DEAF LITERACY: A COMPUTATIONAL PROCESS TO DESIGN SIGN LANGUAGE/PORTUGUESE ARTIFACTS FOR INTERNET

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ABSTRACT
The lack of educational tools for/in Sign Language (SL) is one of the most challenging issues faced by the Deaf communities in Brazil – it causes language barriers (e.g. prejudice, late acquisition, lack of standards etc.). This deficit is detrimental to the development of the Deaf culture (a social movement that regards deafness as a difference in Human experience). 90% of Deaf children are born to non-Deaf parents: a hindrance to SL acquisition (the natural language of the Deaf) necessary for intellectual development. The Internet and the WWW are paramount to provide the Deaf children and their parents with tools for Literacy (SL as the first language and the written modality of the second language). However, most researches and pedagogical literature do not provide educators and designers with means with which to work. This paper addresses the issue by presenting a pedagogical-computational process that allows for flexibility, scientific-based design of Intellectual Artifacts (linguistic interpretation and solution of a given problem).

KEYWORDS
Sign Language; Collaborative Systems; Knowledge Creation; Social Inclusion; Communities of Practice.

1. INTRODUCTION

Over 90% of Deaf children are born to non-Deaf parents, and, therefore, they are seldom exposed to SL: the lack of early SL acquisition is detrimental to the Deaf children’s full access to available human possibilities (Fernandes, 2006): communications, social interaction, intellectual development etc. Chomsky (1988) has shown that natural language and its acquisition play a crucial role in intellectual development, social integration and full citizenship exercise. In that regard, Kyle (1998) shows how the gaps between the Deaf and her family due to the lack of SL use leads to high levels of mental diseases later in life, a threat that is in direct relation to life and survival of the Deaf. Action is needed to reduce such gaps.

Most educational experiences in school have not achieved the desired goal of adequately dealing with the learning and usage of SL by the Deaf children and their parents (Fernandes, 2006). Additionally, there is a lack of research on how the Deaf issues and SL should inform the design of tools to achieve such goal. Pedagogical Architectures (PA) – learning structures that combine different components, articulated from pedagogical, technological and political dimensions (such as pedagogical approach, software, Internet, Artificial Intelligence among others) – have been shown to incorporate an understanding of how to help learners modify their cognitive structures (Carvalho, Menezes & Nevado, 2007), and are extensively used in several other educational areas. However, PA come short when it comes to addressing the Deaf issues, and they do not provide a computational process with which stakeholders (Specialist, Educators, Developers etc.) should work.

Our proposal is a concrete contribution: a process to extend the PA to aid the design of Intellectual Interaction (computer-mediated systems based on SL features and cognitive theories for mind development) in Intellectual Artifacts (defined by de Souza (2005) as those that encode an interpretation of a problem along with a set of solutions in a fundamentally linguistic form – i.e. a system of symbols that can be decoded by
consist of semantic rules). The proposed process thus provides SL-based features, pedagogical guidance, cognitive support, and implementation flexibility, among other properties. The main goal of this paper is to present such process, to be used for educational purposes, Literacy, and to bridge the gap between Deaf children and their parents. The II process has in its core the use of SL, cognitive theories, and the mapping of such features into Intellectual Artifacts. The remainder of this article briefly summarizes SL and its relation to the Deaf issues; then, it discusses a PA for Deaf Literacy; introduces the II process; and presents initial results of its use and lists future works.

2. DEAF ISSUES, LITERACY AND PEDAGOGICAL ARCHITECTURES

The Deaf are not defined by deafness (a deficiency), but rather by a culture, and SL is a major part of the Deaf culture: a term applied to the social movement that holds deafness to be a difference in human experience (which includes the right to use SL) rather than a disability (Skliar, 1999). Society, on one hand, has little to offer the Deaf; on the other hand, there are special signs, sidewalks, reserved parking spaces, ramps, special cars, Braille written material, companion dogs, software that accepts voice command and that “reads” screen text and all other sorts of aids (technical or not) for people from other minorities and their needs. And it is wonderful and rightful that this is so. The point made here being to offer equivalent opportunities for the Deaf. The present research aligns itself with the political and ideological choices of Sánchez (1991) by choosing Literacy of the Deaf who identifies with SL and the visual culture, in a bilingual citizenship: language is more than a way of communication, and it includes a regulation function of thought (Vigotsky, 1991), that acquires meaning only within the social context in which it is ingrained. Bilingualism, considered to be more adequate for Deaf education, is the movement that claims the use of, at least, two languages: SL, as a first language, and a second language in its written form – in our case, Portuguese, the official language of Brazil.

