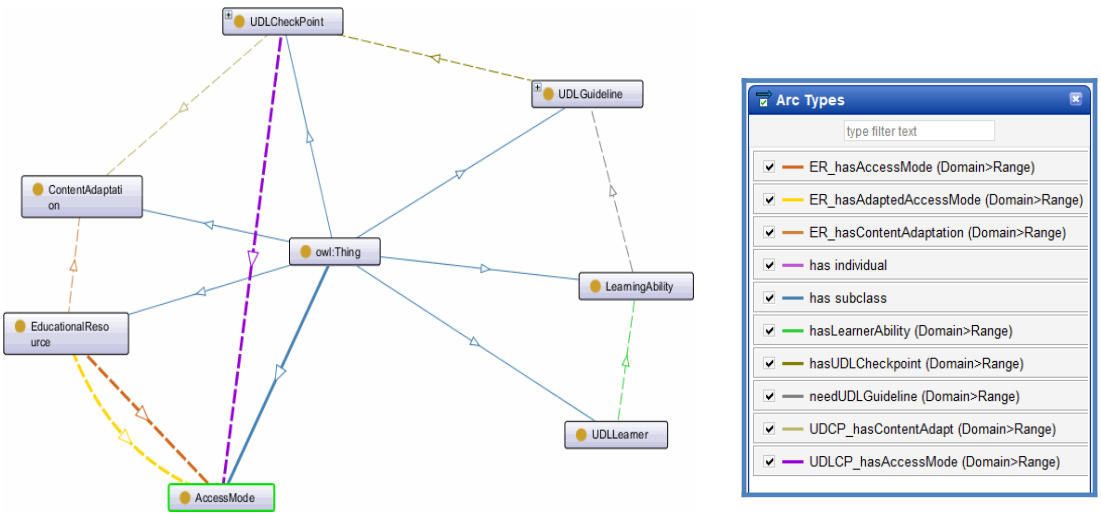

Fig.2. Ontology – Conceptual Model in Protegee

Once we had a UDLOntology conceptualization we selected those concepts from IMS AfA [6] that best fit the conceptual model. As mentioned in the introduction, the IMS AfA promotes inclusion by enabling the matching of the characteristics of resources to the needs and

preferences of individuals. IMS AfA standard v3.0 has two parts: the "Personal Needs Preferences" (PNP) [8], that describes the learner's needs and preferences, and the "Digital Resources Description" (DRD) [9], that describes the resources´ characteristics. The potential and benefits in the use of IMS AfA DRD are in the capability to use Open Educational Resources, and the concept of equivalent resources as suggested by the UDL. IMS considers that primary digital resources can have several equivalent resources with different access modes. Primary and equivalent resources will have different access mode but within the same domain. We selected two attributes from IMS AfA v3.0 specification for educational elements (DRD): the access mode (*AccessMode*) and the educational complexity of the resource (*EducationalComplexityOfAdaptation*).

For the design of UDLOntology we first unified from Table 1 those learning abilities that share the same UDL Guidelines and checkpoint. Next, we mapped UDL checkpoints with the IMS DRD selected above and defined values Visual, EasyRead, and Pictogram 1.2, 2.1 and 2.2 checkpoints respectively as shown in Table 2. Based on [14], we then integrate the result of the above process to AccessibleOCW ontology. We extended *UDLLearner* form *Learner*, and *EducationalResource* from *DigitalResource.*

4.4 Reasoning Process

To evaluate the model we define the instance Learner_DownSyndrom for UDLearner class, and EducationalResource1, EducationalResource2 and EducationalResource3 instances for EducationalResource class. EducationalResource2 and EducationalResource3 are adaptation from EducationalResource1. Since UDLLearner extendes Learner class form AccessibleOCW as stated above, we link Learner_DownSyndrom to Down_Syndrom as defined by ACCCESIBLE. We also link two learning strength to Learner_DownSyndrom: ClearSyntaxInstruccionVocabulary and MultiMediaIustrations as presented in Fig. 3.

Table 2. Learning abilities & UDL Guidelines checkpoint & DRD mapping

Learning abilities	UDL Guideline checkpoint	DRD	Value
Visual Multimedia media ilustrations	1.2: Share information in more ways than sound and voice alone	AccessMode	visual
Clear syntax instructions and vocabulary	2.1 : Construct meaning from words, symbols, and numbers using different representations 2.2 : Make the patterns and properties of systems like grammar, musical notation, taxonomies, and equations explicit.	EducationalComplexityOfAdaptation	EsayRead Pictogram

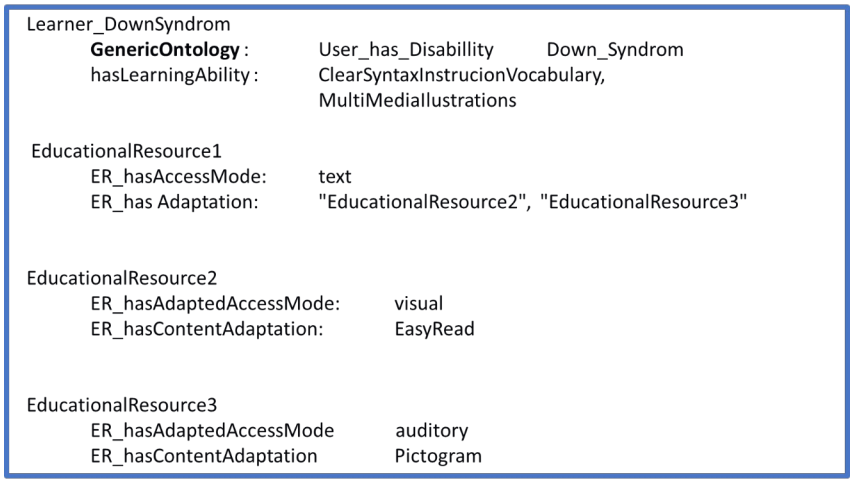

Fig. 3. Simplified Learner profile and educational resources.

