

# Pedagogical model to develop virtual learning objects for people with hearing impairment

Karen Martinez-Zambrano, Jhon Paez and Hector Florez

Universidad Distrital Francisco Jose de Caldas, Bogota, Colombia

## Abstract

Information and Communication Technologies (ICT) have become very important for the educational system thanks to the development of Virtual Learning Objects VLO. Nevertheless, when VLOs are used by students with hearing impairment, they must be designed considering inclusive design conditions to ensure proper interactions. Thus, students with specific disabilities might use VLOs to facilitate their learning processes. Then, in this paper, we propose an approach to the conceptual design of a model for the technological, pedagogical, and cognitive articulation that can be implemented in the construction of a VLO.

## Keywords

Pedagogical Model, Virtual Learning Object, Design Conditions, Sign Language

## 1. Introduction

Information and Communication Technologies (ICT) have been incorporated into the educational system through the development of Virtual Learning Objects VLO, which are tools that can facilitate the teaching process in the educational community. However, VLOs do not normally consider inclusive design conditions such as language and didactic structure. The absence of these conditions are causing difficulties in the development of skills that can occur in communities with some type of disability, such as hearing impairment.

The interaction between a person with a hearing disability and VLOs is essential to improve cognitive processes by developing and strengthening learning skills in different areas of knowledge. When this interaction is not carried out properly, the potential of technological tools may be wasted. As consequence, students with hearing disabilities could generate several deficiencies while learning in different areas of knowledge such as mathematics.

In this way, this work proposes a conceptual model which merges technological, pedagogical, and cognitive principles that can be considered in the construction of a VLO to help to mitigate the difficulties that arise in the teaching processes of one mathematics area which is Euclidean geometry.

This work is structured as follows. Section 1 shows the theoretical framework, which explains the relevant concepts associated with the technological, cognitive, and pedagogical-didactic

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*ICAIW 2021: Workshops at the Fourth International Conference on Applied Informatics 2021, October 28–30, 2021, Buenos Aires, Argentina*

✉ [kbmartinezz@correo.udistrital.edu.co](mailto:kbmartinezz@correo.udistrital.edu.co) (K. Martinez-Zambrano); [jjpaezr@udistrital.edu.co](mailto:jjpaezr@udistrital.edu.co) (J. Paez); [haflorezf@udistrital.edu.co](mailto:haflorezf@udistrital.edu.co) (H. Florez)

ORCID [0000-0003-2223-9883](https://orcid.org/0000-0003-2223-9883) (J. Paez); [0000-0002-5339-4459](https://orcid.org/0000-0002-5339-4459) (H. Florez)



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CEUR Workshop Proceedings (CEUR-WS.org)

context. Section 2 presents the related work, which has been developed through a conceptual analysis of the position of different authors to compile the research carried out. Section 3 presents our approach to the conceptual design of a pedagogical model made up of the components of the technological, cognitive, and pedagogical-didactic context. Section 4 discusses the results. Section 4 exposes the future work. Finally, section 5 concludes the work presented.

## 2. Background

This section presents the theoretical bases and concepts that are relevant for the development of this work.

### 2.1. Learning Process based on VLOs

The learning process based on VLOs corresponds to the set of activities that a learner develops in the environment through VLOs, which are designed based on learning hypothetical trajectories. Normally, when technological tools are implemented in teaching, the understanding of content in different areas of knowledge is facilitated [1, 2]. In this way, VLOs should promote reflective thinking to associate the real-life situations with mental models that are originated by interpretations and concepts within the learning process [3]. In addition, with the integration of technological resources in teaching, a constructive model is structured in an epistemic way that allows guiding a deep, autonomous, and instructional learning based on the interaction and development of new concepts associated with the experience [4].

Besides, the constructivism model is oriented to carry out a learning process through activities based on experiences. This process can contribute significantly to learning. An example of these activities is the development of problem-based learning that can act as a moderator for the learner to structure and construct new knowledge based on their previous knowledge [5].

Learning processes considers the culturally diverse contexts that must develop with non-traditional methodologies such as socio-transformative constructivism that encourages more critical and inclusive teaching. It is useful to generate reflections of situations of the real-life [6]. This is how teaching focuses on developing learning environments that are culturally relevant and promote the strengthening of receptive skills and understanding of explicit information [7].

