Problems and solutions in the design for Deaf Persons who are Sign Language Users to adopt Assistive Technology products

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***Abstract*—Libras is the mother language of people who are Deaf or Hard of Hearing (D/HH) in Brazil, characterizing them as people who use visual cues and signs to communicate with the world. Specialized researchers and educators affirm that people who are D/HH first have to be literate in their mother language (L1, sign language) in order to learn the second language (L2, written language). The teaching-learning process of written language as L2 is still a challenge, subject of many investigations and experimentations. This paper presents results and discussions from exploring and understanding problems and solutions of the design for Deaf persons who are sign language (SL) users to adopt an Assistive Technology (AT) product. This AT product refers to a solution for use in the teaching-learning process of Brazilian Portuguese written language as L2. Our methodological approach is to follow the phases of a framework in proposition, which combines concepts of Co-design, adoption of AT, Human-Computer Interaction lifecycle, Semantic Numbers theory and Writing Process. The framework proposed aims to include co-designers in every phase to guarantee higher chances of being accessible and potentially adopted by the stakeholders. Our results were obtained from two semio-participatory workshops, in which we worked with the Stakeholders Diagram and the Evaluation Frame as co-design artifacts. In the former case, many problems, questions, solutions and ideas were presented by stakeholders, to whom cultural diversity and multimodality were central aspects to be considered in the design of an AT product for Deaf people who are SL users.**

***Index Terms*—people who are deaf, assistive technology, written language, sign language, libras.**

I. Introduction

The Brazilian Sign Language (Libras, *Língua Brasileira de Sinais*) is the mother language of people who are Deaf or Hard of Hearing in Brazil [9], being one of the main cultural characteristic of Deaf Community. Specialized researchers and educators affirm that people who are D/HH first have to be literate in their mother tongue (L1, sign language) in order to learn the second language (L2), in this case, written Brazilian-Portuguese language [15]. However, according to [38], people who are D/HH (as a minority group) live among a majority society, composed by hearing people who communicate through written-spoken language.

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Assistive Technology (AT) is a knowledge area which embeds products, services, tools, methodologies, strategies, among others, whereby designers aim to provide autonomy, enhancement of functional ability, social inclusion and quality of life to/for people with different abilities [6] [10]. With the AT concept and inclusive education in mind, our motivation is to help people who are D/HH by designing with/for them a solution to assist in the teaching-learning process of Brazilian-Portuguese language as L2. In this case, we understand that learning written-language as L2 means to provide an opportunity of autonomy by giving them the chance to choose how, when, what and with whom to communicate, being useful for their personal and professional life, broadening their net of potential friends and contacts among the majority group without leaving their cultural aspects and identity aside.

One evidence of the problem Brazilians who are D/HH experience with written language is the National High School Exam (*Exame Nacional do Ensino Médio*, ENEM), the major exam to access undergraduate programs of public and private universities in the country. In 2018, among 35,335 people who formally required Specialized Assistance during the exam [24], 11,252 people who identified themselves as D/HH were approved. For instance, in 2017, video-exam in Brazilian Sign Language (Libras, *Língua Brasileira de Sinais*) was the type of specialized assistance most required and used [23]. Previous exams in Libras can be accessed at video-exam in Libras website [25].

Although the multiple-choice questions from the ENEM are accessible in Libras, participants must still write an essay in written Brazilian-Portuguese [23]. According to Federal Law n. 10436 [9], Libras does not substitute written Brazilian-Portuguese language. The Pedagogical Report of ENEM for the years 2011-2012 [22] shows the average performance of people who are D/HH in the essay exam. Specialized assistance is shown with each respective average of performance, compared to the maximum performance of 1000: (i) People who had Libras interpreter service, 283.16; (ii) People who had lip-reading service, 555.58; (iii) People who had Libras interpreter and lip-reading services, 347,84; (iv) People who are D/HH and did not require assistance service, 547.28;

and, (v) Hearing people who did not have assistance service, 492.51. It is possible to notice that the average of people who are familiarized with the Brazilian-Portuguese language had better performance on essay exams.

We here present the results from a case study to validate Phase 1 (explore and understand) of a framework in proposition. The case study is meant to address difficulties experienced by people who are D/HH and who are not yet fully literate in written language, by proposing a product design. The framework is composed of four phases and it combines the following theoretical bases: Cycle for Adopting AT by [28], the Co-design by [4], the Human-Computer Interaction (HCI) lifecycle by [35], the Semantic Numbers theory by [5] [15], and the Writing Process by [19].

The product under design is meant to be a combination of Educational Technology and AT, respectively, because of the use of the Semantic Number theory a pedagogical base and the intention to support the autonomy of people who are D/HH. As Kleina [27] informs, AT services or products in education are additional resources to teachers, whose major functionally is to provide autonomy to students, in order to accomplish activities at their own pace.

The remainder of the paper is organized as follows: Theoretical Studies, Methodology, Related Work, Results and Discussions and Conclusion.

II. Theoretical Studies

This section presents background theories to support the framework in proposition For this, subsection A presents the basic concepts of Co-design; B, on the adoption of AT; C, on the HCI lifecycle; and, D, on the Pedagogical bases.

A. Co-design

According to Baranauskas, Martins and Valente [4], co-design is a design process to work with stakeholders through artifacts, building meanings of the product under design. Also, the authors mention that co-design is situated in the pragmatic perspective, from the design perspectives of Fallman[1], which is characterized by situationality, since the design process happens in a "world populated by people, artifacts and practices, each one of them with one's own stories and identities" [4, p. 42]. Still according to [4, p. 43], the design in the semio-participatory model is a "social process with focus on both characterization of the design situation and proposition of solutions", in which stakeholders are involved in dialogue situations, whereby each one can share different points of view.

Organizational Semiotics is one of the fundamental bases of Co-design and it states that an organization have three different layers or information systems The informal layer referring to habits and intentions in one's daily life, the formal layer referring to laws and rules, and the technical layer referring to technological artifacts of interactive system [4]. These three layers compose the Semiotic Onion, in which the technical layer needs the previous knowledge from informal and formal layers, since the design process takes place from the outside (situationality of the problem) to the inside (solution by the technology). In this sense, inclusive participatory practices of design are transversal through layers of the Semiotic Onion and happens in the Semio-Participatory Workshops (SPW) [4].

