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Article

MODELI: An Emotion-Based Software Engineering Methodology for the Development of Digital Learning Objects for the Preservation of the Mixtec Language

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Abstract: In this paper, a methodology termed MODELI (methodology for the design of educational digital objects for indigenous languages) is presented for the development of digital learning objects (DLOs) for the Mixtec language, which is an indigenous Mexican language. MODELI is based on the spiral model of software development and integrates three important aspects for the analysis and design of DLOs: pedagogical, affective-emotional and technological-functional. The premise of MODELI is that the emotional aspect with the inclusion of cultural factors has an important effect on the learning motivation of indigenous users when interacting with the DLO. Principles of the visual, auditory (or aural), read/write, kinesthetic (VARK) model and Kansei engineering were considered for the inclusion of the pedagogical, emotional and technological-functional aspects within the spiral model for the development of MODELI. The methodology was validated with the development of a DLO for a previously unknown variant of the Mixtec language. Usability tests of the DLO built with MODELI evidenced an improvement on the learning motivation and the value of cultural identity of indigenous children. These results are important for the preservation of indigenous languages in Mexico, because most of them are partially documented, and there is social rejection of indigenous culture caused by discrimination of ethnic communities.

Keywords: digital learning objects; Mixtec language; emotion-based learning

1. Introduction

Each language expresses a different vision of the world in which we live. It can represent where we come from, who we are and ideas of the society to which we belong. For these reasons, language is important for people's identity [1]. Language represents "the People" and their ideology that is a fundamental part of the cultural wealth of any nation [2]. The principle of "identity" is very important for the historical continuity of any society, because it promotes the value of a distinctive culture. Identity represents the strength of the society or community to keep its distinctive culture when threatened by the imposition of other values from other communities [3].

Statistics from the 2010 National Population and Housing Census in Mexico presented an increase in the Mexican population who could speak an indigenous or native language [4]. However, when this increase was compared with the total population, a significant decrease was observed. In 1930, the speakers of an indigenous language represented 16% of the total population; however, by 1990, their presence was reduced to 7.5%. By 2010, the fraction of people who could speak an indigenous language was 6.5% [4].

Knowledge of the indigenous languages is passed from fathers to sons as part of their cultural heritage. In most cases, this is performed without the use of formal learning resources (*i.e.*, dictionaries, audiovisual databases). A disadvantage of this situation is that the language is at risk, because no formal record of the language is kept. This risk is higher when few people speak the language variant. As an example, in 2011, the Ayapanec language was spoken by only two people [5], and it was considered as "critically endangered" by the UNESCO Atlas of the World's Languages in Danger [6].

Particularly in the Mixtec language, there are some variants that are considered endangered by the National Institute of Indigenous Languages (*Instituto Nacional de Lenguas Indígenas*, INALI) in Mexico [7]. In general, the indigenous languages are threatened at different levels by the following situations:

- Negative attitudes from members of the indigenous communities towards their own language [7]: Members who migrate to urban areas feel ashamed of their language and, within the process of social integration in the new environment, try to forget their language to succeed. They are afraid of being stigmatized and rejected if they speak their mother language;
- For the Mixtec language, there are many variants (more than 32). This situation makes the appropriate documentation of each variant and the development of learning resources for preservation difficult [8]. While people can speak the language, there is no documentation about its phonology, spelling/writing and grammar rules;
- The indigenous languages are excluded from institutional and public spaces, and their presence in the media (*i.e.*, radio and TV) is practically nil [7];
- Some communities are geographically isolated, and there are no technological resources for communication;

- Many of the indigenous communities have their customary laws that are legally known as *Usos y Costumbres* (customs and traditions) [9]. Thus, any attempt to join these communities for any purpose (*i.e.*, linguistic studies, rural development, health services) must be performed according to their customary laws. This represents a limitation for the development of fieldwork for research and data gathering required for documentation and other supporting activities.

The use of information and communications technology (ICT) has been proposed to improve education and the general living conditions of the indigenous communities [10]. This represents a challenge, because to implement ICT, special attention should be paid to the particular situation of each indigenous community without affecting its cultural legacy. Ignoring the local cultures damages the efforts to implement educational ICT innovations [11]. However, within the cultural context of the indigenous (native) communities, most of them are considered highly marginalized, and the impact of ICT sometimes is seen with positive and negative aspects. Some researchers argue that ICT widens the digital divide and represents a direct threat to ethnic identity [10,12]. Other researchers consider that ICT contributes to (1) equal access to information services for people with social disadvantages and (2) the development of marginalized communities by overcoming geographic barriers, improving communication between people and economic and social sectors [10]. ICT has the potential to promote cultural preservation [11].

Software engineering (SE) is commonly applied to the development of ICT tools or systems. SE is defined as the study and application of engineering for design, development and maintenance of software [13]. However, in the particular case of ICT for cultural elements of an indigenous community with values of *Usos y Costumbres*, there are no known SE methodologies.

Under an intercultural approach, ICT is regarded as a tool for reducing the digital divide by using education focused on the preservation of the cultural elements of the indigenous communities that represent their identity. Within this context, the following questions are considered:

- What type of ICT tool can be more suitable for preservation of a cultural element? In this case, the element of the indigenous language is considered.
- What is the most suitable methodology to build or design this ICT tool?
- Is there any human element that can be integrated into the tool's developing processes to improve the value of identity?
- How can the suitability of the ICT tool be measured?

This work presents an approach to address these questions, and an SE methodology is developed for the purpose of designing digital learning objects (DLOs) [14,15] for variants of the Mixtec language. A DLO was considered as the ICT tool, because it has portability and interactivity advantages for the purposes of learning and dissemination of the indigenous language for future preservation. The human factor of emotion was identified as an important element of the design of the SE methodology and the DLO. In contrast to other works that present general guidelines or sets of good practices, the proposed methodology integrates Kansei engineering, formal pedagogical theory (*i.e.*, the visual, auditory (or aural), read/write, kinesthetic (VARK) model), models of software engineering and formal evaluation methods. Furthermore, the social implications of indigenous culture are considered within the methodology to address important activities for the development of DLOs, such as requirements analysis.

2. Background

2.1. Digital Learning Objects

The Learning Technology Standards Committee (LTSC) defined learning objects (LOs) as "any entity, digital or non-digital, which can be used, re-used or referenced during technology-supported learning" [14,16]. Hence, this definition considers the following elements as digital LOs: computer-based training systems, interactive learning environments, intelligent computer-aided instruction systems, distance learning systems, collaborative learning environments, multimedia and instructional content, learning objectives, instructional software and software tools and persons, organizations or events referenced during technology-supported learning [14].

The advantage of a digital LO (DLO), when compared to another learning tool, is the level of interactivity that can be accomplished with the DLO. This can be a motivating and attractive factor for the user. Furthermore, a DLO can be used individually or collectively with or without the mediation of the teacher, encouraging the student's autonomy and critical thinking. This is important to accomplish the learning task with constructivist principles [15,17–19]:

- learning is a constructive process that requires activation of certain prior knowledge;
- the learning process should lead to the creation of imbalance that allows the student to construct new knowledge.

For the present work, the DLO is conceived of as an independent and autonomous digital entity that is designed to support the teaching and learning processes based on educational technology. This DLO must satisfy the following functional requirements [20]:

- Interoperability: The object must be labeled and cataloged with descriptive information (metadata) to facilitate its storage and later retrieval;
- Reusability: The object must be able to be used in different educational contexts. The separation of the object and context represents the first step for reusability. The simplest way to achieve reusability is the segmentation of the educational content into smaller, mutually-independent LOs;
- Portability: The object must be able to be used on platforms from different manufacturers;
- Durability: Changes in technologies must not affect the design of the object. The DLO must be scalable to extend its useful life;
- Ubiquitousity: The DLO must be able to be accessed from any platform. It must be available for any user who needs information or educational content without the need to know its source or physical location.

2.1.1. Pedagogical Aspect

The pedagogical aspect is important for the development of a DLO, because it determines the LO's set of features (*i.e.*, graphical design, structure and logical sequence, the form of interaction, methodologies). The most prevalent pedagogical models in the learning processes are the constructivist model (student-centered learning, experimentation, knowledge construction, problem-solving) and the social model (collaborative learning) [21].

Meaningful learning can be achieved through constructivism [22], and it is defined as a learning method whereby the required new knowledge is related to previous knowledge [23]. It occurs when learning tasks are consistently related to each other and the student decides to learn them. Under the meaningful learning pedagogical approach, there is an interactive process between the learner (student) and the subject of study. Furthermore, there must be an emotional commitment to integrating new with existing knowledge [22].

In this case, an interface or digital entity can provide educational support in terms of "interactional fit" between the learning objectives and the meaningful representations developed by the learner. A digital entity as the DLO can stimulate the following characteristics of the meaningful learning: openness to experience, changing behavior and discovery and understanding [24].

2.1.2. Development Approaches

Well-developed DLOs can improve the learning process of complex subjects. In [25], the development of an LO for teaching of the clinical assessment of preterm infants for nursing students was presented. The LO, termed SSRNPT (semiotechnique and semiology of the preterm infant) included multimedia material, such as videos, images, sounds, texts, questions and educational schemes. Cognitive assessment of the nursing students evidenced a positive impact of the DLO.

However, the development approaches for many DLOs are not based on formal pedagogical or instructional design models and do not consider the student's interests, skills and knowledge [26]. Thus, to achieve effective DLOs, a formal development approach or methodology is required. In Table 1, a review of recent related work on the development of DLOs is presented with the following information:

- A general description of the approach presented by the related work. Some works present general approaches, while others present specific characteristics that must be considered while designing a DLO for a particular context;
- The set of formal tools (principles, methods, software) considered to define the approach and/or characteristics presented by the related work;
- The DLO developed with the approach presented by the related work.

As presented in Table 1, there are evaluation and general/specific development approaches for DLOs. Evaluation approaches are focused on the continuous evaluation of specific aspects of the DLO to improve their efficiency. As presented in [21,27], evaluation based on questionnaires or sets of accessibility principles can provide insight into the technological, pedagogical and reusability aspects of a DLO.

The development approaches are focused on defining sets of principles, methods, software engineering stages and tools to accomplish an effective DLO. In some works, these approaches were specific to a particular type of DLO, emphasizing the characteristics that the DLO must have [28–34]. While these works considered formal guidelines of instructional design of DLOs and pedagogical theory, the development process was presented in a general form. Hence, there were no details about the practical implications of adapting and applying the stages/phases of these guidelines for the development of DLOs.

Other development approaches are general for the creation of different types of DLOs as presented in [26,35–40]. Although these approaches integrated more formal theory about instructional design,

learning design and usability, most of them remained as "conceptual models". Hence, most of these approaches were not validated through the creation and evaluation of a DLO. Particularly, the formal model presented in [26] was validated through the development of a DLO for image-based language learning of Japanese kanji and Mayan symbols in mobile environments. However, this DLO just considered the visual aspect, and it did not consider the phonetic (speech) and cultural aspects of the languages.

The formal model presented in [26] was termed FLOM (formal learning object model), and it defined the following main points for the development of a DLO:

- Learning objectives: educational goals that must be reached after using the LO;
- Competencies/skills: abilities, attitudes and values acquired after interacting with the LO;
- Requisites: knowledge or competencies that the learner should have acquired prior to being able to take advantage of the LO;
- Content: digital resources that make up the LO;
- Practice: tasks that the learner must perform while interacting with the LO;
- Evaluation: mechanisms designed to measure the knowledge acquired after interacting with the LO;
- Metadata: predefined identifiers that facilitate the storage, organization and searching of the LO.

FLOM was presented as an improved approach for the formal models reported in [41–43]. However, the model was presented in a general form, and no information about the type of tools to be used at each point of the methodology was presented (*i.e.*, how to identify the appropriate competencies and requisites, evaluation methods, usability metrics). The emotional factor that is important for the integration of new with existing knowledge within the learning process [22] was not considered within the conception of FLOM nor the development approaches presented in [28–32,34–38].