Lévy (1999) tells us that the culture of technology must go beyond the mere use of computers for games and leisure, thus limiting its use: the “new intellectual technologies” that are to be used for Literacy. Literacy is the resulting process of social practices of the use of the written form of the oral language as a symbolic system and as a technology, in specific contexts, for specific goals (in our context, to be acquired by the Deaf in a functional use of the language, where the language assumes a character of real meaning).

PA are teaching and learning structures that are articulated around pedagogical, technological and political dimensions. PA should be used to design educational tools (Learning Objects (LO) in some cases) that go beyond the mere transmission of knowledge towards providing an environment for the construction of the world. This construction should be achieved by enticing cognitive activities for the development of interactive work. PA should have a strong pedagogical conception; a methodological systematization: seductive and interactive cognitive activities (e.g. projects, problem-solving, simulated actions etc.) and they should provide a virtual learning environment. (Carvalho, Menezes & Nevado, 2007). Following the concept of a PA, Guimarães et al. (2012) present a conceptual meta-environment framework for Deaf children literacy, called Intellectual Interactions (II) to construct computational Intellectual Artifacts to promote bilingualism (SL/Portuguese).

3. RELATED WORK

The Internet and Collaborative Systems are adequate tools to cultivate Literacy for the Deaf. Existing technologies (e.g. PA and their related LO and artifacts) are inadequate to the Deaf’s specificities (i.e. they are not in Sign Language); they lack usability for the target audience; they do not allow for multiple and full collaboration; they are not designed for Literacy as per the needs of the Deaf. Mostly, they do not present stakeholders with a process for computational development of tools and artifacts, the focus of this paper.

Amongst the surveyed PA that are not geared towards Literacy, Deaf issues, SL and the target audience (namely Deaf children and non-Deaf parents) we direct the reader to the following, for their potential for knowledge creation: Elia & Sampaio (2001), Fagundes et al. (2006), Serres & Basso (2009).

As for those PA that are somewhat related to Sign Language, we find several inadequacies: Silva (2002) presents a web-based one-to-one vocabulary Portuguese/SL, with emphasis on hand configuration and non-
manual expressions only leaving out several other aspects of SL, writing, acquisition etc. It assumes that the student knows Portuguese. Secco & Silva (2009) present an environment in SL, based on a Problem-Based Learning strategy to teach SL. But it presupposes that the Deaf already knows SL (a strange contradiction).

Tavares, Leithardt, Geyer & Silva (2009) present a sensor-based device that captures the movement and send the data to a software that “translates” it into SL. The use of a glove makes it awkward (not natural for the user) and disregards other aspects of SL (such as non-manual expressions). Although it claims to teach Portuguese and SL, it is not clear how that would be achieved.

4. INTELLECTUAL INTERACTION PROCESS

The design of educational tools requires the implementation of some theory of learning and teaching. As pointed before, most PA are not designed as to have the necessary operationality demanded for implementation. Hence the need for a process that will bridge the gap between theories and implementations, by making PA more relevant to computer scientists. The use of II process not only translates concepts into design terminology, but it adds some components of pedagogical strategies to be used to achieve Literacy. II process ties the structure of learning environments to existing models of cognitive development, which can be implemented (and tested) into Intellectual Artifacts. Most theories address only a specific facet of Literacy, thus, their combination allows for the design of a more complex, global learning environment. This can be seen in figure 1.

![Figure 1. Intellectual Interactions Process](image)

As seen in Figure 1, the II process combines the prominent iconicity of SL with cognitive theories in a conceptual model to inform design of artifacts for bilingualism Literacy.

Figure 2 shows the **stakeholders** and the overall **use cases** of the II process. The overall process is comprised of **Designing**, **Implementation** and **Use** of the Artifact. The **Design of the Artifact** creates the **object, the patterns, the knowledge base and the intellectual interactions**.

![Figure 2. The II Process](image)
As can be seen in Figure 2, the process contemplates several stakeholders and activities to be performed for the design of the computation tool that comprises the PA for Literacy (SL/Portuguese) of Deaf children and their parents.

A) Stakeholders

Stakeholders have the following profile: students: Deaf children (of various ages and degrees of development) and their non-Deaf parents – being that they are novice in the use of SL. The educators will have SL experience; and will be aided by mediators and educators (with knowledge from various fields: social sciences, psychology, computer science etc.). The collaborative/interactive tool to be used will focus on SL.

B) Create Patterns

Members of the Deaf community will contribute in the process, along with other stakeholders in the creation of the patterns to be used. Patterns refer to the sign, its iconicity, relations, areas of knowledge where it can be used, best practices that have been shown effective, context of use, codes for the implementation, images, videos etc. Patterns are to be deposited in a repository for knowledge management (creation, updates, re-use) by the stakeholders. As of right now, patterns are implemented as a Web Portal, for internal use only. They require extensive research and development that will be carried on future research.