### 2.2. Sign Language

To develop culturally inclusive environments for the entire population, sign language is created to include a representative means of communication that favors the population with hearing disabilities. Hence, sign language is characterized by incorporating the body as a means of bodily and symbolic expressions. That is why this language should be used to develop an inclusive education mediated by technological tools that comply with design standards that incorporates the learning of grammatical and pragmatic rules of this language in the construction of VLOs [8].

However, sign language is not universal, as each country developed its non-verbal communication system. Therefore, learning in subjects with hearing impairment is affected by the deficit of literacy skills at a very early age [9], since people with this disability do not have adequate

models of the use of sign language, which affects the development of linguistic and cognitive skills [10].

In this way, with the implementation of sign language in education, some factors such as equity, diversity, and social justice are promoted in learners with hearing impairment. With this in mind, sign language aims to foster learning and improve inclusion experiences in the school environment [11]. Also, teaching must carry out a social transformation that proposes didactic strategies for ICT to enable the improvement of communication skills in learning content from interdisciplinary areas in the educational context [12]. However, before incorporating technological tools in teaching focused on learners with hearing disabilities, teachers need to address conflicts generated by social inequality caused in the school environment and prepare learners with disabilities to face a technological and cultural transformation presenting alternatives of interpersonal relationship with the listening community [13].

### **2.3. VLOs for Hearing Impairment**

In recent years, there have been different initiatives that implement VLOs as digital resources, which are self-contained to favor teaching and learning processes in the educational context. Most VLOs are built to support the pedagogical process through the use of instructional design methodologies that comply with the standards and guidelines endorsed by government organizations like education ministries. However, although normally VLOs are not designed for learners with some type of disability, currently there is a need to build different VLOs that incorporate learners with disabilities such as hearing impairment. Thus, there is the need to develop different VLOs conditioned to the cognitive situation of each learner in different areas of knowledge.

VLOs for learners with a hearing impairment must to be organized, flexible, structured, and self-contained resources that are developed through mental skills to facilitate non-verbal communication [14]. Thus, when VLOs are designed and developed focused on learners with hearing impairment, progressive development in school activities are promoted. Also, VLOs for hearing impaired learners incorporate digital didactic content with the reproduction of study material such as sign language to meet the linguistic and cultural needs.

Inclusive education for the population with hearing impairment guarantees access to education for the entire community with high-quality standards and equal opportunities. Some VLOs for learners with hearing impairment have a non-verbal communication design that enables cultural and linguistic interaction by presenting alternatives for interpersonal relationships with the listening community [15]. Then, learners with hearing impairment have been incorporated into the educational environment, which enables identifying learning problems since the cognitive situation of each user might not be properly addressed, generating the need to include digital resources that support teaching [16].

### **2.4. Scholar Technological Activities**

Scholar technological activities are didactic strategies to generate a stimulus to learner to optimize the educational process in society. VLOs in teaching are technological tools that allow presenting the academic content in different areas of knowledge to be approached in a

didactic way, facilitating the integral development of the learner [17]. In addition, ICT enables the creation of VLOs focused on games that incorporate didactic strategies, materials, and communications that mostly enhance significant learning in the curriculum [18, 19], such as in the area of mathematics. Also, the solution of situations based on mathematical problems is a learning process used as a didactic strategy in the area of mathematics that generates an impact on the school environment. Thus, inductive reasoning can facilitate the structuring of problems through logical thinking, allowing learners to propose assertive solutions.

VLOs focused on games are structured and flexible teaching resources with innovative approaches commonly used in interdisciplinary areas such as mathematics that stimulate and optimize the teaching and learning process [20]. The design of VLOs based on games allows acquiring and strengthen skills since these are built interactively, enriching the interest and motivation of the learner in the presentation of relevant content that promotes independent and collaborative teaching [21]. In this way, the integration of these kinds of VLOs in learning creates new trends in education that are applied in different contexts of the school environment to improve the understanding of relevant content in learners [22]. In addition, when creating VLOs as technological didactic resources, they might include strategies to strengthen the development of soft skills in the learner such as descriptive thinking, teamwork, and good use of language.