For the purposes of cultural preservation and improving cultural identity, a methodology must consider the social and cultural aspects of the student and the subject of study. In our work, we found that the emotional factor is important to improve the sense of identity for indigenous people and that emotion affects the learning process of cultural elements, such as language. The works reviewed in this section do not address the development of DLOs for the particular situation of preservation of an indigenous language.

Table 1. Related works on the development of digital learning objects (DLOs): 2012–2015.

Work	Description	Tools	DLO
2015 [26,35]	Specific development approach: formal LO model (termed FLOM) for the development of DLOs. FLOM considered the required components for the construction of DLOs as the life cycle (from inception to implementation) and the tasks and roles of all actors involved in the development, learning, interaction, evaluation and feedback processes. In general terms, the FLOM methodology considered the following main points for a DLO: "learning objectives", "competencies/skills", "requisites", "content", "practice", "evaluation", "metadata".	Theory of instructional design of LOs	Mobile image-based LO for Japanese kanji and Mayan symbols with quantitative evaluation
2015 [44]	Specific characteristics of an LO: development of an LO for the purposes of promoting reflection on inclusion and re-signification of teachers' practice for students with special educational needs or disabilities (SEND). Technical and pedagogical aspects of "content", "usability" and "learning resources" were considered for the LO with the following modules: "limits", "diversity" and "teaching", "deafness".	Constructivist principles	"Incluir" (to include) with questionnaire-based evaluation.
2015 [28]	Specific development approach and characteristics of an LO: development of a mobile LO considering specific characteristics (multimedia elements) to improve motivation for Japanese language learning.	Web interface theory for LO construction, principles of usability, IEEE LOM (Learning Object Metadata) Standard	J-GO mobile LO for Japanese language learning with questionnaire-based evaluation.
2015 [29]	Specific development approach and characteristics of an LO: development of a digital whiteboard interface to support Down Syndrome (DS) students in their learning of addition and subtraction algorithms. The following development stages were defined: "pre-test" (selection of cases, requisites, prototyping, usability heuristics), "test" (task execution, observation), "post-test" (educational evaluation, focus group).	Heuristics, pedagogical theory, special education theory, principles of software engineering	Digital whiteboard with heuristic evaluation.
2015 [45]	General development approach for the selection of LOs: application of collaborative searching to assist users in the search for LOs in repositories.	Stochastic methods, DELPHOS framework for recommendation in LO repositories	-

Table 1. *Cont.*

Work	Description	Tools	DLO
2015 [46]	General development approach for selection of LOs: application of ant-colony optimization to define the most suitable sequencing and selection of LOs for particular courses.	Ant-colony optimization	-
2015 [30]	Specific development approach: instructional design model for a tablet-based LO to enhance mathematical concepts for students with learning disabilities. The conceptual framework considered aspects of feasibility evaluation, project planning, functional analysis, development and implementation, pedagogy and interface design.	Theory of instructional design of LOs	-
2014 [47]	Specific evaluation approach: quantitative approach to examine the effectiveness of digital game-based learning (DGBL) *vs*. static e-learning on learning achievements as digital games affect the user's emotional state, which is directly related to learning performance.	Systems: NeuroSky, emWave, Eye Tracker	-
2014 [36]	General development approaches and characteristics of LOs: overview of the main definitions of LOs, characteristics and attributes of LOs, development requirements of LOs, evaluation metrics and metadata for LOs.	-	-
2014 [37]	General development approach: personalization of LOs and VLEs (virtual learning environments) by identifying connections between learning activities, learning methods, LOs types and sub-activities.	Web 3.0, ontologies	-
2014 [38]	General development approach: definition of a new class of LOs that combine two types of knowledge: (1) reusable knowledge (theoretical and practical information on education design); and (2) knowledge of reuse necessary to describe the reusable knowledge using an extended LO metadata language. The definition model considers theories of learning and instruction and the following development stages: "analysis", "design", "implementation".	Instructional management systems learning design (IMS-LD), unified modeling language (UML)	-

Table 1. *Cont.*

Work	Description	Tools	DLO
2014 [31]	Specific development approach: storytelling design model (SDM) for the creation of storytelling complex learning objects (SCLOs) to support the learning process in a civil emergency context.	Visual story portrait (VS), SDM, Bloom's knowledge levels	SCLOs with questionnaire-based evaluation (system usability scale (SUS) questionnaire)
2014 [27]	General evaluation approach: bottom-up and top-down approaches for evaluating quality and reusability of learning objects (LOs).	Principles of MCDA (multiple criteria decision analysis)	-
2014 [32]	Specific development approach: development of an LO for learning fashion design. The following development stages were defined: "need definition", "information analysis", "knowledge extraction", "knowledge presentation".	Clustering algorithms	Fashion design software with questionnaire-based evaluation.
2014 [33]	Specific development approach: development of more suitable LOs for music students considering their social behavior and motivation.	Technology acceptance model (TAM), unified theory of acceptance and use of technology (UTAUT), constructivist model CLASP (composition, literature, audition, skill acquisition, performance)	Sound recording/manipulation LO with questionnaire-based evaluation
2013 [48]	General development approach for selection of LOs: application of collaborative filtering for "recommender systems" to predict the utility items and LOs for users based on their preferences.	Collaborative filtering (CF)	-
2013 [49]	General development approach for selection of LOs: development of a framework (DELPHOS) to assist users in the search for LOs in repositories. The following criteria were considered: "content similarity", "usage", "quality evaluation", "profile similarity".	Stochastic methods	-

Table 1. *Cont.*

Work	Description	Tools	DLO
2013 [34]	Specific characteristics of an LO: educational software termed "Wandering" to facilitate interactive learning through the creation of location-based interacting learning objects (LILOs). This software encourages students to create their own location-based LOs (LILOs).	IEEE LOs Metadata (LOM) Standard	LILOs with questionnaire-based evaluation.
2012 [21]	General evaluation approach: questionnaire to evaluate the level of technological and pedagogical inclusion of DLOs.	UNE (*Una Norma Española*, a Spanish norm) 139803:2004, Spanish guide to web accessibility ISO 24751, web content accessibility guidelines 2.0 (WCAG)	-
2012 [39]	General development approach: development of a teaching unit model (TUM), which is a type of LO. The development methodology considers the instructional design model, constructivist principles and the competencies model for the pedagogical, functionality and usability aspects of the TUM.	Competencies model, usability heuristics	PIAC (*Plataforma Interactiva para Aprendizaje de Cálculo*, interactive platform for learning calculus) with questionnaire-based evaluation (Nielsen's heuristics)
2012 [40]	General development approach: set of guidelines for the creation of more accessible LOs through alternative media resources.	Principles of universal design, recommendations for creating accessible web content, W3C, best practices for production and application of accessible content	-

Furthermore, the reviewed works do not provide insight into the social implications of trying to adapt their development approaches for this case. While not explicitly defined as a DLO in [50], a learning mobile application was presented for the literacy education of indigenous children. This work pointed out that cultural and social factors, such as concepts of marriage, family, work, life and identity, must be considered when designing mobile learning scenarios. The interface of the mobile application, termed "Pocket School", displayed pictures of animals and sounds (Spanish pronunciations of words). While no formal approach or methodology was presented for the development of the application, there were many valuable pedagogical recommendations within the context of technological tools for the education of indigenous children.

Hence, the present work addresses the issue of developing a formal approach or methodology for the development of DLOs for the preservation of variants of the Mixtec language. The proposed methodology considers Kansei engineering for integration of the emotional factor, formal pedagogical theory (*i.e.*, the VARK model) to identify the learning styles of the users, models of software engineering (*i.e.*, development stages) and formal evaluation methods. The social implications of indigenous culture are considered within the learning context of the DLO.

2.2. Emotional Factor within the Learning Process

Affection and emotion are factors that have been recognized by the research community of HCI (human-computer interaction) for the analysis and design processes of interfaces [51]. However, how to integrate the emotional factor within the ICT's developing process for the learning task of a native cultural element is something that must still be resolved from the point of view of software engineering.

Positive feelings of motivation and pleasure to accomplish learning tasks with the DLO can be achieved if the user can identify cultural elements within the ICT tool's interface. Emotional commitment is important to integrate new with existing knowledge under the meaningful learning pedagogical approach [22].

2.2.1. Definition of Emotion

There is no consensus among researchers about what is an emotion [52]. Some researchers define it as a response to events that are important to people, while others consider it a personal experience or a willingness to act. Other researchers consider it as structures of meaning associated with events that affect people [53–55].

In this work, and for educational purposes, the concept presented by Bisquerra [56] was considered: "Emotions are reactions to information (knowledge) that we receive from our interactions with the environment. The intensity of the reaction is based on subjective assessments we make about how the received information will affect our wellbeing. In these subjective evaluations, elements as prior knowledge, beliefs and personal goals are involved. An emotion depends on what is important to us".

Emotions can be perceived and expressed by different means: language, behavior, facial expressions and physiological patterns. Particularly the facial expressions of the basic emotions of happiness, sadness, anger, surprise, disgust, fear and contempt [57] are universal regardless of societies or cultures.

The features of the face are the primary means to express emotions: the forehead, eyebrows, eyes and eyelids and the mouth.

2.2.2. Emotion as Learning Contributor

Research has demonstrated a relationship between the emotions of the student and learning success, identifying a link between the students' academic achievements and their motivation [47,58,59]. Emotions have also been studied as an important element of the learning process with ICT tools [60].

However, when a cultural element as a native language is considered as the learning subject, no further research has been reported. This is important because cultural and social ideologies are external factors that influence emotions. Meaningful learning can be achieved if the student gets emotionally involved with the subject of study. This can improve the student's interest in the subject [52]. Furthermore, any tool can be more effectively used if it provides emotional benefits to the user (*i.e.*, it is pleasant to use) [61].

2.3. The Municipality of Santos Reyes Yucuna

The municipality (community) of Santos Reyes Yucuna is located in the High Mixtec Region (*Región de la Mixteca Alta*) in the northwest region of the Mexican state of Oaxaca. The territorial extension of the municipality is 16.59 km^2, which is equivalent to 0.07% of the territory of Oaxaca. However, 76.66% of the land of this municipality is not suitable for agriculture.

According to data provided by the Federal Government through the Ministry of Social Development (*Secretaría de Desarrollo Social*, SEDESOL), the municipality of Santos Reyes Yucuna is composed of seven communities that are considered communities with high marginalization levels [62]. Based on the 2010 National Population and Housing Census, the municipality had a population of 1332 inhabitants (658 men, 674 women), where 1122 inhabitants were speakers of the Mixtec language. The mean age of the inhabitants is 15 to 19 years; hence, the population of the municipality is young.

In Santos Reyes Yucuna, there is a seasonal migration to large cities in Mexico (*i.e.*, Mexico City, Puebla, Oaxaca) and the United States. The main cause of emigration is the economic factor.

2.3.1. Governance

Governance between the communities of the municipality of Santos Reyes Yucuna is performed through customs and traditions [9], which determine the different social roles of men, women and children. Only men can apply for political and managerial positions in the municipality, while women and children are assigned household and agricultural land work. Members of the community coexist only with members who share the same religion, language and custom principles.

The social organization of Santos Reyes Yucuna originates in a communal setting that is demonstrated by several activities, such as [15,63]:

- *Guelaguetza*: This represents solidarity and cooperation that are granted in special situations between members of the population, such as weddings, births, funerals and other social events of the community;

- *Tequio*: Activities of community work. *Tequio* is a mandatory participation and implies social solidarity (*i.e.*, it is extensive to all of the neighborhood people without exception). It is organized and arranged by the municipal authority that exercises a strict control on assistance from neighbors. It is unpaid work for community improvement. Figure 1 presents some examples of *Tequio* activities related to building a house: men are in charge of the construction work, while women handle the preparation of food for all of the people;
- Land tenure: Land is communal, and it is distributed to each family living in the community. The land assigned to each family is intended to build a house, perform seasonal agriculture and to keep farm animals (mainly goats);
- Traditional medicine: The knowledge of traditional medicine based on medicinal plants is transmitted verbally from the older to the younger members (including children);
- Religion: Organization of the celebration of the patron saint of the community through the exercise of the Catholic religion.

Figure 1. *Tequio* for the construction of a house.