Knowledge Managers are the specialists and the educators. They will guide the selection of the knowledge that will be addressed in the Artifact, as well as its relations, uses, activities. The developer will implement the Artifact as per the specifications. The developer will also contribute with proven efficient patterns, thus increasing the overall knowledge of the PA.

C) Create Object

In order to create the object, stakeholders should define the knowledge area of the Artifact, The context in which the knowledge will be worked and the genre the Artifact will represent. Brainstorm sessions could be used to derive the overall ideas for the object.

Stakeholders should select the SL signs that will be used to create the interaction elements, knowledge, relations, etc. Such signs should consider the target audience (Deaf children and non-Deaf parents with little to no proficiency in SL). The process relies on SL signs that have one of the most important and easily recognizable characteristics of SL: its greater iconicity when compared to other natural languages. Each element is composed by its iconic formation as per the hand configuration. The Artifact will present the overall object with its elements. When activated, each element will show an animation of how the signs are in Libras – a ludic manner to demonstrate the iconicity of such element. Later explorations will follow the design of the object, and present videos with its relations with other objects within the Artifact. That is, additional knowledge, such as relations among objects, and the written Portuguese will be shown in video as the users interactively explore the environment.

When creating an object, the following should be considered:
1. The overall area of knowledge of the Artifact (e.g. sciences, health issues etc.);
2. The genre to be used (e.g. e-book, instructional LO, storytelling environment, immersive environments, interactive installations, games, distributed interactions over the Internet etc.);
3. Within the selected genre, the stakeholders should create a representation, a concrete, actual scenario of interaction that is part of the context of the child (e.g. a scenario in a child’s breakfast situation);
4. Sense Making (an approach used to study the process people use to make sense of their experience) and Common Sense (shared knowledge, related to life within a culture) should be used to create tasks that require the comprehension of the chosen topic, and its sub-tasks (i.e. knowledge creation, information seeking, mental and cognitive maps, comparison, synthesis, analyses etc.). The use of said tools will enable the selection of concepts and their respective SL signs that belong to the context. Objects, actions, relations etc. are the tasks that will be implemented as activities in the Artifact. Some of the issues to be addressed during this phase:
   a. How do people make sense of a set of complex information?
   b. What are the aspects of representation, evolution and use through time?
   c. How to effectively make sense in a group?
   d. How to deal with static and dynamic environments?
e. What are the uses of such cognitive theories in other areas of human knowledge?

5. Such process will guide stakeholders on the nature of the object: its components, behavior, features, teaching/learning strategies, testing for knowledge acquisition etc. It incorporates features required by Interactive Learning Environments (ILE) (Schneider et al., 1993:1): “the multiplicity of teaching styles (the learning content may be taught in several ways), the multiplicity of learning sources (experience, coaching, hypertext browsing), the use of a rich interface allowing for complex problem situations and for supporting pedagogical reasoning”.

6. From the selected concepts and SL signs, a sub-set of signs will be prioritized, as per their iconicity.

7. The use of scenarios (Carroll, 2003) is a powerful tool: Scenarios provide concrete situations of use to inform design. They also serve as the documentation, as the design rationale, requirements, specification and analyses that will be used in the implementation.

8. Iconicity will be used to generate the “Spontaneous Concepts” in the child (i.e. those acquired in the daily concrete experience) and help her develop “Scientific Concepts” (i.e. more abstract, acquired by explanation, related to previous knowledge and concepts (Vigotsky, 1974).

D) Create Knowledge Base

Given the varied interests of the many stakeholders, and their needs, choice of genre, instructional format, etc., the knowledge of the Artifact should be normalized in order to create the knowledge base to be used in the Artifact. Thus, the SL signs and knowledge selected in the previous phase should be organized in a Conceptual Map (CM).

CM are a geographical representation of concepts (vertices) and their relation (arcs) in a network which narrates this relation. CM is a powerful tool for meaningful learning as it serves as a template to organize knowledge and to structure it. And its similarity to computational graphs allow for an easy conversion for implementations. Knowledge is presented/created by the exploration and navigation through such network. The algorithm to be used to choose the navigational path is genre-dependent, and thus, is beyond the scope of the II process. Suffice it to say that the path will represent the allowed order in which concepts and relations will be presented to the user.

Stakeholders represent elements (i.e. concrete objects, such as a tree, the sun, the cloud, etc.) and its relations (e.g. the tree has branches – composition, whole/part), a causation (e.g. the sun burns the eye) among other knowledge. This representation is fundamental, and precise criteria must be used in the modeling of the knowledge to be presented (according to the choices made by the stakeholders in previous phases of the process). The knowledge modeled in a CM can be transformed into the pattern a  b (i.e. IF a THEN b), in such a way that the previous knowledge presented is a precedent and is used to create a new knowledge: IF there is sun, and the sun burns the eyes, THEN sunglasses must be used for protection.