During the SPW, stakeholders collaborate using different artifacts in each layer along with the research team. With respect to the informal layer, artifacts are Stakeholders Diagram and Evaluation Frame; for the formal layer, artifacts are Ontology Diagram and Semiotic Ladder; and, for the technical layer, artifacts are Braindraw, agile process model of the research group choice and the Code Burning Day.

We here only show results from artifacts of the informal layer (part of Phase 1 of the framework in proposition). The goal of the Stakeholders Diagram artifact, in Fig. 3 of section V, is to list who the stakeholders are in the solution under design. Additionally, they can be asked when, where and in what way stakeholders can contribute to the design process. This artifact is composed of 05 circles, one inside the other, where the central core, first circle from inside out, refers to the name/ title of the solution under design. The second circle, called "Contribution", represents "Main Actors" and refers to the stakeholders that will directly and frequently use the proposed solution. The third circle, called "Source", represents "Clients, Providers" and refers to the stakeholders that will use the solution, not directly and frequently, but who are an important source of knowledge. The fourth circle, called "Market", represents "Collaborators, Competitors" and refers to stakeholders that could invest in the research or owners of related solutions. The fifth (outer) circle, called "Community", represents "Bystanders, Legislators" and refers to the ones that could indirectly benefit from the solution under design.

Also from the Informal layer, there is the Evaluation Frame artifact, in Fig. 4 of section V, whose goal is to list problems and questions, as well as ideias and solutions for each category of stakeholders (Contribution, Source, Market and Community), in the early stage of the design process [4].

With co-design, we aim to conduct a design process with different stakeholders, in order to consider different points of view in the written-language teaching-learning process of L2 to Brazilians who are D/HH.

B. Adoption of Assistive Technology

The Cycle for Adopting AT consists of four phases [28]: (i) Development phase, in which information about the users, their preferences, attitudes, needs, expectations and abilities are investigated; (ii) Selection phase, in which objectives, environment and resources are assessed for the AT product to be selected or developed, tested and re-assessed; (iii) Learning phase, in which stakeholders learn how to use and customize the AT product; and, (iv) Integration phase, in which monitoring and evaluation of the AT product use by stakeholders occur. [28] point out the importance to adoption into account in the AT selection/development phase, in order to prevent problems in the integration phase of the AT by stakeholders in their daily life.

[1]D. Fallman, "Design-oriented human-computer interaction," in ACM CHI Letters, vol. 5. New York: ACM Press, 2003, pp. 225–232.

The Technology Acceptance Model for Inclusive Education (TAM4IE), proposed by [36], takes into account five constructs to verify AT acceptance: (i) Subjective perception, defined as "the result of measuring hedonic quality attributes triggered during human-computer interaction" [36, p. 27]; (ii) Perceived usability, defined as "the result of the perception of usability inherent to the technology" [36, p. 28]; (iii) Perceived usefulness, defined as "the degree to which an individual believes that the use of a technology can minimize educational barriers faced by him/her" [36, p. 28]; (iv) Future expectations, defined as "the result of user's reflection regarding potential future benefits reached by the use of technology" [36, p. 29]; and, (v) Facilitating conditions, "the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system" [36, p. 29].

Hersh and Johnson [21] proposed the Comprehensive Assistive Technology (CAT) model based on the need to formulate user and development requirements for new AT products, focusing on the social model to understand different abilities. They state that the CAT model "provides a simple, effective, and unified modelling framework to support the ongoing dialogue that occurs between" the stakeholders of the AT product [21, p. 194].

According to [21], the CAT model has four levels: Person, Context, Activities and AT. Person referring to who will use the AT product, listing people' characteristics (profile, needs, abilities and preferences), social aspects ("community support, education and employment") and attitudes ("attitude towards AT and general attitudes") [21, p. 207]. Context refers to user's life characteristics, observing the user's social and cultural aspects, national context (infrastructure available, legislation, and AT support by the government) and local settings (where will the user use the AT product?, alone or with someone else?, and physical variables). Activities are divided into two groups, according to Hersh and Johnson [21, p. 209]: (i) "mobility, communication, access to information, and cognitive activities"; and, (ii) "contextual activities of daily living, education, employment, and recreational activities". Assistive Technology (AT) attribute refers to activities of specification (what tasks will the AT product accomplish?, and user's requirements regarding physical, sensory and cognitive skills), design issues (design for all or for a specific person?, and technology selection), system technology issues ("system interfaces and technical performance") and user issues (facility and attractiveness of use, "mode of use, training requirements, and documentation") [21, p. 213].

These related theories highlight the importance of considering the persons, the context, and the activities the persons need to accomplish in the context, before considering selecting an existing or developing an new technology. Moreover, these theories ground the Monitor phase of the proposed framework, which authors mention the integration phase and further-term evaluation.

C. Human-Computer Interaction lifecycle

As we are willing to design a new AT product, it was necessary to considerer HCI aspects and techniques on this process. For that, we took concepts from Preece, Rogers and Sharp [35, p. 8], who explain about the goal of Interaction Design (ID). The authors mention that ID is about how to "create user experiences that enhance and improve the way that people work, communicate, and interact".

According to the authors, the HCI lifecycle consists of four phases [35]: (i) Contextual Analysis, in which needs are identified and requirements are elicited, through activities, such as interviews, questionnaires, focus group observation, brainstorming, Persona design, among others; (ii) (Re)design of the solution, through activities, such as storyboard, sketch, scenarios, card sorting; (iii) Prototype, in which an interactive version of the product is developed; and (iv) Evaluate, in which the evaluation of the interactive prototype happens, through activities, such as heuristic evaluation, walkthrough, Goals, Operators, Methods and Selection Rules (GOMS) model, usability testing, user experience evaluation, among others.

D. Pedagogical bases

Semantic Numbers is one of the pedagogical base for the teaching-learning process of the AT product under design. As presented by Duarte and Padilha [15], Semantic Numbers is a methodological transcription system for the literacy of people who are D/HH in Brazilian-Portuguese language as L2, and for the literacy of hearing people in Libras as L2. Both languages, Libras and written Brazilian-Portuguese, have different structures. Semantic Numbers help students to learn how to write using the formal structure, avoiding direct transcription from one language to another [15].