2.3.2. An Unknown Mixtec Variant

Santos Reyes Yucuna has schools for basic education (primary and secondary levels), and bilingual education is taught in Mixtec and Spanish. For this purpose, the Ministry of Education has provided free textbooks translated into the Mixtec language. However, these resources do not provide support for the real needs of the community, because the Mixtec language of the textbooks does not match the variant spoken by the people in Santos Reyes Yucuna. Hence, these resources are not used or understood correctly.

When this situation was addressed by an expert in Indian-American linguistics, Professor Gabriel Caballero Morales [64], it was identified that the Mixtec variant of Santos Reyes Yucuna was undocumented and unknown in the literature. Previous to the present work, no record or documentation had been performed about this Mixtec variant.

Because the Mixtec language is a tonal language, the meaning of a word relies on its tone. Because of the geographical dispersion of the overall Mixtec population, there are different tones,

pronunciations and vocabularies between communities. In some cases, these differences severely restrict the communication between communities [65,66]. A way to overcome this situation is to extend the knowledge of the different variants to accomplish a general understanding and translation between the language variants. However, for this purpose, the Mixtec variant of Santos Reyes Yucuna has an unknown status with no development of formal learning resources.

3. Development of MODELI

The proposed methodology is defined as MODELI (methodology for the design of educational digital objects for indigenous languages). This methodology is supported by the protocols of the spiral model [67,68], which is one of the prescriptive process models of software development [69]. Prescriptive or conventional models define (prescribe) a distinct set of activities, actions, tasks and work products that are required to achieve high-quality software. These activities may be linear, incremental or evolutionary. The spiral model is defined as an "evolutionary software process that couples the iterative nature of prototyping with the controlled and systematics aspects of the waterfall model" [68]. It is used when requirements are not well understood, new technologies are to be used and risks are high. Figure 2 presents the general framework of the spiral model, which consists of the following stages:

- Communication: The aim of this stage is to establish the means to accomplish effective communication between the developer (software engineer) and the user. This stage leads to obtaining the software requirements, defining the user profile, performing initial prototyping and proposing a development plan;
- Planning: In this stage, the required resources, project alternatives, timelines and other project-related information are envisioned. Risk analysis is performed to assess both technical and management risks;
- Modeling: This is the analysis and design of the elements of the software. In this stage, there is continuous communication between the developer and the user. Engineering tasks are performed to build one or more representations of the software;
- Development: The overall design, programming and testing of the software are performed at this stage;
- Implementation: In this stage, the software is tested with the user, and feedback is obtained to improve the design of the software.

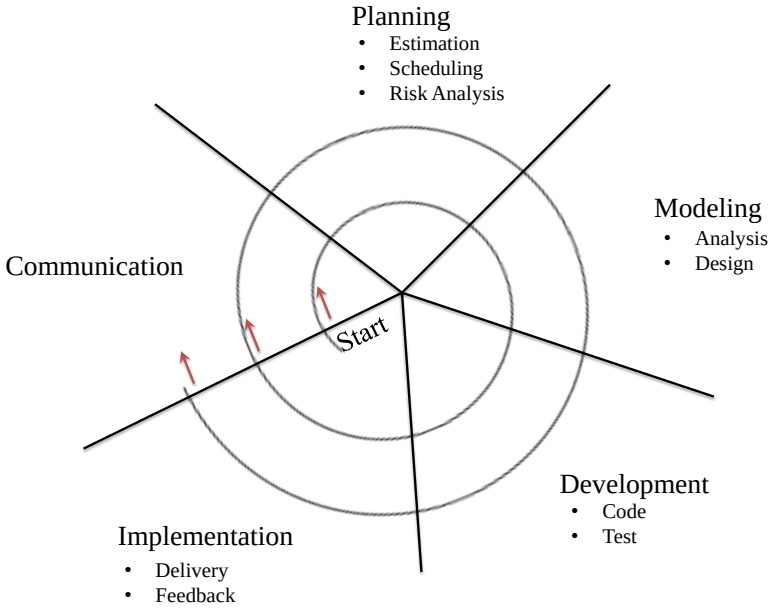

Figure 2. Spiral model of software development [68].

The spiral model is adapted into MODELI using the engineering levels presented in Figure 3. These levels represent the metamodel of MODELI:

- The user (person): To integrate the emotional factor within the SE process, it is necessary to determine the appropriate means to identify it and analyze it. For this purpose, Kansei engineering (KE) [70] was used to identify words with emotional "value" to develop the interface and operability of the DLO;
- The description of the elements that participate in the learning process (context): The pedagogical element is addressed by identifying the learning profile of the user (learning style), which is important to design the competencies and teaching-learning strategies for the DLO. For this purpose, Neil D. Fleming's VARK model [71–74] was considered;
- The coordination of these elements to generate the interactions to acquire the required knowledge (cognitive task): The requirements analysis and usability SE stages for the DLO are performed with the person and context elements.

The life cycle of MODELI, which integrates the stages of the spiral model is presented in Figure 4. The stages are organized in a similar form to the waterfall model. However, the dynamic characteristics of the spiral model are facilitated by the following key elements of MODELI: analysis of the user (person) and the community, instructional and emotional design through VARK and Kansei , validation and evaluation performed with ECOBA (*Evaluación de Calidad en los Objetos de Aprendizaje*, quality assessment of learning objects [75]). The elements integrated by MODELI can lead to the development of a functional ICT tool (in this case, the DLO) to support the learning task of an indigenous language. In Table 2, a description of each stage considering the approach of MODELI is presented. The phases and sub-phases of each stage are described in Sections 3.1–3.3.

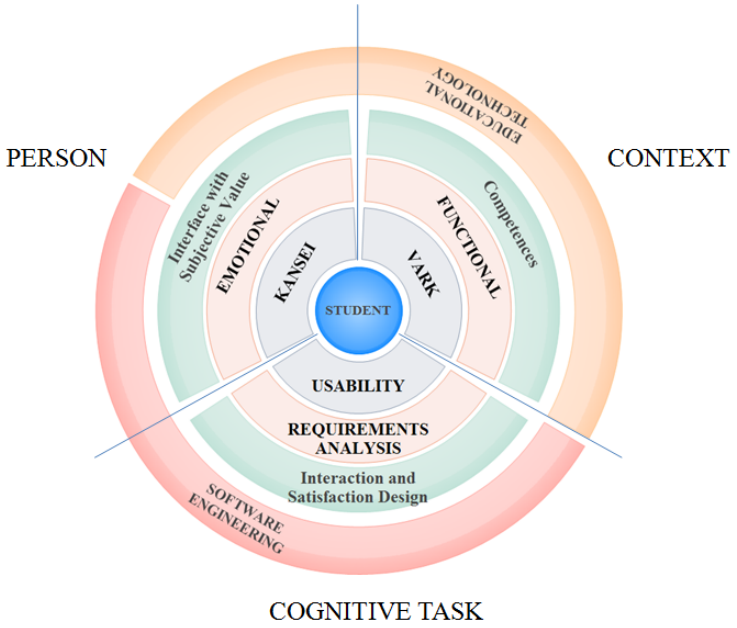

Figure 3. Engineering levels of the metamodel of methodology for the design of educational digital objects for indigenous languages (MODELI).

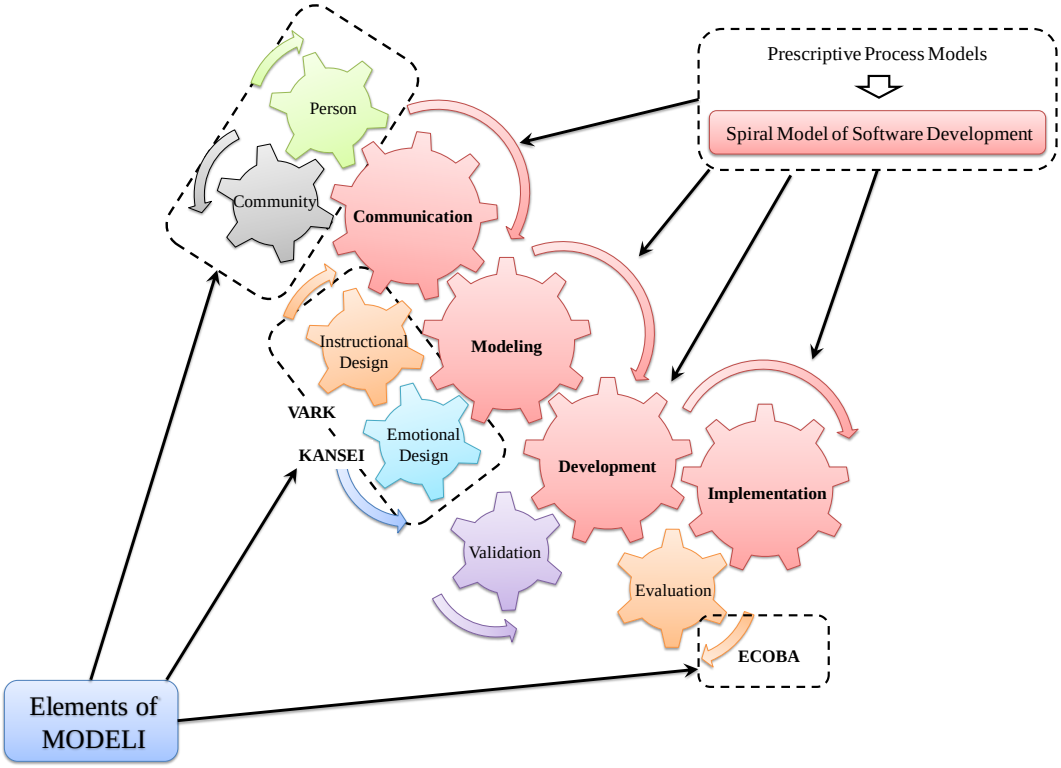

Figure 4. Life cycle of MODELI.

Table 2. Description of the life cycle of MODELI.

Stage	Phases	Sub-phases	Techniques and Tools
Communication	Analysis of the user (person) and the community	Cultural requirements Functional requirements	Interviews and case studies Data flow charts, Kansei
	Analysis of learning strategies	Definition of the learning style	VARK
	Project planning	Development plan Integration of multi-disciplinary team Conceptual scheme for the DLO	 Interface draft, Templates
Modeling	Analysis	Contents Competencies Interface	 Bloom's taxonomy Templates
	Design	Instructional design Functional design Affective and emotional design Interface design	Storyboard Kansei Semantic differential Norm UNE-71361, LOM-ES v1.0
Development	Codification and validation	Prototyping	Storyboard, PowerPoint/Flash, ECOBA
Implementation	Testing/evaluation	Usability	ECOBA
	Feedback	Learning performance Standards and metrics	Nielsen's usability rules

3.1. Communication

In this stage, the project initiation and the requirements gathering are performed. It involves communication among the customer (user), the ICT developer and any other person or team related to the technical and social contexts of the ICT project.

For the present work, this stage was very important and intense, because special social protocols had to be followed to start and maintain contact with the ethnolinguistic community. As presented in Section 2.3, the government of Santos Reyes Yucuna is based on customs and traditions. Thus, any contact attempt from an outsider must follow and respect the customs of the community. This has to be considered by the SE specialist and developers.

On the pedagogical side, it is important to identify the vocabulary and the contexts of use to define semantic fields for the language learning routines of the DLO. These contexts of use must be representative of the culture of the community.

Finally, the definition of the ICT's user and learning profiles are important for the instructional and emotional design of the DLO, which are addressed in the communication and modeling stages as presented in Figure 4. The MODELI phases and sub-phases of the communication stage are described in the following sections.

3.1.1. Analysis of the User (Person) and the Community

In Table 3, the sets of activities to perform the requirements analysis for the user and the community are presented. The coverage identifies the members (participants) of the development team and the objectives to be accomplished for a particular event that is aimed to obtain the cultural and functional requirements for the DLO. For each objective, there is a sequence of goals to be achieved with a set of activities.

Table 3. Requirements analysis: cultural and functional requirements.