E) Create Intellectual Interactions

In order to create the intellectual interactions, designers will use the object created by the use of the process presented (including the scenarios, the choice of knowledge area, genre, conceptual maps and other materials that was developed during the creation of the object). The intellectual interactions are the instantiations of an element and its relations, and it is trigger by the user exploring and manipulating such elements. The first instantiation of an element will be of its essence (i.e. if the user touches a tree, then the animation, the sign, and the initial knowledge presented will be that of the tree alone). When instantiated, the Artifact will present an animation of the iconicity of the element (i.e. an animated hand will superpose the element in a direct representation of the element in SL). Then, a video will be presented with additional knowledge (e.g. other concepts, relations and the written Portuguese corresponding to the knowledge presented). The next instantiation is outside the system, which means it can be pre-determined or randomly selected by the user, and it is a choice between the essence of the element and its knowledge (relations). Any independent spontaneous knowledge may be instantiated. All dependent knowledge may only be instantiated if their functional dependency is already a part of the instantiated knowledge.

The element and its relations will come from the CM that was transformed into a graph. The interactive activation of an element by the user should keep a memory of the knowledge in the domain of the Artifact, so that its dependent relations may be used in later interactions (that is to say, once activated, the element will be marked as visited, and will become a concept from which other concepts could be built). This makes the element a part of the previous knowledge structure of the given session of use of the Artifact. The initial
interaction occurs outside the process (either by the mediator, educator or the user, or by a pre-defined order). Further activation of any element presents new opportunities for knowledge presentation: it can be a repetition (an important strategy for teaching/learning) or a new concept and its relation. This will guarantee the functional dependencies of the knowledge structure ingrained in the system.

**F) Implementation**

In order to implement the Artifact, the designer will have to guarantee the functional dependencies mandated by the CM. The main goal of the environment is to present the users with enticing elements that will elicit interaction. Given an activation of an element, the Artifact should then keep track of the presented knowledge as the element and its relations are explored by the student. The mapping of the CM into a graph is suggested as a simple way to implement such behavior. The choice of which path in the graph (CM) to take next is dictated by the PA. Not all element from the Artifact needs to be instantiated, as it is true to the relations. This is a real-world model approach (it may be the case that some elements must be repeatedly presented, in order to fixate a given knowledge; or the user may not come back to an element, thus not exhausting its possibilities in that specific session – note that the interactions may vary from session to session, from user to user, from moderator to moderator, based on the pedagogical choices, among other variables). In this sense, the intellectual interaction differs from a learning object that must present a sequence of progressive knowledge (although it may also do so).

**G) General Flow of the II Process**

Figure 3 shows the flow of the II process.

![Figure 3. The II Process flow](image)

5. **CONCLUSIONS: SHORTCOMINGS AND NEXT STEPS**

The huge gap that exists between the Deaf child and her non-Deaf parents regarding communication and affective ties due to the lack of SL acquisition and use is detrimental to the Deaf’s intellectual development. This is a source of prejudice. Mostly, the families find little or misguided support from wrongful understanding of the Dear issues and culture. The proposed process is based on current, sound cognitive theories to complement PA in the design of computational tools.

This paper presents a process for the design of Intellectual Artifacts aimed at addressing Literacy in Sign Language/Portuguese for Deaf children and their parents. Therefore, the process should be validated for other SL and cultures. Primitives to capture SL iconicity are shown. Then, we provide educators with a framework with which to derive the knowledge base using cognitive theories. This knowledge base, in a CM form, can then be transformed into a graph that will serve as the basis for the implementation. The implementation is dependent on the pedagogical choices made. The process structures in a precise way the activities to be used to create the computational tool that implements a PA. Most PA lack such process, and, therefore, our proposal advances the state of the art by providing developers with guidance for effective implementation that adequately uses all the properties of the PA.

The creation of the Patterns is now implemented in a Collaborative Web Portal for internal use. At present, to apply the process requires extensive participation of members of the Deaf community, a feat which requires further research: usability aspects, for instance: how to deploy such web portal for the community that is sound enough, with usability geared towards their specificities, where stakeholders can use, create, share Elements to be used in several areas of knowledge, genres etc. based on the element’s
This is a task that will be addressed in future works. Additionally, once there is a substantial repository of patterns available, the creation of the Artifacts can be, in the long run, automated: designers could navigate the patterns, and aggregate them into the tool. Our future work will contemplate such issues.

Currently, we are applying this process to develop several Artifacts. The evaluation of the process will be performed with educators, designers and the target audience.

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