An example of Semantic Numbers is presented in Fig. 1, from Duarte and Benassi [5], which illustrates from top to bottom: (a) A title in dactylology, which represents the manual alphabet of the word "Grandson" in Brazilian-Portuguese, written as "*Neto*"; (b) Two frames, one on each superior corner of a central photo, where the student should include the corresponding number to the handshape parameter of the sign in the central photo. In the example of Fig. 1, the handshape parameter of a right hand is "21", as the number written by the student in the frame of the left corner; (c) The photo of a person signing in Libras, where in Fig. 1 is the sign of "Grandson" (*Neto*); (d) A frame which shows an amplified handshape in a larger central frame picture; (e) A written Brazilian-Portuguese sentence withhidden subject: "*(Eu) encontrei meu neto ontem à noite*" ("(I) met my grandson last night"). Above each word of the sentence, there is a circle with a number inside, where the student can organize them using the semantic order of Libras. The example of Fig. 1 shows two differences from sign and written language; first, in Libras there are no verb conjugations, for that it was included "Past" ("*Passado*") before the word "Met" ("*Encontrei*") to specify past tense; and, second, in Libras there are no articles or prepositions, for that "*à*" receives a circle with an 'x' mark

above it (instead of a circle with a number) to indicate no need to sign in Libras.

Fig. 1. Example of Semantic Numbers [14, p. 61].

Flower and Hayes [19] state that the writing process involves three main elements: (i) The rhetorical problem, which refers to the problem, purpose, and audience of the text; (ii) The long-term memory, which refers to the knowledge about the topic, the target audience and the writing strategies; and, (iii) Writing process, which refers to the author monitoring his/her own progress, including the following three steps: planning (organizing, goal setting), translating (putting the idea on "paper") and reviewing (evaluating, revising). From this, we highlight that the AT product under design must be able to provide the construction of knowledge by the student, beginning with small phrases stepping up to complex texts.

III. Methodology

Originally, the Cycle for Adoption of AT [28], represented in Fig. 2a, was designed to know the environment and the stakeholders, to select an AT suitable for both, to train stakeholders to use of the AT in the environment and to evaluate this use. The authors mention developers' characteristics; however, this group may not represent stakeholders of the At adoption process, having as activities to provide support or training. Furthermore, as the research team wanted to conceive a new AT product, it was necessary to use the HCI lifecycle [35], represented in Fig. 2b, which included other techniques, such as, ideation and prototyping, for example. After studying these theoretical bases, we realized that stakeholders should jointly participate applying those techniques, and, for this, Co-design [4], represented in Fig. 2c, could be "conducting wire" of the proposed framework.

The proposed framework architecture includes stakeholders as co-authors and it is presented in Fig. 2d. This proposal consists of four phases, namely: (Phase 1) Explore and Understand, grounded by the Development phase [28], Identify Needs phase [35] and Informal layer [4]; (Phase 2) Design and Develop, grounded by the Selection and Learning phases [28], (Re)Design and Prototype phases [35] and Formal and Technical layers [4]; (Phase 3) Evaluate, grounded by the Integration phase [28], Evaluate phase [35] and Technical layer [4]; and, (Phase 4) Monitor, grounded by the Integration phase [28].

During the Explore and Understand phase, eight activities were conducted, as shown in Table I, numbered from A1 to A8.

For the activities (A3, A4, A5 and A7) stakeholders participated in, research objectives and proceedings were explained, and they were requested to read and to sign the Informed Consent Form (ICF), if they agreed to willingly participate.

From Table I, with Theoretical Studies (activity A1) aimed to understand basic concepts and to support the framework proposal for the AT product design and adoption, starting with theoretical base concepts, on Co-design [4], Adoption of AT [11] [21] [28] [36], HCI lifecycle [35], Semantic Numbers [13] [14] [5] [15], AT [6] [27] and Writing Process [19]. Literature Reviews (A2) were conducted and have been updated with related works, aiming to learn what has been investigated in these topics of interest.

As the next activity of the Explore and Understand phase, we needed to find out who would stakeholders be of the AT product under design. For this purpose, we used the Stakeholders Diagram artifact from the Informal layer of the Semiotic Onion [4] (A3). Using this artifact, representatives - initially defined by the research team - were invited to participate in the 1st SPW.

The 1st SPW happened with two different groups, on different dates in the same month. From I, A3.1 and A3.2 represent sessions conducted in person, which were respectively conducted in two different locations, with the assistance of a Libras interpreter.

Also, A3.3 shows a third group which answered an online survey with the same content as in person sessions. The decision of applying an online survey to collect additional information was based on the impossibility of having a large number of representatives to participate; they were listed as stakeholders by the research team.

During these in person SPW sessions, first, the artifact was explained and some examples were given to each circle. Later, participants started to raise ideas from stakeholders and to discuss if their ideas could be in each layer. All the answers from the Deaf participants were written through the intermediation of a Libras interpreter, who assisted the communication between the research team and participants.

In order to closely know who some of these stakeholders are (life context, abilities, needs and activities) and to create Personas (A6), six interviews (A4) were conducted and three surveys (A5) were applied. For Pratt and Nunes [34], the technique of creating Personas can provide an easier way to find patterns among stakeholders' profiles, as well as allowing identifying differences among a group of stakeholders that could be believed to behave or to interact as a pattern.