Coverage	Sequence	Activities
Participant: Analyst requirements researcher. Event: Initiation of the SE project. Objective: Establish formal contact and communication with the ethnolinguistic community.	Understand the community's values and points of view in a thoughtful way. Integrate knowledge of various fields to establish relationships between community members and their daily lives. Maintain a respectful attitude towards the diversity of beliefs, values, ideas and social practices as well as towards multiculturalism.	The analyst must be presented formally to the community via local authority and/or institutional project. The formal authority can provide guidance and knowledge about the customs and traditions of the community. The working team is formed, establishing rules of operation and coexistence with community members. These rules must respect the customs and traditions of the community. Activity planning (schedules, work schemes, participants) must be approved and signed by mutual agreement.
Participant: Analyst requirements researcher and user. Event: Educational status Objective: Identify the main activities of the community for the most important contexts.	Identify: Work and recreational activities Craft activities Activities specific to the community Land work activities Household activities Transportation and public places Symbols and cultural values Celebrations Family roles	Through scheduled meetings with the users, a set of activities is developed to analyze the audio-visual perception of the social and cultural contexts. This is performed through drawings. Audio and written records of Mixtec words are performed for the vocabulary identified in the perception meetings.
Participant: Analyst requirements researcher and linguistics specialist. Event: Classification Objective: Classification of vocabulary words in semantic fields.	Analysis of the semantic fields. Phonological analysis of the Mixtec words in the semantic fields. Identify images associated with each word in the semantic fields.	Correct writing of the Mixtec words is verified by a specialist in linguistics. Then these words are translated into Spanish. Identify the phonological representation of each word. Create a database with the semantic fields and the phonetics of each word. Create a database with images attached to the semantic fields to provide meaning for each word.

As presented in Table 3, initially, there must be contact with the local authority instead of the members of the community. For this work, the contact with the authority was realized via the Coordination

of Activities of Local Community Development of the Technological University of the Mixteca [76]. Then, social integration with the community was gradually performed by participating in the activities presented in Section 2.3.1.

The profile of the user for the DLO was defined after social integration was achieved. The user of interest was defined as children and young adults within the range of six to 14 years old. This was defined to improve the identity and language retention within the young members of the community for future preservation. Then, the activities presented in Table 3 were performed with these users for the requirements analysis. During the interviews, the following contexts were identified as those with the most importance: land, home and family. Furthermore, the emotional factor and the learning strategies were studied during the interviews with the users.

For the emotional factor, Kansei engineering (KE) was used. KE aims at the development or improvement of products and services by translating the customer's psychological feelings and needs into the domain of product design. Hence, products designed under KE can bring forward an intended feeling. KE Type I (category classification) [77] was used to identify words with emotional value for the development of the DLO. Information about this process is presented in Section 3.2.2.

Figure 5 presents examples of drawings made by the users during the interviews and group activities. These drawings present information about the perception of the users regarding their social contexts. This perception is important to identify attitudes and emotional responses of the users and define the user profile. These drawings also contain some Mixtec translations.

Figure 5. Elements of the "land", "family" and "home" contexts.

3.1.2. Analysis of Learning Strategies

In Europe, the notion of "competence" has been popularized in the context of higher education. This concept is defined as "the knowledge, skills and attitudes required to perform a given occupation and the

ability to mobilize and apply these resources in a given environment successfully producing the desired result" [78]. This concept of competence integrates declarative knowledge and cognitive, affective, psychomotor and social skills and abilities. Competencies can be classified as [79,80]:

- Specific: a set of abilities and skills linked to a degree or vocational training (*i.e.*, discipline, professional and academic skills, language knowledge, project management);
- Generic: a set of abilities and skills necessary for employment and life as a citizen; these abilities are not linked to a particular degree or vocational training (*i.e.*, communication and abstraction skills, critical reasoning, ethics, creativity, collaborative work).

More details about specific and generic competencies can be found in [80]. However, the relevant aspect of this work is that many elements of these competencies overlap with those presented in the white paper (*Libro Blanco*) for language learning and translation of the National Agency for Quality Evaluation and Accreditation (*Agencia Nacional de Evaluación de la Calidad y Acreditación*, ANECA) in Spain [81]. Learning strategies to achieve or improve these competencies for language learning can be developed by considering the learning profile (style) of the student.

VARK is a tool designed by Neil Fleming in collaboration with Collen Mills [71], which provides users with a profile of their learning preferences or styles. The acronym VARK identifies the sensory modalities for learning:

- Visual (V): This mode describes a preference for the use of maps, diagrams, graphics, labels, hierarchies and other forms of graphical representations for written concepts;
- Auditory or aural (A): This mode describes a preference for information presented through the sense of hearing. The consideration of this mode allows the students to learn through lectures, tutorials, tapes, discussion groups, classroom lectures and web-based chats;
- Read/write (R): This preference involves reading and writing of texts. Often, people who prefer this mode use slide show presentation programs (*i.e.*, MS PowerPoint), the Internet, lists, faxes, dictionaries, quotations and words;
- Kinesthetic (K): This preference relates to the use of experience and practice (simulated or actual). It includes demonstrations, simulations, videos and movies from the "real" stuff, as well as case studies and practical applications.

Because the VARK model can integrate the four modalities, it is considered multimodal. The application of the VARK questionnaire [82] is the standard means to determine the mode(s) or predominant learning style(s) for a user. Table 4 presents an overview of the teaching strategies proposed for each learning style [74]. These were considered for the development of the DLO.

Table 4. Teaching strategies.

Visual	Auditory or Aural
Written instructions	Verbal instructions
Concept maps	Repeat similar sounds
Diagrams, models, summary tables	Debates, discussions and dialogues
Computer animation	Brainstorming
Videos, transparencies, photographs and illustrations	Read the same text with different reflections
	Guided reading and discussion
Use of gestures by the teacher	
Picturesque language	
Read/Write	**Kinesthetic**
One-minute writing tasks	Role play and dramatizations
Literary compositions, newspapers, blogs and reports	Group dynamics that require sitting and standing
	Use of the blackboard to solve problems
Production of reviews, reports and synthesis of texts	Handling of objects for explanation of phenomena
	Gestures to accompany the verbal instructions
Proofreading for colleagues and peers	

As part of the activities to be performed with the group of users, the VARK questionnaire was applied. In addition to the VARK questionnaire, the behavior of the users was considered, and it was found that the visual and kinesthetic modes were the predominant learning styles. Table 5 presents the overview of the user profile identified by the interviews and the VARK method together with the appropriate teaching strategies to be considered for the DLO.

Table 5. User profile for the DLO.

Age: 6–14 years old
Gender: female: 80%, male: 20%
Language:100% Mixtec speakers
Community: Santos Reyes Yucuna

Description:
-Children and teenagers of Santos Reyes Yucuna reconstruct the images of their environment (*i.e.*, redraw the images seen in their sociocultural environment).
-They give consideration to the use of their symbols and colors, such as the "heavenly bodies" (sun, moon, stars) and elements of their home and land.
- Their drawings have bright colors and their favorite colors are red, bright blue, yellow, gold, green, pink and purple.
- They are good observers and they are well organized as individuals and as a group. Their expressions and attitudes show their emotions, they like listening to stories, tales and legends, recreating themselves in scenes that they build in their mind with colorful drawings.
- They like to listen, however, they get impatient if this action goes on for a long time. They can stay focused on their activities regarding the presence of noise or other distractors.
Learning preferences:
Given the characteristics of the user profile and user behavior, the predominant learning preference (style) was identified as visual. The second learning style was identified as kinesthetic.
Strategy learning process:
Consistent with the learning preferences a teaching strategy focused on written instructions, transparencies, community contextual photographs and colorful illustrations is considered. For purposes of maintaining the interaction, direct manipulation of elements is considered for the interface of the DLO. The use of sound is also considered for the DLO.

3.1.3. Project Planning

In this phase, the integration of the multi-disciplinary team was performed. The team consisted of an SE specialist and a specialist in Indian-American linguistics, Professor Gabriel Caballero Morales [64]. Professor Gabriel Caballero provided support during the activities performed with the users as part of the requirements analysis process (see Table 3). During this process, it was identified that the Mixtec language of Santos Reyes Yucuna was a new (previously unregistered or undocumented) Mixtec variant.

Phonetic identification of sounds (pronunciations) was performed to write the language's vocabulary appropriately and to proceed to its documentation. An initial step to start the documentation of the vocabulary and the selection of the elements for the DLO was the identification of the main social contexts for the users: land, home and family [15].

For the purposes of designing an ICT tool as the DLO for language learning tasks, the specialist in linguistics recommended the use of word-based semantic fields for the representative vocabulary of each social context. Table 6 presents an example of representative words for the semantic field of the context

"land". Spanish and English translations of these words are presented together with the correct spelling in Mixtec.

Table 6. Elements of the semantic field "land": "animals in the field".

Picture	Spanish	English	Mixtec of Yucuna	Correct spelling
	Mosca	Fly	xicama	tyikama
	Aguila	Eagle	xaá, la'a xia	tyáa
	Ardilla	Squirrel	mutu	matu
	Avispa	Wasp	xiyaco	tyiyoko
	Borrego	Lamb	nanchi	mpee
	Vaca	Cow	xixiki	tyindyiki
	Burro	Donkey	buruu	vurru
	Zopilote	Buzzard	xiyokó	tiyoco
	Zorrillo	Skunk	xini	tiñi'in
	Chivo	Goat	xixúu, chishu'u	tyityáa
	Conejo	Rabbit	iluú	ilu
	Coyote	Coyote	xiguai	ndiwa'i
	Culebra	Snake	coó, ko'o	koo
	Gallina	Hen	chuxi	tyaxi
	Gallo	Rooster	xaxi	tyeli

Additionally, speech recordings were performed with the users of the pronunciations of the words of the semantic fields to keep a record of the Mixtec variant. At this point, an overview of the project

planning was envisioned. This overview is presented in Figure 6 and presents the conceptual abstractions that constitute the components and interactions occurring between processes and the people involved in the development of the DLO.

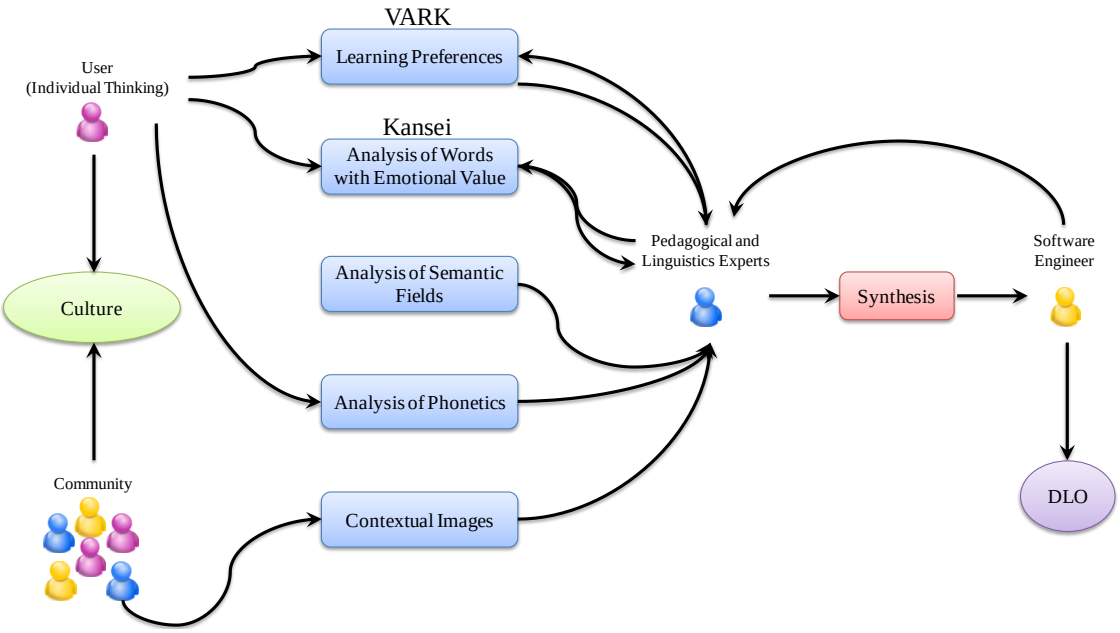

Figure 6. Conceptual scheme for the DLO: project planning.