Besides, the solution of situations based on mathematical problems consists of the development of symbolic tools that contribute to the learning process using didactic strategies in mathematics to promote in the learner a construction of knowledge through guiding reasoning a structure of thought, imagination, and the interpretation of multiple contexts, relating them to mathematical concepts. However, sometimes the learner addresses inappropriate techniques for solving situations based on mathematical problems by applying routine procedures such as performing operations with the numbers given within the situation or doing a search for keywords identifying which operation must be used to get the solution. Thus, the use of inappropriate techniques can affect the cognitive process of learners. In this way, understanding the problem and algorithm relation encourages the development of phases of abstraction that allows intuiting and proposing assertive solutions by contextualizing real-life situations with mathematical content.

Society perceives mathematics as the basis of scientific and technological knowledge. Thus, inductive reasoning is a means of constructing scientific and social knowledge that guides a process of observation of particular situations that allows learners to make conjectures by identifying behavior patterns found in problems. Also, teaching and learning processes use inductive reasoning to promote reflection and the application of mathematical content as a didactic strategy to address situations based on mathematical problems. In the educational context, particularly in the area of mathematics, learners make approximations of mathematical content in reality through environments focused on experience, implementing inductive reasoning to generalize particular situations.

### **3. Related Work**

Most educational institutions have incorporated learners with hearing impairment, contributing to learning equitably through technological tools. The use of VLOs facilitates and motivates

learning in the area of mathematics. However, VLOs do not normally successfully reach the hearing impaired population, disfavoring inclusive teaching because they do not have an inclusive design. In this way, this section presents a compilation of research developed by different authors that contribute to the improvement of the cognitive process of the population with hearing impairment.

Peligero et al., [23] present research to identify the differences that occur in a color categorization exercise between deaf and hearing children. The authors conducted this research with a sample of 64 subjects divided into two groups, one group conformed by 32 deaf children and the other group conformed by 32 hearing children, both groups with an age range between 8 and 14 years. In addition, a color recognition test was run a color categorization exercise grouping the colors in four experimental conditions. When analyzing the results, it is determined that deaf children have a different way of naming colors.

Valle et al., [23] propose the development of research that allows examining the use of visual-spatial representation by deaf and hearing students while solving mathematical problems. For this research, the authors had the participation of 305 people made up of 156 hearing people and 149 deaf people. The research instruments developed for this study were a) 15 mathematical problems, b) test of spatial relationships of primary mental abilities, and c) Minnesota Paper Form Board Test, which was solved using pencil and paper. The results of the three tests were evaluated by the following representation categories: visual-spatial schematic representation, visual-spatial pictorial representation, non-visual representation, and no response. The research findings determined that deaf students generate and use visual-spatial schematic representation to show the spatial relationships contained in math problems, achieving greater success in problem-solving.

Bull et al., [24] present the development of a hypothesis that identifies number processing skills as the basis for mathematical difficulties that occur in the hearing impaired population. In this way, the authors carried out the development of this hypothesis with 40 participants, twenty of them are deaf students and the remaining twenty students are hearing. To identify the number processing skills in the participants, the authors performed two comparison tasks. With the execution of the comparison tasks, the authors found that the visual information presented successively caused greater difficulty for the deaf participants. In conclusion, the authors identified that deaf participants present a better result in the comparison exercise when the information is presented visually simultaneously. In other words, carry out two or more instructions in the same period of time.

Emmorey et al., [25] carried out a hypothesis test to verify that the hearing impaired population improves visual mental image construction skills when using sign language as their primary language. To validate the hypothesis, the authors took a sample of 20 deaf people and 20 hearing people. One of the findings identifies that deaf people better develop the skills determined by the right hemisphere, such as the generation of images and processing of imaginable signs using linguistically coded representations of categorical spatial relationships.