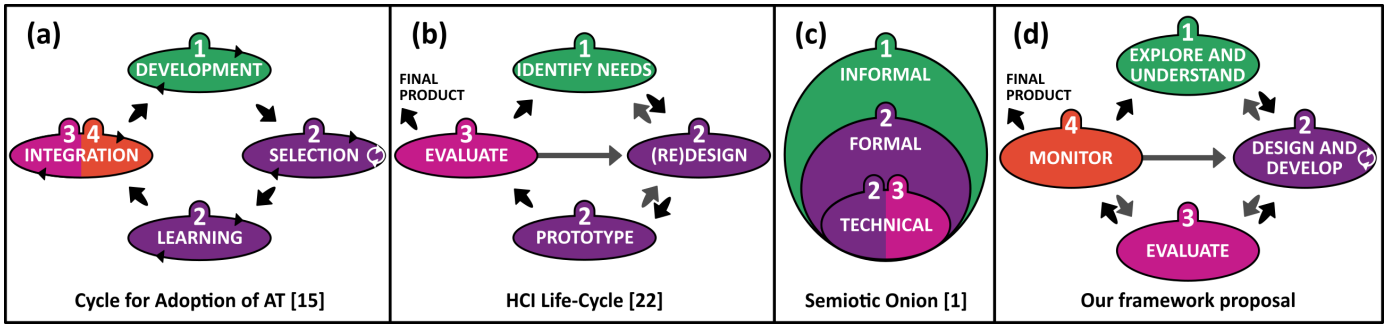

Fig. 2. Framework proposal architecture [31].

TABLE I
ACTIVITIES (A#), PARTICIPANTS AND TIME TABLE OF THE EXPLORE AND UNDERSTAND PHASE

Activity	Participants	Time table
(A1) Theoretical studies	Research team.	Feb-Mar 2018
(A2) Literature review	Research team.	Feb-Mar 2018
(A3.1) 1st SPW: Stakeholders Diagram	01 Deaf person; 01 Libras interpreter; 01 Information Systems (IS) undergrad. hearing student.	Apr 2018
(A3.2) 1st SPW: Stakeholders Diagram	03 people who are Deaf; 01 Libras interpreter; 02 hearing students from the IS course.	Apr 2018
(A3.3) 1st SPW: Stakeholders Diagram (online survey)	02 hearing teachers of Specialized Educational Assistance (SEA)[2]; 01 hearing professional of Pedagogical Support; 01 Linguistic undergrad. hearing student; 01 Libras interpreter; 03 IS undergrad. hearing students; 03 professionals from the computing area.	Apr 2018
(A4) Interviews	06 people who are Deaf (in person with the Libras interpreters' help.	Apr-May 2018
(A5) Profile survey	03 Libras interpreters, (being 02 conducted online and 01 in person.	May 2018
(A6) Personas	Research team.	May 2018
(A7) 2nd SPW: Evaluation Frame	01 Deaf person; 01 hearing SEA teacher; 01 Computer Science Master degree hearing student.	Dec 2018
(A8) Requirements elicitation	Research team.	Dec 2018 Dec 2018

The Evaluation Frame artifact, also from the Informal layer [4], was used for identifying problems/questions and ideas/solutions to each category of stakeholders, defined with the Stakeholders Diagram (A3). The Evaluation Frame was designed during the 2nd SWP (A7), in order to know what stakeholders understand as problems or have doubts about the teaching-learning process of a written language by people who are D/HH, and ideas or solutions they have and can be discussed as potential requirements for the AT product under design.

As the final activity of Phase 1 (Explore and Understand), requirements were elicited (A8) by the research team, based on these seven activities previously conducted.

IV. RELATED WORK

One of the topics of interest (Focus and Scope) of SBC JIS is "Accessibility", being a valid repository to search for related papers. Knowing that, a search for related works was conducted in the JIS; however, papers that included some of the following keywords were not found: codesign OR co-design; auditive, auditory; "hard of hearing"; Portuguese AND learning OR teaching; disabilit*. On the other hand, 22 papers were found for the following keywords: educat* (12), accessibility (4), "sign language" (2), deaf (1), "assistive technology" (1), "participatory design" (1), impair* (1). From these results, some repeated papers were found among different keyword outcomes: one in "sign language" and deaf, one in "assistive technology" and educat*, two in accessibility and educat*; also, two Editorials and one research group report, returned as results from educat* search, were discarded and the paper from impair* search was not related to the theme of interest. Thus, 08 results were discarded, 14 papers remaining to be read and analyzed.

From 06 papers included for reading from the initial search using the keyword *educat**, four of them can be interesting for reflecting on the following approaches for the design of educational systems: Tangible Interfaces to consider a different type of interaction [37]; Comparison between automatic and human evaluation of users' learning outcomes [2]; Collaborative learning in a virtual learning environment [33]; and The use Semiotic Inspection Method for communication evaluation [42].

Among the 04 papers included for reading from the initial search using the keyword *accessibility*, one of them was related by the techniques used. Thus, the paper Menezes, Hornong and Baranauskas [30] evaluated the use of a mobile application for informal real-time communication (Whatsapp) in a formal educational setting. The authors used three types of artifacts to understand potential users, context, tasks and technology: stakeholders diagram, evaluation frame, and semiotic ladder. The application was used for warm-up, before classes and, as a result, Menezes, Hornong and Baranauskas [30] mention that "For this process to be effective it is essential that the mobile application usage makes sense not only from a technological point of view but also from a pedagogical point of view" (p. 37).

The paper with the keyword *deaf*, by Ascari, Pereira and Silva [3] discloses results and discussion on a systematic review about the interaction with Augmentative and Alternative Communication (AAC) systems for mobile applications. According to authors, three papers mention deaf or deaf-blind users in this context, whereby the use of images and pictograms, automatic translation and learning gestural language have been investigated.

Both papers found keyword "sign language" are briefly described in this paragraph. Silva et al. [41] developed a formal language to describe Libras signs, called FleXLibras, and a collaborative system to construct a vocabulary in Libras, called WikiLibras. According to the authors, FleXLibras makes possible to represent Libras through 3D avatars and automatic creation of Libras videos. Anjo, Pizzolato and Feuerstack [1] investigated real-time requirements for Libras automatic recognition, using static and dynamic images as input to test image processing and artificial intelligence algorithms. These two papers clearly show that to represent and to recognize sign languages, and by analogy, to learn are not trivial tasks. They have specific grammar and are complex due to their intrinsic characteristics of being visual and gestural.

For "participatory design", the paper by Rodrigues et al. [39] was found, in which four steps of the Personas Enrichment Process are followed for the therapeutic domain solutions design, namely: identification of stakeholders, characterizing the users, creating the Personas, and presenting and validating the Personas. In this case, participatory design is the method adopted by the authors to enrich the process of creating Personas.