3.2. Modeling

As presented in Figure 4, the stages of the life cycle of MODELI for the ICT tool interact with each other through the software development process. The analysis of contents, competencies and the draft of the interface are performed while the activities in the communication stage are realized.

More particularly, the modeling stage in its analysis phase is focused on answering the following questions:

- What is the content of the organizational structure of the DLO?
- What strategy should be followed for the learning process?
- What are the activities that the user should follow?
- What level of aggregation and structural granularity must the DLO have?

The learning object must have specific content to address these questions. For this purpose, MODELI consists of four design sub-phases (see Table 2):

- Functional design: This sub-phase identifies, analyzes and evaluates the Mixtec language considering the user profile and skills to acquire. The functional design is related to aspects of accessibility, navigation and usability-focused user training. The accessibility features provided by the standards of the web accessibility initiative (WAI) of the W3C agency (World Wide Web Consortium) are considered [83]. Likewise, the accessibility standards of the ICT UNE 139803:2012 norm for web content are considered [84,85];

- Instructional design: In this sub-phase, the systematic-pedagogical processes are applied to create an instructional environment with clear and effective resources to achieve the objectives and goals of the learning object;
- Affective and emotional design: This sub-phase is focused on describing the appearance of the DLO from the emotional and cultural perspectives that complement the cultural symbols and technical aspects of the learning object. This involves setting a screen template and establishing the "theme" or "image" of the DLO from the perspective of graphic design;
- Interface design: In this sub-phase, the structure and organization of the user interface of the DLO are described. The interface design involves designing a template for the interface and designing the script for the activities to be performed with the DLO.

Sections 3.2.1–3.2.3 present the details of these design sub-phases.

3.2.1. Functional and Instructional Design

The organization of the educative content for the LO was developed considering the features presented by [14,20,86] and the UNE-71361 norm LOM-ES (learning object metadata profile for the education sector in Spain) v1.0 for application profile [87]. The structural data of the DLO is documented with information related to: (1) name and academic objectives; (2) user profile (*i.e.*, academic level, geographic location); (3) model (*i.e.*, heterogeneous, complex, dynamic); (4) organizational structure (*i.e.*, atomic, collection); and (5) aggregation level (*i.e.*, basic purpose, learning object). Table 7 presents the template for the structural data of the DLO, defining and describing the information associated with each data field (*i.e.*, models and organizational structures) of the structural data.

Table 8 presents the description of the metadata categories for the DLO. The metadata are organized data describing the characteristics (*i.e.*, language, version, creation date, interactivity and difficulty levels, description of use) of the DLO. This enables fast retrieval of the LO from banks or databases of DLOs (see "interoperability" from Section 2.1). The organization of the metadata presented in Table 8 is based on the LOM-ES v1.0 standard [87].

Tables 9 and 10 present the "filled" templates presented in Tables 7 and 8 for the case of the DLO for Mixtec learning considering the semantic field "land" (animals in the field).

For the instructional design sub-phase, systematic pedagogical processes were applied to create an instructional environment with clear and effective resources to achieve the objectives and goals of the learning task. For this purpose, a template was created to guide the activities of the instructional designer. In this template, sets of properties and conditions for the curriculum coverage and didactic sequences were defined according to the cultural environment for the occurrence of certain events. Table 11 presents the template (format) for the instructional design of the DLO for the semantic field "land" (animals in the field). By understanding the information presented in this example, the format can be adapted for other semantic fields.

In the intrinsic conception of the DLO for the Mixtec variant of Santos Reyes Yucuna, three levels of abstraction were considered: global, thematic and specific. These levels enable the future modeling of extended content for a course and/or the unification of other thematic and specific learning objects. This is similar to the aggregation levels of the DLO presented in Table 7. However, while the aggregation

levels are related to its organizational structure, the abstraction is related to the management of the learning content.

Table 7. Structural data of the DLO.

Field	Description
Name of the DLO	Define the name of the learning object clearly and simply referring to the type of information contained in the DLO. It should be short (maximum 30 characters), clear and precise.
Author	Name of the author and/or co-authors of the DLO.
Institution	Name of the institution or entity that supports the DLO.
Objective and purpose of the DLO	Short description of the objective and purpose of the DLO. Define the knowledge or skill required to be achieved by the students when interacting with the DLO (*i.e.*, discipline, idea, educational skill, security level).
Academic level targeted by the DLO	The main academic context where the DLO will be used (*i.e.*, primary school or undergraduate).
Student profile to whom the DLO is aimed	This profile is closely related to the profile required by the course where the DLO is to be used (*i.e.*, ethnicity, manager, secretary).
Regional context	It must do reference to the time, culture, geography or region where the DLO will be applied. This is done to specify the extent of the content of the learning object. This includes the spatial location (name of the place and geographic coordinates), period (date or range of dates, name of the period) or jurisdiction (name of administrative entity).
Learning preferences	Identify the type of learning preference considered for the DLO as stated by the VARK model.
Learning competencies	Identify the learning competencies for the users of the DLO. The learning preferences and competencies must be consistent with the objective and purpose of the DLO and the curriculum coverage.
Relevant contextual and cultural factors	For the case study, it consists of factors or elements identified to induce an emotional response.
Objectives for curriculum coverage	It must specify the type of objective to be achieved. Only one can be selected based on Bloom's taxonomy. It must be consistent with the learning preferences and the type of competencies.

Table 7. *Cont.*

Field	Description
DLO model	The model is closely related to: - The functionality that indicates the roles of the structural components from the point of view of the teaching-learning process. These components are: previous assessment, concept maps, navigation map, learning activities and / or evaluation. - The estimated curricular coverage which indicates the set of contents to be created for the appropriate educational level. Based on the information unit to be handled, the DLO can be classified as: - Heterogeneous: It consists of various types of information units such as textual objects, images, e-books, multimedia objects, metadata. - Complex: Supports a single DLO aggregation with more than one component of any information unit. It can include URL references. - Dynamic: The DLO integrates associated methods that enable the user to interact with other types of information units (*i.e.*, real-time execution of video). - Semantic relationship: The DLO is aimed at applications in the semantic web, where a hierarchy of concepts with attributes and relationships is established. These define an agreed terminology to define a semantic network of interrelated information units.
Organizational structure	It indicates the elements that comprise the DLO (sound, text, images, animations, etc.) and defines the following types of structure: - Atomic: a single object that is indivisible (in this context). - Collection: a set of objects with no specific relationship. - Network: a set of objects with an unspecified relationship between them. - Hierarchical: a set of objects whose relationship can be represented by a tree structure. - Linear: a set of completely ordered objects.
Aggregation level	The aggregation levels define and organize the structural and functional granularity of a DLO. This granularity is related to the type of object and curriculum coverage (*i.e.*, the discipline and educational level). Therefore when defining the level of aggregation three variables are considered: structure, function, and estimated curricular coverage. In compliance with the LOM-ES v.1.0 norm, there are four levels of aggregation: - Level 1 (basic purpose): It is the smallest and may consist of multimedia elements or fragments. Such objects have an explicit function or a specific curricular coverage. - Level 2 (learning object): A collection of Level 1 learning objects (*i.e.*, a lesson). Functionally it is characterized as the smallest level with an explicit didactic function (instructional design). It includes one or more learning activities and its evaluation, and (optionally) concept maps and/or previous assessment systems. The estimated curricular coverage is one or more blocks of knowledge of a given course or cycle. - Level 3 (teaching sequence): A collection of Level 2 learning objects (*i.e.*, a course). Functionally it includes learning and/or assessment activities that are implicit in the objects of Level 2 and the concept maps that constitute them. Optionally it could include a navigation map or container for those objects of Level 2. The estimated curricular coverage is a sub-area of knowledge of a given course or cycle. - Level 4 (training program): This is the highest level of granularity and it may consist of a set of courses integrated into one educational resource for obtaining a degree. Level 4 objects are composed of Level 3 objects and, exceptionally, by Level 2 and Level 1 objects. Therefore, it may include a navigation map or a container of Level 3 objects. It may also be composed of other Level 4 objects recursively.

Table 8. Metadata for the DLO.

Category	Elements	Description
General	Title	Description of the name assigned to the learning object.
	Language	Language of the learning object.
	Description	Textual description of the contents of the learning object (this description does not have to be in the appropriate language and terms for users of the learning object).
	Key words	These words describe the main theme of the learning object.
	Author	Name of the author and/or co-authors of the learning object.
Life cycle	Version	Description of the version of the learning object.
	Institution	Name of the institution or entity that supports the learning object.
	Creation date	Date of creation or modification.
Educational use	Type of educational resource	It identifies the applied resource (*i.e.*, simulation, video, slides, exercise, questionnaire, narrative, self-evaluation, experiment, etc.).
	Interactivity level	Level to which the learner can influence the behavior or appearance of the learning object. Selectable scale from very low to very high.
	Semantic density	It is estimated according to its size and duration. It will be adjusted to the level of difficulty of the learning object.
	Level of the learner (user)	Main user for whom the learning object was designed (*i.e.*, teacher, author, trainee, manager, coach, etc.).
	Context	Principal or recommended environment where the learning object is to be used (first cycle, upper secondary, graduate).
	Difficulty level	Selectable scale from very hard to very easy.
	Typical learning time	Average (estimated) time needed by the average learner (user) to assimilate the content of the learning object.
	Description of use	Comments regarding how the learning object should be used.
	Language of the learner (user)	It identifies the language of the user of the learning object. It differs from the language of the learning object stated in the "General" category.

Table 9. Structural data of the DLO: semantic field "land".

Name of the DLO	**Animals in the Field**
Author	Olivia Allende Hernández
Institution	Technological University of the Mixteca
Objective and purpose of the DLO	This DLO is designed to strengthen competencies in the Mixtec language variant of Santos Reyes Yucuna. The topic of interest for the DLO is the semantic field of "land" where animals that live together in the field are presented. Interaction between the DLO and the student leads to the appropriation of the topic in the Mixtec and Spanish languages. In this DLO, audiovisual material as audio and pictures of local landmarks together with interactive exercises under the cultural context of the ethnic group are implemented. Discipline and basic computational skills are required.
Academic level targeted by the DLO	Primary school
Student profile to whom the DLO is aimed	Member of the ethnolinguistic Mixtec community (Mixtec speaker), 14–16 years old.
Regional context	Santos Reyes Yucuna, Oaxaca, Mexico.
Learning preferences	Visual and kinesthetic
Learning competencies	Generic competence: - Oral communication in the native language - Knowledge of a second language - Capacity for analysis and synthesis - Recognition of diversity and multi-culturalism - Teamwork and independent learning Instrumental competence: - Basic computational skills Specific competence: - Oral and written expertise of the native language
Relevant contextual and cultural factors	Language, color, affection and collaboration (elements identified from the *Tequio* activity).
Objectives for curriculum coverage	Cognitive learning (Bloom's taxonomy)
DLO model	Heterogeneous
Organizational structure	Hierarchical
Aggregation level	Level 2 (learning object)

Table 10. Metadata for the DLO: semantic field "land".

Category	Elements	Description
General	Title	Animals in the field
	Language	Mixtec and Spanish
	Description	Vocabulary of the semantic field "land"
	Key words	Animals, land, field, Mixtec language
	Author	Olivia Allende Hernández
Life cycle	Version	1.0
	Institution	Technological University of the Mixteca
	Creation date	July 2014
Educational use	Type of educational resource	Text, pictures, sound
	Interactivity level	Low
	Semantic density	Low
	Level of the learner (user)	Apprentice
	Context	Primary school
	Difficulty level	Very easy
	Typical learning time	15 minutes
	Description of use	Support for learning activities for the Mixtec and Spanish languages.
	Language of the learner (user)	Mixtec and/or Spanish

Instead of addressing the approach of the learning subject (content) as a whole, it can be decomposed into units of related study as defined by the abstraction model. Figure 7 presents the conceptualization of the global learning object for the DLO of the Mixtec variant of Santos Reyes Yucuna. Thus, each part of the content can be modeled by a DLO independently under the principle of digital support of the DLO and according to the following basic characteristics:

- Its purpose is to facilitate user learning;
- It is independent of other objects, because it has a meaning by itself;
- It supports a modular integration of growing hierarchy: it can be integrated with other objects to form a more complex object.