Marschark et al., [26] present a study in which they want to prove that deaf students have a visual learning style. The authors researched the relationships between language and visual-spatial skills, the solution to situations based on mathematical problems, and the hearing thresholds of deaf students. To carry out the study, the authors had the collaboration of 39 deaf students and 32 hearing students. The instruments used for the development of this study were:

a) visual-spatial tasks solved with pencil and paper, b) partner cancellation tasks, and c) Corsi block tasks. When carrying out the implementation of the instruments in the students, the authors concluded that the visual-spatial tasks exploit some slightly different cognitive abilities in deaf students. Furthermore, native deaf students show better visual-spatial working memory than hearing people. Also, when the hearing loss is higher, there are more visually dependent to identify objects and events in the environment.

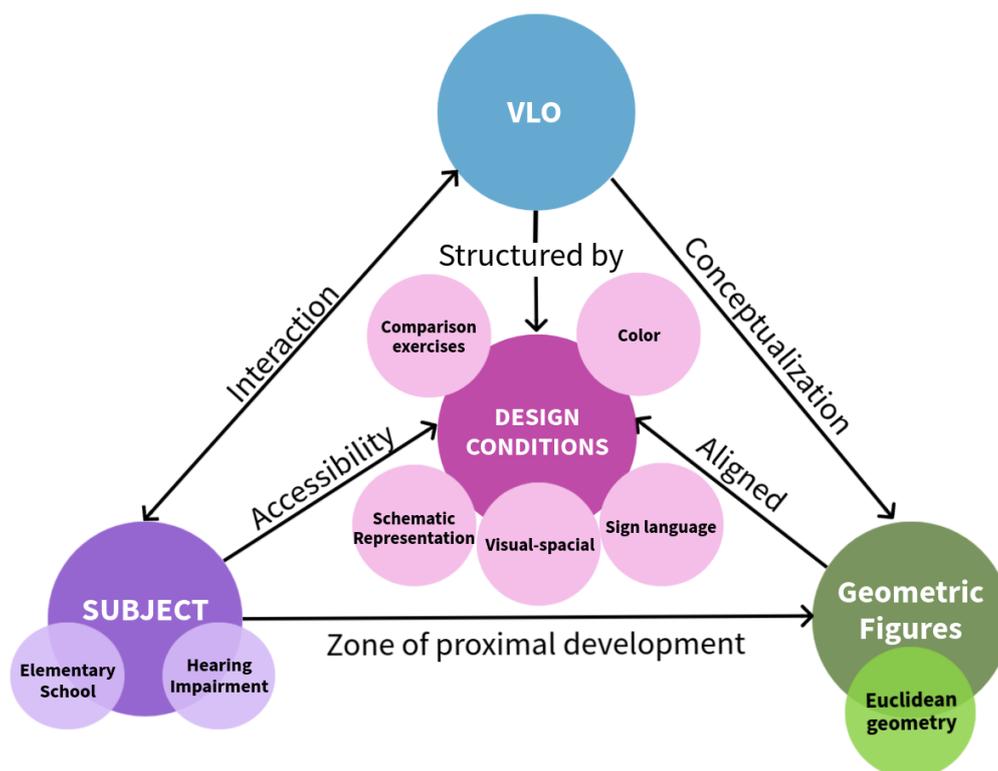
Having said the above, the design of VLOs must meet the needs of all populations. The design conditions in technological tools for educational purposes is relatively recent and needs to be explored in order to be able to meet the needs of the populations.

#### 4. Proposed Pedagogical Model

This section presents our approach of a model for a conceptual design of technological, pedagogical, and cognitive articulation. The conceptual design is made up of four components. The first component is defined by the *Technological Articulation* that is oriented to the design of VLOs. Subsequently, the second component is defined by the *Pedagogical Articulation* that is based on the construction of a set of inclusive design conditions. The third component is defined by the *Cognitive Articulation* that addresses the concept of Euclidean geometry figures. Finally, the fourth component is defined by the *Subject* that refers to elementary school students with hearing impairment. The conceptual design of the technological, pedagogical, and cognitive articulation includes several types of relationships between the mentioned components. These relationships represent the process of executing certain actions.