Besides the review conducted on JIS, we found the work by Ferreira and Bonacin [17] with a semiotic study to analyze the barriers on the Web for people with hearing loss. For this, the authors used "Artifacts and methods from Organizational Semiotics [...] in the elicitation and analysis of problems, barriers, as well as solutions" [17, p. 694] during sections of participatory design. For these sections, participants could register their insights "on post-its using the written language, or could be explained with the use of the interpreter for translation" [17, p. 699].

V. Results and Discussions

In this section, we present results and discussion from three activities conducted during the Explore and Understand phase, A3 (Stakeholders Diagram), A7 (Evaluation Frame) and A8 (Requirements elicitation). Results and discussion from activities A2 (literature review), also A3 (Stakeholders Diagram), A4 (interviews), A5 (profile survey), and A6 (Personas) can be found in [32].

A. Stakeholders Diagram artifact

From the results of the 1st SWP, conducted through two in person sessions, A3.1 and A3.2, and one online survey, A3.3, stakeholders were listed by participants. Fig. 3 shows the artifact with participants' opinions.

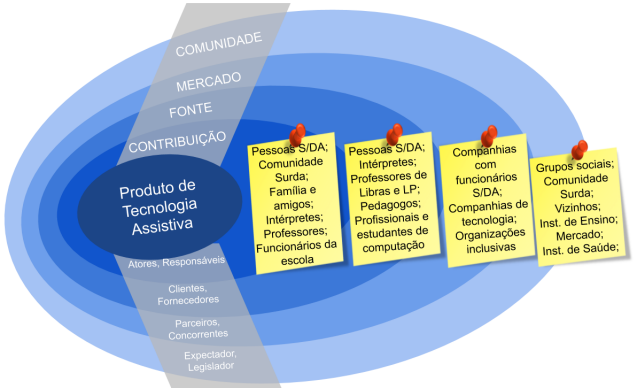

Fig. 3. Stakeholders Diagram of the 2nd SPW (A3)

For the circle Contribution (main actors) were identified: people who are D/HH, Deaf Community, family and friends of people who are D/HH, Libras interpreters, teachers (SEA and regular classroom), and school employees.

For the circle Source (clients, providers) were defined: people who are D/HH fluent in Libras, Libras interpreters who are specialists, teachers of Libras and/or Brazilian-Portuguese language, pedagogy professionals which have contact with the Deaf Community, and professionals and students of the computing area.

For the circle Market (collaborators, competitors) were identified: companies that have employees who are D/HH, technology companies, and organizations that seek for social inclusion.

For the circle Community (bystanders, legislators) were defined: social groups (such as associations engaged in the struggle of the Deaf Community), people close to the environment (for example, neighbors), government, educational institutions, labor market, health institutions, and the Deaf Community. From this list, we can observe that some stakeholders appear in different circles, such as people who are D/HH, Deaf Community and Libras interpreters. These results may show that these stakeholders are important representatives to collaborate and they may influence different social and/or professional circles.

B. Evaluation Frame artifact

Having results from the Stakeholders Diagram, we started planning the 2nd SWP (A7), in order to collaboratively use the Evaluation Frame artifact for brainstorming.

Before the 2nd SWP, we modified the original artifact, including extra information to each field, aiming to make it more accessible to the stakeholders, to which we added: (i) Stakeholders' type in each layer aiming to point out who they are; (ii) Red color and question mark to indicate the problems and questions column; and, (iii) Green color and a lamp symbol to indicate the ideas and solution column. Fig. 4 shows this altered artifact at the end of the SPW.

This workshop happened in a computer lab of the University and seven people were invited beforehand. However, on the scheduled workshop date, only three volunteer participants were present. Among the invited participants absent, there were a Libras interpreter and a hearing Libras teacher.

Fig. 4. Evaluation Frame of the 2nd SPW (A6)

During the 2nd SWP, three volunteers participated: one Deaf person, one hearing teacher of SEA and one Computer Science (CS) Master degree hearing student and three researchers: two undergraduate students and one supervisor. Before starting to use the artifact, a profile survey was applied to participants, whose answers are displayed in Table II.

The participants were representatives from two layers of the Stakeholders Diagram; P1 is a stakeholder from two groups, the Contribution layer, for being a Deaf person, and the Source layer, for being a Libras teacher. P2 is a researcher in the HCI area, being a representative from the Source layer. P3 is a teacher in SEA with experience in Deaf students education, being a representative from Contribution layer.

In the original methodological steps of the Evaluation Frame artifact [4], participants should write ideas in post-its and display them on a board. However, during this artifact execution, there were participants interacting as the original proposal and there were participants who asked the research team to write their problems and solutions and to display them on the board. Also, members of the research team included their own problems and ideas to stimulate participants to interact. Fig. 5 show a picture of the 2nd SWP context, with one researcher and the three participants.

TABLE II
PARTICIPANTS (P#) PROFILE

	P1	**P2**	**P3**
Characteristic	Deaf person	Hearing person	Hearing person
Age	29	23	48
Gender	F	M	F
Education	Libras Undergraduate student	CS Master degree student	Specialized in Psycho-pedagogy and in SEA
Professional occupation	Temporary Libras teacher	Scholarship student	Elementary school teacher
Previous participation in a workshop for technology design	Yes, during Undergraduate thesis	No Yes, during Undergraduate projects and internship, and Master's projects	No
Stakeholders Diagram	Contribution and Source	Source	Contribution

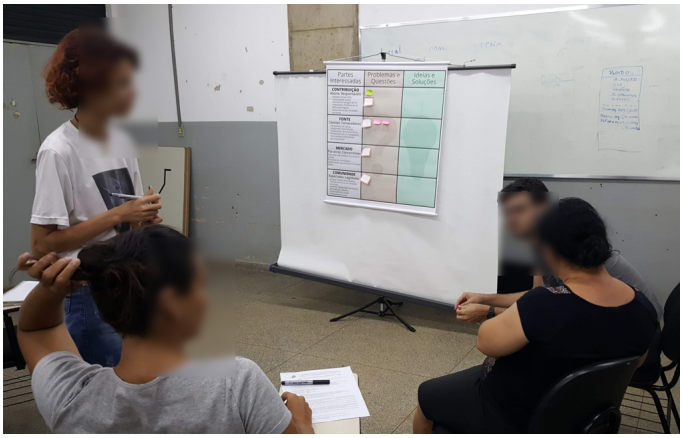

Fig. 5. Context and participants of the 2nd SWP: Evaluation Frame (A7)

Table III shows participants' responses to problems/questions and ideas/solutions concerning 'Contribution' stakeholders (main actors).