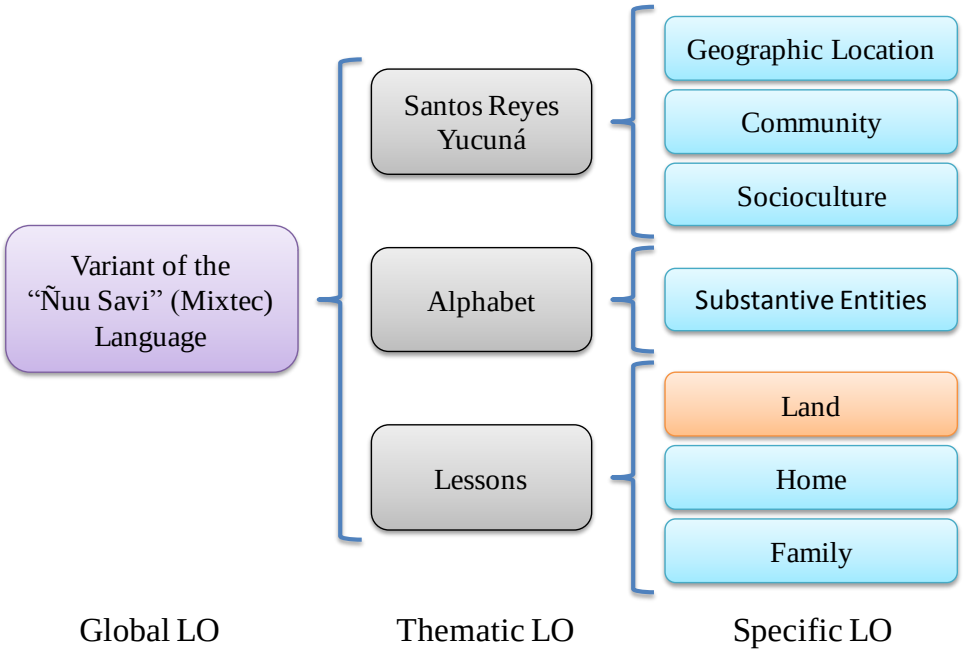

Figure 7. Conceptualization of the global learning object (LO).

The presentation of the content within the DLO then can be performed with didactic sequences. The structure of the didactic sequences for the learning object of "land" consists of a set of scenes that are classified as scenarios based on the real environment of the community of Santos Reyes Yucuna. This has the purpose of creating a motivational factor during the learning process of the student, who is the primary user of the DLO (as presented in Table 5, the student is six to 14 years old).

Table 11. Format for the instructional design of the DLO: semantic field "land".

Name of the DLO	**Animals in the Field**
Author	Olivia Allende Hernández
Pedagogical objective	Learn the pronunciation and written form of the names of farm animals in Mixtec and Spanish languages.
Educative context	Primary school/Santos Reyes Yucuna, Oaxaca, Mexico.
Type of DLO	Basic level
Aggregation level	Level 2 (learning object)
Didactic sequence	Basic primary school (6 to 14 years old children)
Competence or knowledge area of the DLO	Oral and written command of the native language.
TOPIC: Semantic field "land"	CONTENT: Mixtec and Spanish names of farm animals within the natural context of the user's community.

Curriculum Coverage	**Didactic Sequence**	**Resources**
Oral communication: - Active and comprehensive listening of the words of the semantic field "land" by hearing them in Mixtec and Spanish. - Representation of scenes of everyday life inspired by the accounts given by the user. Visual communication: - Recognize and visually identify the scenarios of the actual context. Reading: - Recognition of different types of scenarios from the environment of the users from illustrations and photographs. - Memorize the words related to the pictures of the context. - Reproduction of oral texts. Management of the language: Use in conversations and stories of the new words incorporated through hearing and writing texts. Management of technology skills: Interaction with the movement of the "mouse".	- Each screen presents a scene from the actual scene of the community of Santos Reyes Yucuna. - A specific situation is set where images illustrating the scene are presented with words significant to the user. - Intuitively the user places the cursor on the artifacts (scene elements) activating the sound to hear the question "What is its name?" that starts the activity. The Mixtec and Spanish words are presented in written and audio form. - The user can choose to explore all the pictures of the animals on the scenario, listening to the phonetics, and viewing the written form of each presented animal. - The user can use the navigation tool of the DLO to continue the teaching sequence and change the scenario, acquiring knowledge of significant new words. - The user can terminate his/her learning activity through the exit icon of the application.	Computer with Windows operating system (OS Version 8.0 or above). Mouse or keyboard.

The teaching or didactic sequences for basic education (primary and secondary school) are based on the user's everyday environment. These are related to each other by the continuity of the sequence of images/pictures of farm animals and community settings (samples of the interface with these elements are presented in Section 4). For this reason, the interactivity level is considered as low. In each scene

of the didactic sequence, language is presented through the voice of men and women from the native community. The orthography for each word is presented in both Mixtec and Spanish languages.

The importance of the instructional design is that it establishes the guide to define the didactic sequences within the DLO. The instruction is met in three phases defined as previous conditions, operating procedures and results [88]. Previous conditions are related to the initial behavior of the user that is determined by the teacher before the beginning of the instruction itself. Furthermore, the specific learning objectives must be described to the users (students) to inform them about the skills or knowledge that are expected to be acquired by them after they use the DLO. This is done to identify: (1) what the student should be able to do after the learning activities with the DLO are accomplished; and (2) what the student was not able to do before these activities were accomplished. The operating procedures consist of the didactic sequences of the DLO together with the interaction between its elements and the user. The consistency of the specific learning objectives with the learning activities forms the basis for the assessment phase.

3.2.2. Affective and Emotional Design

Emotion is an experience with many dimensions, and it has at least three or more response mechanisms: behavioral-expressive, physiological-adaptive and cognitive-subjective. Feelings, emotions and meanings play an important role in the design of the interface objects produced by software engineering (SE) [51]. The integration of such factors in product development involves changing the approach of the functional requirements to the emotional needs of the users.

The idea of considering cultural factors through the emotional factor in the design of the interface does not only involve obtaining a media device with functional and practical value for the learning process. It also considers that the device can have affective properties to provide the end user sensations and even self-esteem. However, this is not a reason to set aside the functional properties; although these are not perceived as attractive attributes, these are considered to be implicit characteristics of the DLO.

Emotional design studies the interactions between the user and the product, focusing on the relationships between the physical traits and their emotional influence on the user. The goal of the emotional design is achieved during the user experience process when people interact with the objects and get an impression [89].

In this work, to integrate subjective cultural values through emotional factors within the learning object, the adaptation of Kansei engineering (KE) and the semantic differential (SD) method has been performed. This is consistent with the premise that, when words intended to convey certain meanings are expressed, two conceptual dimensions of value are acquired:

- denotative, which refers to the meaning found in dictionaries; and
- connotative, which refers to the personal perception of the concept/meaning.

For the present work, Kansei engineering type I (KE-I) was considered. In KE-I, there is a manual identification (with the support of surveys aimed at the target market segment) of relations between affective needs and product characteristics [70]. Within the context of product development, Kansei is defined as the "impression a person has about a particular device, environment or situation using his/her senses of sight, hearing, touch, smell and cognition" [90]. While Kansei can be translated

as "feeling", there are two other concepts associated with this word: Kankaku ("sense") and Kannou ("sensation"). Hence, Kansei is the "feeling" generated by the cognitive processing of a set of "sensations" (emotions). When an external stimulus is captured by the user's "senses", it is processed based on the experiences, expertise and knowledge of the user. This generates a response called "feeling" (conscious or unconscious), which results in images or subjective impressions. How these concepts are related to each other can be explained by the following example:

- if a consumer wants or desires to eat, the motive or concept can be described as "food";
- the feeling (Kansei) for that concept can be described as "tasty";
- attributes as "spicy" or "sweet" are sensations (Kannou) related to the feeling of "tasty";
- the attributes are perceived by the "sense" (Kankaku) of taste;
- physical properties associated with each attribute can be identified.

Table 12 presents an inventory of Kansei, Kannou and Kankaku words obtained with KE-I for the graphic elements of the DLO. This method was performed in three main steps [70]:

- Collection and quantification of the user's response in Kansei terms (psychological evaluation). This step was performed in two procedures:
  - Identification of emotional needs: This procedure was performed at the beginning of the project. Through the technique of "brainstorming" with the group of users (see Section 3.1), the subjective needs that should inspire the DLO were identified. The main needs were identified as "attraction", "beautiful" and "identity";
  - Validation of emotional content: This procedure was performed during the validation process of the DLO. Using the format ECOBA of aesthetic and functional design" [75] and Kansei engineering (see Table 12), the perception of the DLO was obtained to collect data to provide the subjective character to the interface in its terminal phase.
- Identify the design features for the product (*i.e.*, the DLO) from the user's perception: For this step, 30 children from the municipality of Santos Reyes Yucuna were surveyed to define the characteristics and cultural attributes for the design of the interface. These characteristics are presented in Table 13.
- Implementation of the tool considering the previous data: The tree structure presented in Figure 8 allows hierarchization of the attributes granted to the Kansei value (in this case "attractive"). Then, based on the analysis of the data obtained in the previous step, a "storyboard" is designed (see Section 3.3), creating the DLO prototype with the attributes that form the category detected by the user as a subjective factor. Similarly, the degree of significance of the Kansei value and the required attributes to build the DLO are presented in Figure 8 for "attractive".

Table 12. Domain of words with Kansei value.

Kansei Category, Motive or Concept	Kansei (Feeling)	Kannou (Sensation)	Kankaku (Sense)	Physical Properties
Images	Attractive	Joy, motivation	Sight	Color, intensity, clarity, texture, contour
Audio	Perception	Motivation, action	Hearing	Intensity, tone, accent
Titles	Attractive	Motivation, action	Sight	Font
Color of the header menu	Attractive	Motivation, action	Sight	Tone, saturation, luminosity
Color at the bottom of the menu	Attractive	Motivation	Sight	Tone, saturation, luminosity
Facial expression	Attractive	Joy, happiness, confidence, motivation	Sight, hearing	Tone, luminosity
Context color	Symbolism, expressivity	Harmony, contrast	Sight	Tone, saturation, luminosity
Dominant theme	Expressivity	Joy, happiness, confidence, motivation	Sight, hearing	Tone, saturation, luminosity
Font size for the header	Attractive	Motivation	Sight	Color, thickness
Text of the main menu	Attractive	Motivation	Sight, hearing	Size, thickness, color
Color of the main menu	Attractive, symbolism, expressivity	Joy, motivation	Sight	Tone, saturation, luminosity
Main font style	Attractive	Motivation	Sight	Size, thickness, color

Table 13. Attributes and cultural value.

Element	Description
Attribute	Color, space, light, celebrations, music (sound), stewardship, *Guelaguetza* (cooperation), *Tequio* (collaboration), unity, fraternity, equality.
Value	Attractive, adorable, satisfaction, pretty, beautiful, good, bad, ugly, boring, trust, tender, sweet, surprise, joy, serious, annoying, friendly.
Colors	Red, purple, pink, yellow, gold, green, blue, black.