The conceptual design of the technological, pedagogical, and cognitive articulation is presented in Figure. 1. The VLOs, which are technological tools that facilitate learning in the educational context, conform to the first component associated with technological articulation. The inclusive design conditions correspond to the second component of the conceptual design that is part of the pedagogical articulation. The objective of inclusive design conditions is to find a set of categories that favor the learning process in the population with hearing impairment in the educational context. Inclusive design conditions are defined by five categories.

- Color is the first category, which is a visual perception that is generated in the person's brain by interpreting nerve signals that are sent to the retina of the eye. The retina interprets and distinguishes the different wavelengths of the visible part of the electromagnetic spectrum. Color has three attributes: brightness, hue, and saturation. Within the different wavelengths of the visible part of the spectrum, a range of colors is produced that stands out in the visual system of the person with hearing impairment since they are easier to remember and recognize [23].
- The Schematic Representation (SR) is the second category, which is a graphical representation of a series of ideas or concepts. This type of representation is visually symbolized by a scheme that allows contextualizing abstract concepts [27].
- The third category is the implementation of comparison exercises, which is a resource that allows establishing a similarity relationship between two elements from patterns [24].



**Figure 1:** Model for a conceptual design of technological, pedagogical and cognitive articulation

- The sign language is the fourth category. This is used as a means of communication in deaf people. It is characterized by incorporating the body through bodily and symbolic expressions. People with hearing impairment who use sign language as their primary language generate visual mental images faster than others [25].
- Finally, visual-spatial content design is the fifth category. Visual-spatial processing is the ability to tell where objects are in space, allowing people to develop the cognitive ability to mentally represent, analyze, and manipulate objects [26].

The third component of the conceptual design of cognitive articulation is determined by the figures of euclidean geometry, which study the properties of plane geometry that comply with axioms and postulates proposed by Euclid. Plane geometry is a part of the geometry that is defined by two dimensions, i.e., plane geometry deals with geometric figures whose points are contained in the same plane.

The subject is the fourth component of the conceptual design. For this conceptual design, the subject corresponds to a student of primary education level comprised between an age range of 6 to 10 years. In addition, the subject is part of the population with hearing impairment. Hearing impairment is defined as the difficulty that a subject has to perceive sounds. A subject with hearing impairment presents limitations in language development; therefore, the use of an auxiliary language such as sign language is a resource that allows the subject with hearing

impairment to interact, communicate, think, and learn based on non-verbal communication [28].

The conceptual design of the articulation presents the following relationships:

1. The first relationship establishes the association between the component of the technological articulation (VLO) and the subject. This relationship is determined through a communication process between the VLO and the subject called interaction that consists of a two-way information exchange that is carried out to achieve a specific purpose. On the one hand, the VLO promotes interaction with the subject through the use of ICT that is designed to reduce the difficulties that arise in the learning process in different types of populations, such as the population with hearing impairment. On the other hand, the subject through interaction with the VLO presents a participatory action process that generates an advantage of the potential of technological tools that results in the possibility that the subject with hearing impairment develops skills in learning different areas of knowledge.
2. The second relationship connects the components of the technological and cognitive articulation i.e., VLO and geometric figures respectively. This one-way relationship is established through the process of conceptualizing educational content. The conceptualization process is relevant to generate a representation of an abstract concept. The conceptualization generates a logical development of ideas that implies reasoning of the thought that facilitates and motivates the contents and the systematization of the ideas related to the object under study.
3. The third relationship is determined by the component associated with the subject and the cognitive articulation component (geometric figures). The relationship between these two components is one-way through the zone of proximal development. The Zone of Proximate Development ZPD is a concept developed by the Russian psychologist Lev Vygotsky defined by the distance that exists between the activities that a subject can carry out without help and the activities that he can carry out under the guidance of an expert. For a primary school student with hearing impairment, the ZPD activities require an assisted learning training process [29], which in this conceptual design, is given by the design of a VLO that addresses a mathematical object of study defined as the component of cognitive articulation called geometric figures.
4. The fourth relationship is defined by the components of the technological articulation and the pedagogical articulation component i.e., VLO and inclusive design conditions. This relationship is established from the structure that the VLO design must carry, which is determined by a set of inclusive design conditions that improve the learning process in the population with hearing impairment, which corresponds to the set of appropriate practices for an education that contemplates diversity and contributes to equity and social justice [30]. The inclusive design conditions are a) color, b) schematic representation, c) implementation of comparison exercises, d) visual-spatial content design and e) use of the sign language.
5. The fifth relationship established is given by the component associated with the subject and the component of pedagogical articulation. This relationship is mediated by accessibility. Accessibility is used to name the level at which any subject, beyond their

physical condition or their cognitive faculties, can make use of ICT. The subject can have and use these technologies under equal conditions regardless of their disability. These technologies are characterized by having inclusive design conditions that facilitate the subject's learning process.