Problem/question 1 ("Read and interpret data in some systems") and Problem/question 5 ("How to keep Deaf students motivated with their own text productions?") refer to the difficulty of people who are D/HH to read and to write long texts in written language. Four ideas for this problem were highlighted by participants: Idea 1 ("Multimodality is important, it allows several ways to access information"), Idea 5 ("Explore contextualized images and texts to work with people who are D/HH"), Idea 7 ("Use of videos with subtitles and Libras"), and Idea 10 ("Images showing who the content's author (e.g., History class)"). Those ideas show the importance of working with visual aspects to provide different types of

TABLE III
EVALUATION FRAME RESULTS FOR THE CONTRIBUTION LAYER

Contribution (Main Actors)	
Problems and Questions	**Ideas and Solutions**
1. Read and interpret data some systems.	1. Multimodality is important; it allows several ways to access information.
2. Will this technology be useful for undergraduate people? who are D/HH?	2. Practice of Libras (by hearing learners).
3. Text the Deaf student production is always written in his/her language and at a second moment the correction is made to Portuguese (by the teacher).	3. Stimulate the use of free software for content production.
4. Will the proposed technology be concerned about different of complexity of Libras?	4. Deaf people would prefer to use cell phones (access on any device).
5. How to keep deaf students motivated with their own text productions?	5. Explore contextualized images and texts to work with deaf people.
6. How to present non-verbal expressions and gestures (could videos be better than 3D animation?)?	6. Users can/must be content designers.
	7. Use of videos with subtitles and Libras.
	8. Awareness (identification) of what is (in)correct, both for hearing and deaf users.
	9. Be aware of language parameters of the Libras.
	10. Images showing who the content's author is (e.g., History class).
	11. Gamification.

visualization for the same information available, through the use of images, videos and/or animations. Desire a product with a multimodal perspective shows that a group of people who are D/HH can be diverse.

Problem/question 2 ("Will this technology be useful for undergraduate people who are D/HH?") was displayed because the proposed AT product is to be used in the teaching-learning process of written language and to training for the ENEM essay (undergraduate candidates). For that matter, Idea 8 ("Awareness (identification) of what is (in)correct, both for hearing and for Deaf users") can be applied to answer Problem/question 2, because students have different levels of writing skills, even in higher education. Also, the participants discussed, but did not displayed as an idea, the possibility of the AT product cover not only the ENEM essay, but also academic writing, such as, articles and academic works.

Problem/question 3 ("Text production of the Deaf student is always written in his/her language and at a second moment the correction is made to Portuguese (by the teacher)") was pointed out because many Brazilian-Portuguese language teachers use this strategy to teach written language to Deaf students. In this case, Idea 8 ("Awareness (identification) of what is (in)correct, both for hearing and for Deaf users") can be an alternative strategy that may be a way to encourage students to revise their own productions and to ask for other people' review.

Problem/question 4 ("Will the proposed technology be concerned about the Libras different levels of complexity?") ask if we encompass all kinds of learners, from beginners to advanced, if content could start with easier lessons and gradually progress to more complex lessons. Idea 09 ("Be aware of the Libras language parameters") could be a response to Problem/question 4, which refers to Libras' grammar that must be respected when translated or interpreted. Also, Idea 11 ("Gamification"), in which the user could accumulate points and advance to new levels of complexity in the writing teaching-learning process.

Problem/question 6 ("How to present non-verbal expressions and gestures (could videos be better than 3D animation?)?") was presented since some tools show Libras communication through animated 3D avatars; however, an investigation must be conducted to determine which type of information display is better for context of the proposed AT product. Idea 9 ("Be aware of the Libras language parameters") also can be applied to answer this question; one participant mentioned that non-verbal (facial and corporal) expressions are not easy to be represented by animated avatars, and people who are D/HH can lose information without this sign language parameter.

As said earlier, some ideas are not associated to specific questions. For example, Idea 2 "Practice of Libras (by hearing learners)" that refers to "put themselves in someone else's shoes" and find out that the teaching-learning process of a sign (visual-spatial) language is as hard for those who know an oral-written language as the teaching-learning process of an oral-written language as for those who know sign (visual-spatial) language. Idea 3 ("Stimulate the use of free software for content production") seeks to integrate other open source technologies for content production, such as video or text editors, to discourage the practice of cracking proprietary tools. Idea 4 ("People who are D/HH would prefer to use cell phones (access on any device)") was presented because, during 2nd SPW, it was suggested that the proposed AT product would be available for desktop use since public schools have poor internet connections for online use.

Table IV shows participants' responses of to problems/questions and ideas/solutions concerning 'Source' stakeholders (clients, providers).

From Table IV, Problem/question 01 ("Can technology interfere with the interpreter's career (as a replacement)?") was given by one research team member, as an example to stimulate participants' interaction with the artifact. Nonetheless, according to Brazil (2005), Deaf students have the right to a Libras interpreter in the classroom; thus, the use of an AT product by law cannot replace a professional.

For Problem/question 2 ("How to explain the way technology works for novice users?"), participants came up with Idea 1 ("Instructional video, virtual tour, step by step, screen on screen"), showing how to access each available information/data, its objectives and possible results, and how the teaching methodology and learning outcomes evaluation will

TABLE IV
EVALUATION FRAME RESULTS FOR THE SOURCE LAYER

Source (Clients, Providers)	
Problems and Questions	**Ideas and Solutions**
1. Can technology interfere with the interpreter's career (as a replacement)?	1. Instructional video, virtual tour, step by step, screen on screen.
2. How to explain the way technology works for novice users?	2. Libras interpreters must communicate non-verbal expression.
3. How to integrate a new solution with other AT product?	3. Deaf person uses the Pedius application to answer phone calls.
4. Understand the linguistic process (both sign and written language).	4. Deaf person used Sony Vegas to create videos.
5. How to create accessible media?	5. Review button, and review screen (for teachers).
	6. Send presentations (teachers who do not know Libras) for translation (Libras professionals).

work.