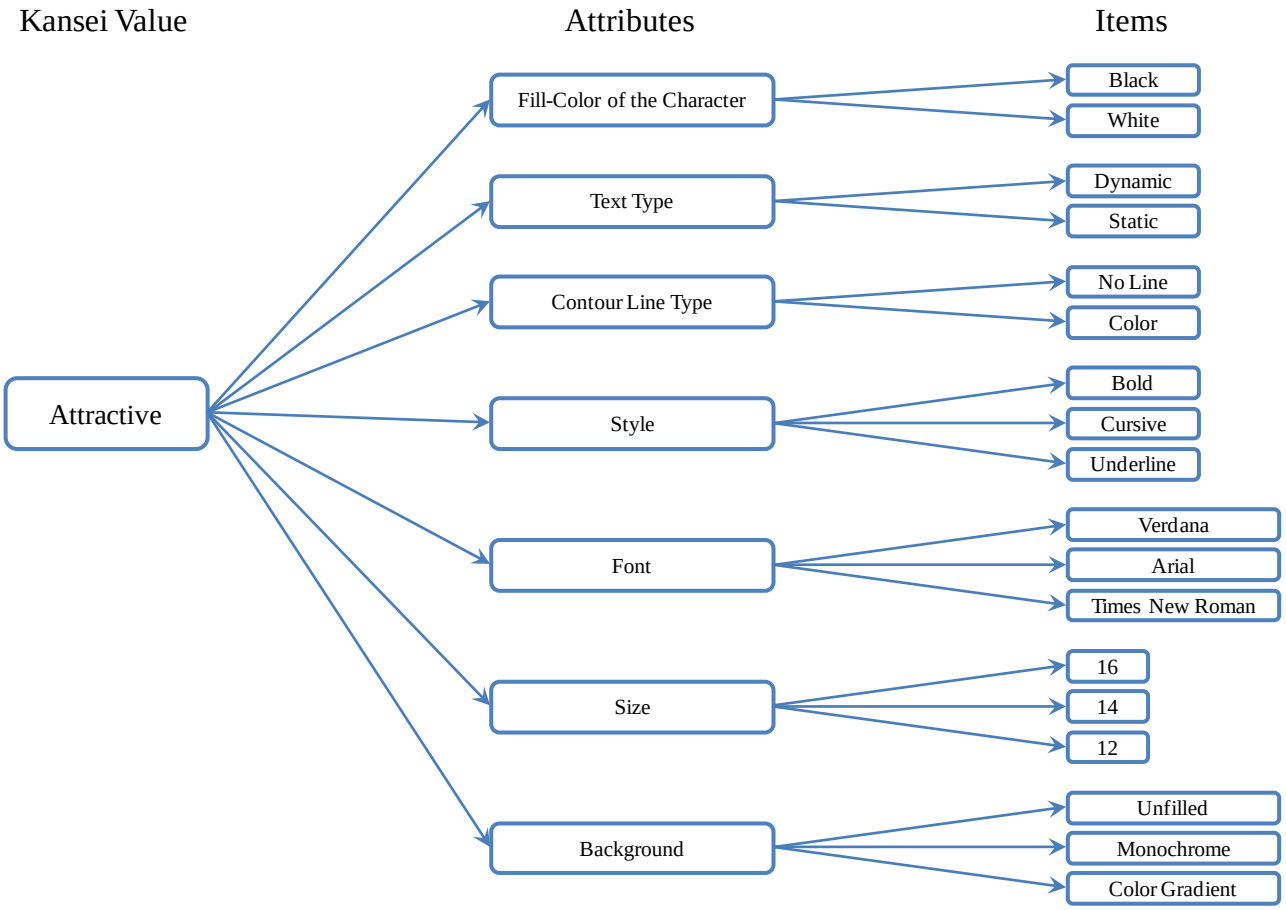

Figure 8. Attributes for the Kansei value "attractive".

3.2.3. Interface Design

During all stages of MODELI, there is a sub-phase of prototyping of the DLO. The prototypes were generated through "storyboards" using PowerPoint software. The new data that were obtained from the users during each stage and phase of MODELI were integrated into the prototypes in order to recursively perform evaluation and correction of the DLO.

Particularly, the interface design sub-phase was developed in parallel with the data of the instructional and affective/emotional design sub-phases. The interface design sub-phase also forms part of the

development and implementation stages of MODELI. More information about the interface and the evaluation are presented in Section 4.

3.3. Development and Implementation

In this stage, the technical development process of the DLO is performed. It consists of the selection and use of software tools for prototyping, development and evaluation of the final product. For the development of the DLO for the semantic field "land", the integration with other media besides programming support and the mean for the adaptation of inference rules was considered.

Macromedia Flash has the required features for this purpose, because it can be adapted to (and it can integrate) various multimedia elements, such as text, image and audio. This tool was used to create the prototype of the final learning object.

An important aspect of the development and implementation stages was the inference rules that coordinate conditions and actions for the functionality of the DLO's educational sequences. The adaptation of the inference rules for the learning process is based on the ECA (event condition action) rules or "production rules" [91]. In general, the rules can be described as instructions that activate an action or set of actions if a condition (or a combination of conditions) or if an event (or a combination of events) occurs. Table 14 presents some inference rules established for the DLO.

Table 14. Inference rules: **IF** <condition> **THEN** <action>.

Event: The user selects an element of the interface (*i.e.*, the picture of a farm animal). **- Rule**: **IF** the user moves the cursor over the picture **THEN** the phonetics of the element (pronunciation of the name of the animal) and text (written name of the animal) are activated.
Event: The user chooses to advance the lesson and to go to the next scenario. **- Rule**: **IF** the user presses the "SIGUIENTE" button (NEXT) **THEN** display the next scenario of the application.
Event: The user chooses to return to the previous scenario. **- Rule**: **IF** the user presses the "ANTERIOR" button (PREVIOUS) **THEN** display the previous scenario of the application.
Event: The user chooses to leave the application. **- Rule**: **IF** the user presses the "SALIR" button (EXIT) **THEN** close the application and finish the process.

4. Results and Discussion: DLO Prototypes and Evaluations

The DLO presented in this section is focused on the semantic field "land" with sub-context "animals in the field". MODELI can be applied to the development of other DLOs (*i.e.*, home, family) with the associated sub-contexts.

4.1. Initial Prototype

Through the technique of "storyboards" and with the support of PowerPoint software, an initial DLO prototype was developed. Figure 9 presents this prototype for the semantic field "land". This prototype was developed to assess the impression of the interface on the users with the considered preliminary features at the affective and emotional level. The DLO is used as described by the inference rules presented in Table 14. Disclaimer: The characters presented in Figure 9 are the copyright, trademark and property of Disney Enterprises. The image used in Figure 9 was only used for academic prototyping and initial observations.

The evaluation process was performed through recognition of the facial expressions of 18 test users (six to 14 years old children) [57]. The observations regarding this evaluation are presented in Table 15, while Figure 10 presents the complete range of emotions that the test users were able to experience with this prototype. As presented in Table 15, the expressions observed in the users represented the emotional feelings of "joy", "surprise" and "tenderness". The initial prototype was pleasant to use and visually attractive for the users (it was described as "beautiful"). For Figure 10, the users were asked to measure their impression from "none" to "a lot" for each emotion. Some users did not answer, as they did not feel the emotion as in the case of "disgust" and "contempt". While the users mainly expressed happiness (joy, pretty, beautiful) and a sense of excitement, there was an evident lack of the sense of "identity". This was expected, because the pictures of the interface consisted of commercial cartoon characters.

Figure 9. Didactic sequence of the initial DLO prototype: "animals in the field".

Table 15. Recognized expressions and emotions in test users with the initial DLO prototype.

Recognized Expression	Representation of the Emotional Feeling	Description
- Brightness in the users' eyes, smiles. - Words expressed in the Mixtec language for "beautiful". - Contraction of the zygomatic muscle.	Joy	The users radiate warmth and a strong sense of happiness. It was pleasant to their eyes.
- Upper eyelids pulled up and mouth hangs open.	Surprise, tenderness	Emotionally it caused amusement.

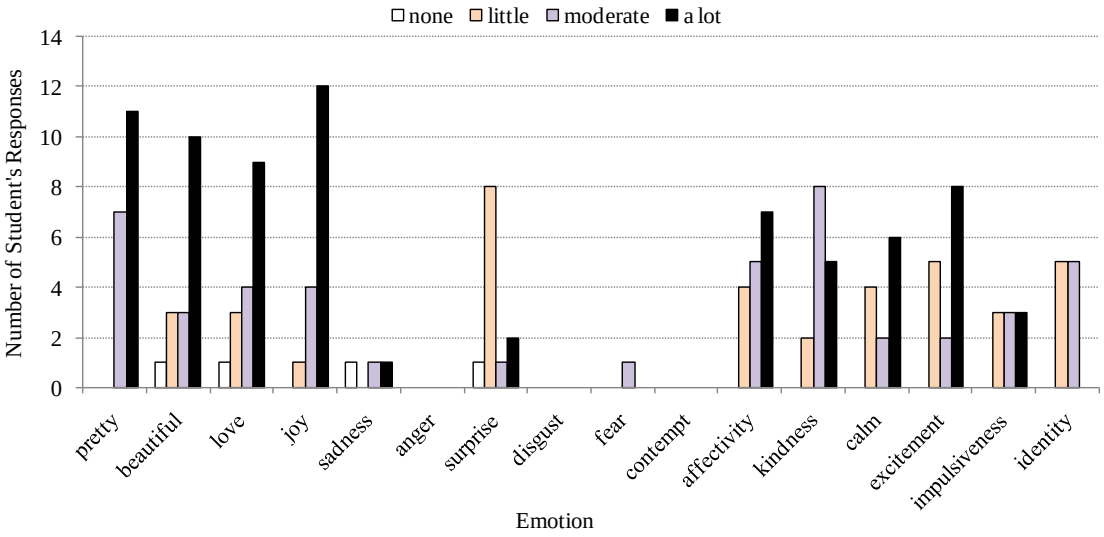

Figure 10. Emotional impact of the initial DLO prototype on the users.

4.2. Final Prototype

The final DLO prototype was developed with Macromedia Flash software, and as presented in Figure 11, it considered elements from the actual environment of the users. Furthermore, the integration of colors that were emotionally significant for the users was presented within the DLO's interface: copper symbolizes the color of the earth/land, yellow represents the radiant Sun, green represents hope and their plants and crimson red is the traditional Mixtec color. The "Mixtec Song" (*Canción Mixteca*) was considered as background music for the main entrance of the DLO. This song, written by Oaxacan composer José López Alavez in 1915, has become an anthem, both for the region of Oaxaca and Mexican citizens living abroad who miss their homeland [92].

As presented in Figure 11 the DLO for "animals in the field" (context "land") was created considering a set of scenes from the real life of the users, including actual landmarks of Santos Reyes Yucuna. Multimodal features provided representations of the Mixtec vocabulary associated with the context. The users (six to 14 years old children) enthusiastically recognized the pictures (images) presented on the interface. By moving the cursor and pressing any of the elements presented in these scenes, the user could read its name and hear it with native Mixtec pronunciation (see Table 14).

In Table 16 and Figure 12, the results of the evaluation of the final DLO prototype for "animals in the field" are presented. In comparison with the initial prototype, the expressions of the users involved an identification of places and people within the DLO. The emotional feeling of "joy" was more significant, as there was an "identity" feeling, and there were verbal expressions of this feeling. In Figure 12, the users' responses for "beautiful", "love", "joy" and "kindness" were more equally distributed between "moderate" to "a lot". Particularly, the number of responses for "sadness" increased. This was identified to be related to nostalgia. The sense of "surprise" decreased to "none" and "little", and there were two cases of "little anger". However, the number of users with the sense of "identity" increased to "a lot". As for the emotional, affective and functional factors, these events can facilitate collaborative and participatory learning under the scheme of cultural identity. Nevertheless, the "anger" response has to be explored in future work.