To evaluate the ontology, we use the simplified learner profile and resources representation only with the properties that make to our objective, *hasAccessMode*, *hasReqAccessMode* and *hasAdaptedAccesMode*, as depicted in Fig. 1. The learner is a *Learner_lowVision* and has a *colour_blindness* disability (according to ACCESIBLE ontology). It requests for an auditory alternative for visual digital resources. digitalResource1 is visual digital resource and has two adapted digital resources: digitalResource2 and digitalResource3. digitalResource2 is an adaptation resource of digitalResource1 with textual alternative and digitalResource3 is an adaptation resource of digitalResource1 with audio alternative. To semantically answer the research question, the rule used to map learner with appropriate digital resource is depicted in Fig. 4.

All the properties constraints on the rules are asserted except for *hasAccess* that is inferred. The reasoning process is the following: 1 – *hasReqAccessMode* (*Learner_lowVision*, *visual_auditory*) *auditory* is the access mode a learner with low vision disability seeks, either in an adaptation or an original resource, as a replacement for *visual* access mode. 2 - *accessMode_existingAccessMode* (*visual_auditory* , *visual*) maps for the existence of the original access mode *visual* given a requested access mode (*visual_auditory*). 3 - *accessMode_adaptionRequest (visual_auditory*, *auditory*) maps for the alternative access mode *auditory* given a requested access mode (*visual_auditory*). 4 a – ***hasAccessMode*** **(** x, *auditory*) maps for a digital resource with access mode *auditory*. In the scenario that there is **no map,** 4 b - **hasAdaptedAccessMode (**x, *auditory*) maps for access mode equal to *auditory*, of the digital resource that is being adapted.

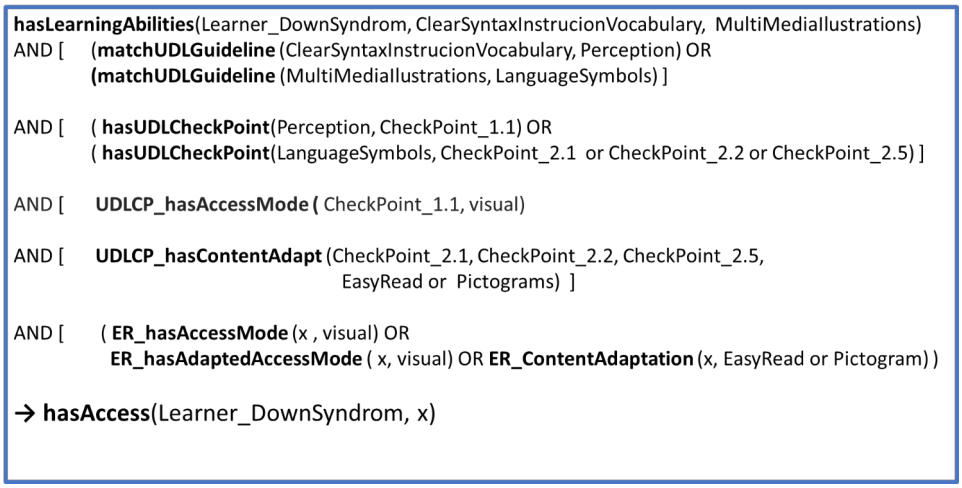

Fig. 4. Simplified Learner profile and educational resources

5 Conclusions and Future work

In this work we present an ontology in the Education domain based on UDL principles and IMS AfA named UDLOntology, that extends some clases of AccessibleOCW Ontology. UDLOntology focused on individual learning skills and strengths rather than disabilities. It models learning abilities based on UDL Guidelines and checkpoints resulting in a flexible ontology, and presents advantages for both, learners and teachers. For learners' side, the UDLOntology avoids the need to ask for their disabilities to determine the learning profile preserving their privacy. As per the teacher´s, it is a reference for inclusive curriculum design, content design, and assessment, based on learning abilities and strengths. Our work contributes towards building an inclusive education, especially with the goal of supporting and empowering people with learning disabilities, by focusing on using ontologies that enables to highlight learning skills and strengths rather than disabilities.

As future work, we will insert new educational resources, complementing UDLOntology, and mapping the learning and strength skills of all students with intellectual disabilities to the three principles of the UDL Guidelines: Commitment, Representation and Action and Expression, contributing to the development of expert learners in accordance with UDL objectives. We will also add ULDOntology to the SELI course authoring platform to guide teachers in creating educational resources that adapt to the learning skills of each student during their course design.

Acknowledgment. The research presented in this publication was carried out in the Smart Ecosystem for Learning and Inclusion ERANETLAC Project and received funds from the National Agency for Research and Innovation of Uruguay (ANII) with the code ERANET_R & I_2018_1_1008465.

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