For Problem/question 3 ("How to integrate a new solution with other assistive technology product?"), one participant mentioned two different applications for communication; one is Idea 3 ("Deaf person uses Pedius application to answer phone calls") that converts speech into text, and another is Idea 4 ("Deaf person used Sony Vegas to create videos") for video editing. Both were pointed out by the participant for being very intuitive and easy to learn.

Problem/question 4 ("Understand the linguistic process (both sign and written language)") is a about the difficulty for researchers and/or co-authors to communicate with participants and/or colleagues without a sign language interpreter intermediation.

Problem/question 5 ("How to create accessible media?") refers to people resource (sign language interpreter, technical video editing), infrastructure (special room with good lighting, soundproofing) and financial support, especially in public institutions, to produce accessible instructional materials.

There were ideas not related to problems or questions in the Source layer, such as Idea 2 ("Interpreter must communicate non-verbal expression") that refers to Libras interpretation in instructional and teaching videos, since this is one of the Libras parameters; Idea 5 ("Review button, and review screen (for teachers)"), in which the review button refers to text revision, whereby someone could mark writing problems or suggest writing improvements; the review screen refers of sending text for reviewing; Idea 27 ("Send presentations (teachers who do not know Libras) for translation (Libras professionals)") refers to having human resource available to help with the development of accessible content.

Table V shows responses of participants to problems/questions and ideas/solutions concerning 'Market' stakeholders (collaborators, competitors).

Only one problem/question was listed: "Would large companies with Deaf employees invest in training to use the proposed technology? What would the motivation be for this to occur?". Art. 93 of Brazilian Federal Law n. 8213 [7] states that "A company with 100 (one hundred) or more employees is obliged to fill 2% (two percent) to 5% (five percent) of its vacancies with [...] people with disabilities [...]". The law guarantees a place; however, training is not mandatory for the company to offer; this could be part of an internal company policy. An idea was raised for the question presented ("Investing company would advertise in Libras."); in case the company has an internal policy for employee training, this could be advertised in video (with Libras, subtitles and audio) to show its values of inclusion and accessibility.

TABLE V
EVALUATION FRAME RESULTS FOR THE MARKET LAYER

Market (Collaborators, Competitors)	
Problems and Questions	**Ideas and Solutions**
1. Would large companies with Deaf employees invest in training to use the proposed technology? What would the motivation be for this to occur?	1. Investing company would advertise in Libras.

Table VI shows responses of participants to problems/questions and ideas/solutions concerning the stakeholders of the 'Community' (Bystanders, legislators).

TABLE VI
EVALUATION FRAME RESULTS FOR THE COMMUNITY LAYER

Community (Bystanders, Legislators)	
Problems and Questions	**Ideas and Solutions**
1. Can technology stimulate hearing people to learn Libras?	1. Attention for to Legislation (Law of Inclusion).
2. A Deaf person who learns written language expands job opportunities.	
3. Respect to diversity in Deaf Culture.	

From Table VI, Problem/question 1 ("Can technology stimulate hearing people to learn Libras?") was about if hearing people know that there is a free product for them to learn Libras, would they willingly access? Idea 1 ("Attention to the Legislation (Law of Inclusion)") refers to promoting conditions of equality aiming at social inclusion [10]; to disseminate the Law may make people aware of people with different abilities' rights and culture. Idea 3 ("Respect to diversity in Deaf Culture") is complementary to Idea 1, whereby information about cultural diversity may sensitize people about wanting to learn how to communicate in sign language.

Idea 3 ("A Deaf person who learns the Portuguese Language expands job opportunities") refers to stimulating people who are D/HH to learn the Brazilian-Portuguese language, which is the other side of Problem/question 1 presented to the circle Community. In this circle, it was clear that both sides (in a mistaken of looking at the situation, if we consider a binary configuration), Deaf and hearing people, can have benefits from learning each other forms of communication.

C. Requirements elicitation

From the results of the activities A1 to A7, 16 requirements were listed and are identified by as Functional Requirements (FR) and Non-Functional Requirements (NFR) shown in Table VII.

TABLE VII
REQUIREMENTS ELICITATION (ACTIVITY A8)

Item	Requirements	Description	Activity
NRF1	Durable AT	Providing durable AT product, for long-term use.	**A1**
NFR2	Easy to customize	Choosing interface preferences (color, type of font, among others).	**A1**
NFR3	Neutral interface	Ensuring neutral interface language for all ages.	**A2**
FR1	Switch on/off	Providing option to enable/ disable animations.	**A2**
NFR4	Simple interface	Providing short and simple texts in the interface.	**A2; A4**
NFR5	Visual explanations	Using pictures and videos in examples and explanations; Adding images that conceptualizing highlighted words.	**A2; A4 A5; A7**
FR2	Spell checker	Reporting grammar mistakes, when available; Review button for students.	**A2; A4 A5; A7**
RF3	Dictionary	Providing dictionary access in Libras and Brazilian-Portuguese language to search words.	**A2; A5**
FR4	Word suggestions	Providing verb conjugation options.	**A4; A5**
FR5	Speech speed control	Providing gradual/paused speech option.	**A4; A5**
NFR6	Multimodality	Various formats to present the same information.	**A7**
FR6	Homework	Activities to practice Libras and text-writing.	**A7**
FR7	Instructional tour tour	Explaining how the technology works for novice users.	**A7**
NFR7	Multiplatform	Access on any device (mobile, desktop, web).	**A7**
FR8	Review screen	Teachers can revise students' work and give them feedback.	**A7**
FR9	Advertising	Libras advertisement for the	**A7**

D. Categorization of artifacts' outcomes

During the 2nd SPW, it was noticed that showing participants the Stakeholders Diagram was not enough for them to understand which representative each one was in the co-design team. To make it clear, each participant was explained which stakeholder he/she was representing. With that in mind, for the next semio-participatory workshop (to be conducted), we want to anticipate explanation by categorizing stakeholders taking into account their circle definition and labeling as proposed by Hayashi et al. [20]. Detailed categories are shown in tables VIII to XI, respectively named by circle as, Contribution circle: Advanced users and Staff; Source circle: Service providers; Market circle: Collaborators; and, Community circle: Organizations, Groups, Legislator and Institutions.