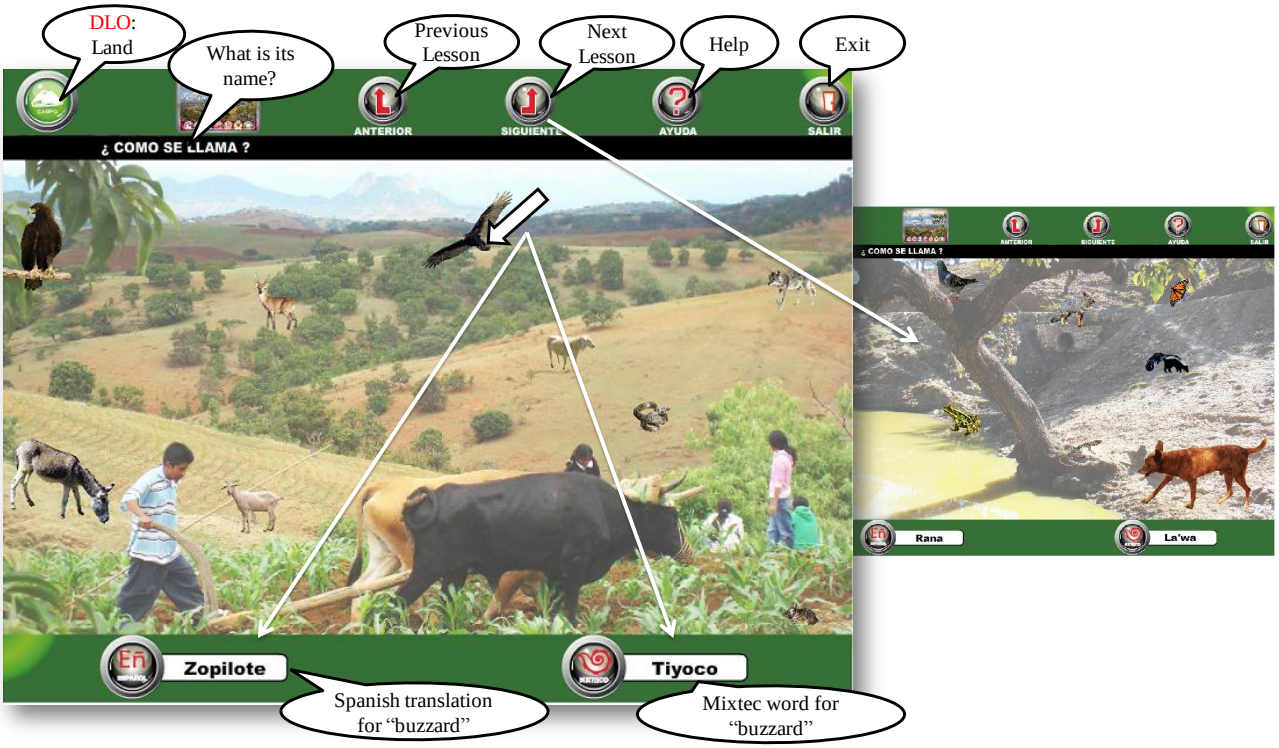

Figure 11. Didactic sequence of the final DLO prototype: "animals in the field".

Table 16. Recognized expressions and emotions in test users with the final DLO prototype.

Recognized Expression	Representation of the Emotional Feeling	Description
- Brightness in the users' eyes, smiles. - Words expressed in the Mixtec language for "beautiful". - Contraction of the zygomatic muscle.	Joy + Identity	Representative images were taken from the social contexts of the community. Users expressed joy and felt identified with the places, animals and people showed in the images (pictures).
- Upper eyelids pulled up and mouth hangs open.	Surprise, tenderness	Emotionally the representative images caused amusement and surprise.
- Verbal expression of identity.	Identity	There are representative images that transmit values, cultural symbols and knowledge (*i.e.*, work, land). There were explicit expressions of identity.

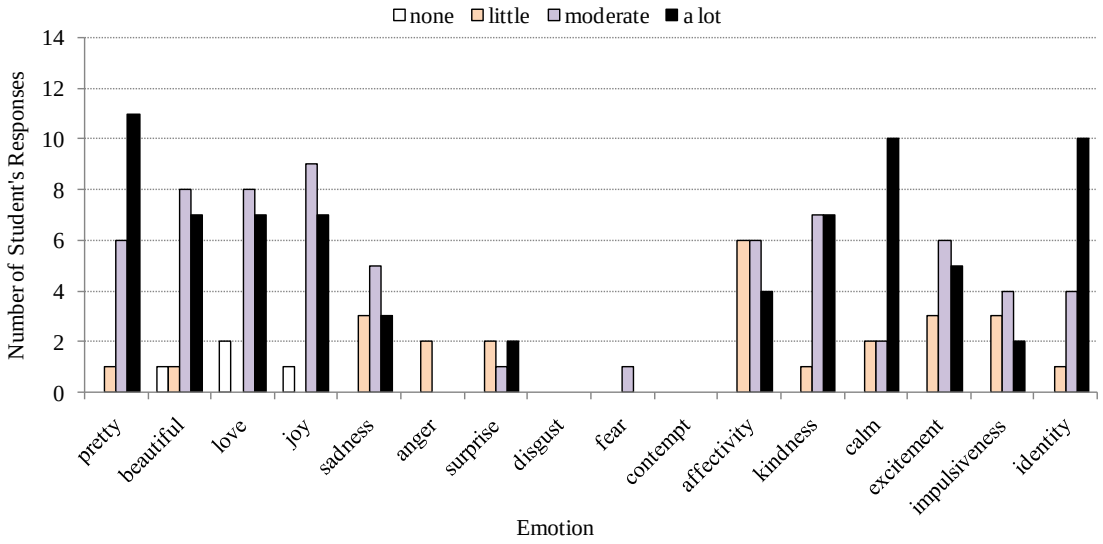

Figure 12. Emotional impact of the final DLO prototype on the users.

4.3. Evaluation and Pedagogical Usability

Because MODELI is a user-centered design (UCD) methodology, the ethnic group was very important in all of the development stages of the DLO. Regarding the DLO's usability, this is closely related to the UCD methodology to obtain a usable product. In accordance with the ISO 9241-11 standard, usability is defined as "the extent to which a product can be used by specified users to achieve specific goals with effectiveness, efficiency and satisfaction in a specified context of use"[93].

The development team evaluated the usability of the DLO with the support of the heuristics of Jakob Nielsen [94]. For this purpose, the five main basic attributes of usability were identified: learnability, efficiency, retention through time, error rate and subjective user satisfaction. A questionnaire was developed to evaluate each of these attributes with the following criteria: "no (never)", "sometimes" and "yes (always)". A score of "0", "1" and "2" was assigned to each criterion respectively ("2" being

the most favorable score). After assessing the responses of the test users, the data were converted into percentages. The results are presented and discussed in Table 17.

Following the usability evaluation of the DLO under Nielsen's approach [94] and considering the pedagogical aspect of social constructivism [95], the term "pedagogical usability" is conceived for this study as "the degree of efficiency of the interactive learning process through which the user achieves the pedagogical tasks effectively and satisfactorily". Under constructivism, the zone of proximal development (ZPD) is defined as the length of the actual developmental level as determined by the ability to independently solve a problem [95]. The interaction with the DLO allows the individual or collective achievement of pedagogical tasks. Furthermore, a meaningful learning [23] is encouraged given the cultural nature of the DLO, which enables the user to assimilate new information based on prior knowledge. This fact, together with the integration of cultural elements of the user in the interface of the DLO, stimulates the user's emotions, generating an intrinsic motivational factor [96], which culminates in the satisfaction for learning. Kansei engineering (KE), together with the semantic differential (SD) method, enabled the identification of the emotional needs of the users as presented in Table 12 to establish a prediction model to meet the emotional needs required as characteristic attributes of the product.

Finally, the guidelines given by ECOBA [75] for the assessment of learning objects were applied. This evaluation was performed interactively during the development of the DLO prototypes to be continuously improved. ECOBA presents a generic form of assessment applicable to any DLO based on the veracity of the contents and the inclusion of student participation in the learning process. According to ECOBA conversions, evaluation and quality assessment are performed by weighting a number of criteria and includes three main aspects of evaluation: educational content, usability and functionality. In applying ECOBA with these criteria, the following conclusions were obtained about the DLO:

- For learning and accuracy of the content, the DLO was considered as "very good";
- For aesthetic, functional and instructional design, as well as assurance of competencies, the DLO was considered as "good".

Therefore, it is possible to assert that MODELI has been tested and applied for the prototyping of a DLO (specifically, "animals in the field"), which has been approved and accepted by the end user.

Table 17. Results of the usability evaluation of the final DLO prototype ("animals in the field") under Nielsen's attributes.

Usability Attributes	Yes (always)	Sometimes	No (never)	Description
Learnability	92.30%	7.70%	0.00%	Intuitively the user learned to use the application. The users expressed the sentence "it is easy". The evidenced learning, together with the positive users' comments, became relevant because the users had no previous contact with the DLO.
Efficiency	84.60%	15.40%	0.00%	The user successfully took the mouse, observed the interface, correctly identified and selected the elements placed at the DLO's interface. The user reached a high level of productivity, and the efficiency was even greater since the application is bilingual.
Retention through time	100.00%	0.00%	0.00%	Having stopped using the DLO for a period of 15 days, the user remembered the aim and use of the learning object.
Error rate	69.20%	23.10%	7.70%	30.80% of errors made by users occurred in children whose age range was six to eight years. Failures occurred when the users wanted to end a session. This highlighted the need for an indicator of feedback for progress and error.
Subjective user satisfaction	100.00%	0.00%	0.00%	The application has a friendly interface, with a cultural basis of ethnicity which generated a positive, pleasant reaction of identity. Users expressed satisfaction and comfort in the interactive process exclaiming phrases like "I like it!", "It is my house!", "It is Yucuna!". Listening the phonetics (pronunciation) of words brought smiles on the users (children). This was a clear manifestation of user satisfaction.

5. Conclusions and Future Work

In this paper, the creation of a methodological model for the design of digital learning objects (DLOs) for sustainability of the Mixtec language through the emotional factor was presented. This methodology, termed MODELI, is based on the prescriptive models of software development, and it was evaluated through the creation of a DLO prototype for the semantic field "animals in the field" within the context "land". The initial analysis of the phonetics and semantics of the words identified within the context "land" led to identifying the Mixtec language variant of the community of Santos Reyes Yucuna as a new variant.

Through the lifecycle of MODELI data, parameters, characteristics, qualitative and subjective attributes of the object of study of the community of Santos Reyes Yucuna were obtained. The DLO's assessments by ECOBA and Nielsen's attributes support the feasibility of MODELI for the objectives

defined by the present work. The DLO has features, such as: multimodal, specific degree of granularity and easy degree of difficulty.

The multimodal content of the DLO, which as presented by MODELI, is based on cultural and emotional elements, involves an intrinsic motivation factor to generate a sense of pleasure in executing the teaching tasks (didactic sequences). As presented in Figures 10 and 12, the inclusion of the cultural factor is important to highlight the values and emotions related to the "identity" that will have the greatest impact on the preservation of the language in the younger generations. Children were the most interested users in learning to write the Mixtec language, as well as the manifestation of their interest in acquiring technological skills.

Because there are more than 32 variants of the Mixtec language, MODELI can be applied for the development of DLOs for these Mixtec variants. Similarly, the same outline scenarios for teaching and learning may be used as templates for the different variants as presented in Figure 13.

Figure 13. Template of didactic sequence (scenario).

This work also demonstrates the need for an interdisciplinary team committed to assisting in the creation of a database of DLOs to mediate the learning and preservation tasks for the language with this tool, especially for unknown language variants. The absence of experts for variants of the Mixtec language makes it difficult to identify the semantics and phonetics for the development of DLOs for the purposes of language learning. This has to be considered by the software developer. Furthermore, given the governance based on "customs and traditions", it is essential for the researchers to achieve social inclusion within the Mixtec communities through "*Guelaguetza*" and "*Tequio*".

As future work, the following are considered:

- Create a website with cultural aspects of the Mixtec people. This website can have support for an online learning platform based on DLOs and may also serve as a container of digital learning objects;

- Assign categories for elements, such as farm animals and birds, mammals, reptiles, *etc*., that generate a perception of context for other DLOs;
- Create a concordance between such elements and the emotions that these may generate;
- Generate other semantic axes for learning of the Mixtec language;
- Document and catalog the pronunciation and spelling/writing of the Mixtec language variant through other cultural sources, such as legends, stories, myths, *etc*., from the community under study;
- It was unexpected to have found that the population had mobile phones for communication and satellite television for entertainment. However, this provides a guideline to consider future work through the development of educational applications aimed at strengthening the Mixtec language through mobile devices;
- More in-depth studies are required regarding the elements that contribute to the influence of subjective values into the design of the interface under the scheme of Kansei engineering. The link between Kansei and design elements is the greatest challenge of the study.

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Author Contributions

The main research was performed by Olivia Allende-Hernández as part of her Masters Thesis in Software Engineering. Santiago-Omar Caballero-Morales provided guidance for the masters thesis and performed drafting, Spanish to English translation and revision of the present paper.

Conflicts of Interest

The authors declare no conflict of interest.

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