6. The sixth relationship is formed by the components of the cognitive articulation and the pedagogical articulation. These components establish a one-way alignment relationship. Alignment is a concept used to refer to a certain order or organization of objects or people. The geometric figures component of cognitive articulation is aligned with the set of appropriate inclusive design conditions that favor the learning process in the population with hearing impairment.

In summary, the conceptual design of the technological, pedagogical, and cognitive articulation is a model that integrates a set of design conditions defined by five categories, which contribute to the improvement of learning of an object of study in the educational context. This model is elaborated to be used in the construction of VLO that allows mitigating the difficulties that arise in the teaching process of Euclidean geometry in the hearing impaired population.

## 5. Discussion

According to the literature review, we could determine that research works cited in the Related Work section focus on the study of some conditions that promote the improvement of the cognitive process of the population with hearing impairment. In particular, this work develops the conceptual design of a model of technological, pedagogical, and cognitive articulation that integrates the following five inclusive design conditions: a) color, b) schematic representation, c) implementation of comparison exercises, d) use of sign language, and e) visual-spatial content design. In this way, our work based on the developed model presents an approach that can be implemented in the design of VLOs for students with hearing impairment.

The model was developed through an educational context with the hypothesis that subjects with hearing impairments must use other senses and skills to have a better academic performance. The objective that the model has an integration of inclusive design conditions is presented with the need to facilitate the learning of a mathematical object in people with hearing disabilities. In this way, the model is a pedagogical strategy that generates positive social change since it promotes equity, diversity, and social justice, contributing to inclusive education.

## 6. Future Work

The following phases of the research work correspond to the design, implementation, and validation of VLOs following the components presented in the proposed pedagogical model. To achieve this, we will build an online platform that enables the creation of these VLOs. The first phase carries out the design of VLOs for students with hearing impairment that helps to mitigate the limitations that arise in the teaching process of the figures of euclidean geometry. The second phase develops the implementation of VLOs for students of primary education with hearing impairment. Finally, the third phase validates the VLOs by measuring the performance

of the learning level of the figures of Euclidean geometry in students of primary education with hearing impairment.

The methodological structure of the project in the three phases uses instruments with a mixed research approach. On the one hand, the instruments that are developed through a qualitative research approach such as the preparation of semi-structured interviews, use an experimental research design that develops a process of observation and evaluation of personal experiences having a descriptive scope allowing to identify different characteristics of the subject's behavior. On the other hand, the instruments that are used through a quantitative approach are applied with the elaboration of questionnaires and activities through the Geogebra software, and their validation is carried out with a decision matrix or rubric that evaluates the participants regarding the learning of the mathematical objects under study. In addition, the results of the participants' ratings are analyzed using descriptive statistics.

## 7. Conclusions

VLOs are elements that facilitate learning in different areas of knowledge. However, they are normally designed without taking into account the population with disabilities such as hearing impairment. Therefore, this impacts inclusive teaching because they do not allow access to information in an equitable way. Thus, this characteristic can generate deficiencies in the cognitive process of students with hearing impairment, affecting the development and strengthening of their skills in learning mathematical objects.

In the construction of the pedagogical model, a literature review was carried out to search for a set of inclusive design conditions that would mitigate the deficiencies presented in the learning process of a mathematical object in the population with hearing impairment.

In the process of designing the pedagogical model, an analysis of the components was carried out, achieving a relationship between the subject and the technological, pedagogical, and cognitive components.

The proposed model can be extended to the construction of VLOs for the teaching of any mathematical object of study; however, the model must be directed to the same population under study.

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