Table VIII shows the categorization of stakeholders the Contribution circle.

TABLE VIII
CATEGORIZATION OF STAKEHOLDERS IN THE CONTRIBUTION CIRCLE.

Contribution (Main Actors)	
Advanced users	People who are D/HH; Family of people who are D/HH (hearing people); Friends of people who are D/HH (hearing people); Deaf Community.
Staff	Teachers (SEA and regular classroom); Libras interpreters; School employees.

From Table VIII, Advanced users are stakeholders related to the most direct (primary) users of the AT product, such as people who are D/HH, family members and friends who want to learn Libras, and the Deaf Community. Staffs here are represented by teachers from SEA and regular classrooms, Libras interpreters and school employees; these are stakeholders who would indirectly use the AT product as a tool to assist other people.

Table IX shows the categorization of stakeholders from the Source circle.

TABLE IX
CATEGORIZATION OF STAKEHOLDERS IN THE SOURCE CIRCLE.

Source (Clients, Providers)	
Service providers	People who are D/HH fluent in Libras; Specialist Libras interpreters; Teachers (Brazilian-Portuguese Language/Libras and Brazilian-Portuguese Language); Pedagogy professionals that have contact with the Deaf Community; Computer professionals and students.

From Table IX, Service providers are those who would provide knowledge, such as people who are D/HH and are fluent in Libras, specialized Libras interpreters, teachers and pedagogy professionals; besides, computer professionals and students would be included during the AT product design process.

The Table X shows the categorization of stakeholders from the Market circle.

TABLE X
CATEGORIZATION OF STAKEHOLDERS IN THE MARKET CIRCLE

Market (Collaborators, Competitors)	
Collaborators	Companies that have Deaf employees; Technology companies; Organizations that seek social inclusion.

From Table X, Collaborators are represented by companies and organizations that can invest in the AT product in the search or social inclusion.

Table XI shows the the categorization of stakeholders from the Community circle.

TABLE XI
CATEGORIZATION OF STAKEHOLDERS IN THE COMMUNITY CIRCLE

Community (Bystanders, Legislators)	
Organizations	Social groups, such as associations engaged in the struggle of people who are D/HH.
Groups	Deaf Community; People close to the context (neighbors).
Legislator	Government.
Institutions	Labor market; Health institutions; Educational institutions;

From Table XI, Organizations are involved at a level of society where public policies and major decisions can be debated; they are represented by social groups, such as associations. Groups are represented by people that can be benefited by the dissemination of the AT product, such as Deaf Community and neighbors. Legislator refers to the people related to the government. Institutions are organizations that can provide AT product use to people who are daily involved with the institution context, and can be benefited by it.

As a lesson learned from the Evaluating Frame, notes are displayed in the artifact (with concerns, doubts, pains, wishes, needs, facts) from representatives, since they are the only ones that could give evidence about their personal life experiences. Since we group different types of representatives (stakeholders) in a workshop, it is interesting to hear, to see and to think about a diversity of points of view.

One point of discussion is the type of access of the proposed AT product (desktop, mobile, web). During the 2nd workshop, one participant mentioned that people who are D/HH would prefer to access the AT product using their cell phones. However, as shown in the partial results of Freitas, Souza and Straub's [18] research, teachers complain about the quality of internet connection in computer labs of public schools in our city. Thus, this fact would represent an obstacle to using the proposed product.

Another point revealed by participants is that primary users could produce content using open source technologies to be aggregated as instructional materials in the proposed AT product. People who are D/HH as content producers might be stimulated to know the technology to learn or to learn by contributing. Also, this participation could help as a solution for the problem of lack of human resource to make videos and accessible media in Libras.

As learned lesson from both artifacts from Informal layer of Co-design, we highlight a lack on the accessibility regarding people who are not fully literate in written-spoken language. In the first moment of both SPW, Deaf co-authors were shy only observing others writing their ideas in post-its and, to overcome this, the research group offered to write for them. However, this can be a barrier for autonomy of stakeholders, not encouraging them to participate as co-authors. One idea to provide a more independent participation would be to collect ideas from people who are D/HH in the format they wish, for example, in Libras and, then, transcribe their ideas to the post-its.

VI. CONCLUSION

Our proposed framework grouped concepts of three research methodologies: co-design, AT adoption framework, and HCI lifecycle. Also, pedagogical strategies of Semantic Numbers and Writing process are being studied to compose the teaching-learning process of the proposed AT product.

All the three research methodologies share a key factor that is basically "stakeholder"-centered design, which means that not only primary users are important but everyone around. Kintsch and DePaula [28, p. 4] mention that "Developers also face the challenge of learning not only about users' preferences, knowledge, attitude, goals and abilities, but also those of the caregivers". Authors cited caregivers, however, analogically, in our case, stakeholders are people who are D/HH, Libras interpreters, teachers, parents, friends, neighbors, among others. In this sense, interviews with people who are D/HH and Libras interpreters were essential to know their relations with Libras, Deaf Culture, Brazilian-Portuguese Language, ENEM and computer use. Although people who are D/HH share the same characteristic, which in this research is to be sign language users, each individual has his/her uniqueness, skills and experiences to share and to interact with the world.

According to INEP [22], since written Brazilian-Portuguese is not the first language of Deaf, Hard of Hearing and Deaf-blindness candidates of ENEM, the essay exam has a special review, favoring content instead of form. Nonetheless, the special review does not reduce the low performance of the people who are D/HH in the essay exam, as seen in previous research [32]. Problems in essay exams for Deaf candidates, who communicate primary in Libras, begin with interpreting and understanding the statement with the reading task, and gets even harder with the writing task. With this, research motivation is stated to improve the autonomy of the people who are D/HH in the written language teaching-learning process.

With the Stakeholders Diagram use, as an artifact of Co-design, stakeholders of the proposed AT product were categorized to clarify who could collaborate during the next phases. With the Evaluation Frame artifact, some problems and solutions were raised by the people that have roles in the context. Continuing this work, we have selected and conducted evaluations on a related available AT product as an activity of Phase 2 (Design and Develop) of the framework [31].

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