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Challenges of knowledge management and creation in communities of practice organisations of Deaf and non-Deaf members: requirements for a Web platform

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This study analysed the role of knowledge management (KM) tools used to cultivate a community of practice (CP) in its knowledge creation (KC), transfer, learning processes. The goal of such observations was to determine requirements that KM tools should address for the specific CP formed by Deaf and non-Deaf members of the CP. The CP studied is a formal knowledge organisation based on learning and the evaluation of socio-linguistic aspects pertaining to the Brazilian Sign Language (Libras). Non-Deaf and members of the Deaf community cultivated such knowledge organisation through specific collaborative meetings and the use of Internet-based tools for KM. Knowledge was created to validate an intellectual artefact (a computational description model of the phonetic structure of Libras (PSL)) to be used as basis in the development of tools to aid the Deaf community in their learning, communication, informational, educational and other needs necessary for full exercise of citizenship. The Internet-based KM tools were paramount for the cultivating of the CP. Nevertheless, additional requirements for the KM tools emerged, such as: video-conferencing, video manipulation features, better management of asynchronous communication, among others.

Keywords: community of practice; deaf; collaborative meetings; knowledge management; knowledge creation

1. Introduction

Initially driven to reclusion, and mistreated clinically as not normal, the deaf struggled for years in order to be considered as members of a minority, thus lagging behind when compared to non-deaf people and in greater need for scaffolding tools. Deaf is a term used for those who partake in the visual, gestural, sign language (SL) and culture – a movement that considers deafness not as a deficiency, but rather as a human experience) and non-deaf (a preferred term to refer to hearing people, and hearing stakeholders, such as parents, families, educators, etc.). The members of the deaf communities are now regarded as individuals with special needs whose inclusion should aggregate social, political and citizenship dimensions. These dimensions take many forms, such as full access to information, knowledge creation (KC), education, among others, all of them in their own language (i.e. SL). Citizenship inclusion of the deaf means their integration with rights and duties in participating in their social environment (Skliar 1999). The denial by society of their basic needs have excluded the deaf, and caused dire consequences: lack of acquisition of a natural language, lack of education, etc.

Collaborative interactions are relevant for human, social, historical and political formation of the individual, and may aid in the creation of the deaf's identity. A good practice is that such activities be mediated (by computer systems and other members of the deaf community – a community that holds the deaf culture and issues such as education, citizenship, etc., comprised of deaf and non-deaf) as interactive interlocutors scaffolding the sharing of social languages, so that the deaf may create and share knowledge with non-deaf (Arcoverde 2006, p. 255). According to Arcoverde (2006),

> 'the ties established form the dialogic and ideological ties needed for the multi-lingual encounter of utterances, voices, intonations, themes and points-of-view, thus creating a new space for social interaction for the Deaf'.

Collaborative online systems over the Internet are powerful tools to bridge some of the gaps, and bring the deaf communities together, in communities of practice (CP) around a given subject. A CP is a formal organisation composed by a group of people who share a certain interest on a subject and want to learn

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about it. Web platforms, discussion meetings, practices, exchange of experiences and other activities can mediate the learning in order to create, transfer, manage knowledge on the specified knowledge domain (Wenger and Snyder 2001).

Most of the issues faced by the members of the deaf community can be related to language-dependent occurrences, and are hindrances to KC and require tools to aid them in their task. Antunes (2011) and Guimarães *et al*. (2011) present a computational description model of the phonemes of Libras (Brazilian sign language), based on the study, compilation and adaptation of phonetic models, developed by linguistic, for computational use. The phonetic structure of Libras (PSL) is an intellectual artefact used on Internet-based collaborative tools designed for a CP formed by members of the deaf community for KC, learning, transfer, management, among other tasks about Libras. An intellectual artefact is a product created by an intellectual activity, based on the interpretation of a problem and the conception of the solution, presented in a linguistic code (de Souza 2005).

KC theories and knowledge management (KM) tools were thus combined and evaluated in their role of cultivating such CP in an educational/learning environment. The main contributions of the present study are that modules of the KM system that proved useful for KC in the CP under study are pointed out, along with new requirements necessary to address the problems that emerged during the research that the KM system did not contemplate (e.g. videoconferencing).

2. Objective

The main objective of this article is to present the results of the investigation of the role of KM tools in cultivating a CP in the form of system's requirements. The discussion is anchored by theoretical aspects of KC in a CP formed by deaf and non-deaf members. Results include both asserting the KC tools expected and registering additional features required by the Internet-based KM tools in the cultivation process of such CP.

Thus, the present study is an account of the use of a KM tool in a CP organisation that emerged with the purpose of cultivating a space that would allow the interaction between deaf and non-deaf in order to collaborate through the study of SL; the results present needs and requirements necessary to inform the development of intellectual computational artefacts that must be developed to perform such tasks as knowledge registration, socialisation and citizenship awareness, among others.

3. Methodological steps

In order to achieve the goal, several meetings of the CP cultivated by the use of the PSL and formed by non-deaf and deaf students of an undergraduate course in linguistic with emphasis in Libras was studied. The social and technical protocols for the meetings (i.e. the system, the format, the role of each participant among other things) were designed to provide an interaction environment between deaf and non-deaf participants that should allow collaboration for KC and learning within the organisation. These meetings were conducted to identify a set of minimum representative signs in Libras for each parameter described in the computational description model of the PSL (Guimarães *et al*. 2010a, 2011, Antunes 2011), and were ethnographically studied in order to generate the systems requirements.

There were in total 16 meetings during a period of two months, with at least an interpreter, and other members of the deaf CP in each meeting. The meetings lasted for no longer than 2 h, and were recorded for additional analysis. The studied CP centred on collaboration and KC about linguistic aspects of the Libras (Brazilian sign language), mediated by KM tools adapted from Gimenez *et al*. (2010).

The environment in such CP presented a major challenge regarding communication and knowledge sharing between members of different backgrounds, cultures and languages. A basic procedure was to establish a '*modus operandis'* that primarily contemplated and respected the differences, and then build on those differences to better cultivate the CP through collaboration. In each meeting, the meaning occurred within a democratic environment that was conducive for each participant to be aware of her role, practices and responsibilities during the meetings; also, an environment that would allow each and every participant to actively take part in all aspects of the tasks at hand, with a voice in tasks such as gathering information and using it to solve the problems that emerged.

The deaf were mostly responsible for sharing their knowledge in Libras, and use that knowledge for the purposes of the CP aforementioned. Thus, they were the main contributors in the KC process of the CP, by sharing information, experiences and skills in order to improve the overall intellectual artefacts deemed to be desirable in order to inform the design of supporting tools for the needs of the deaf communities.

The social and technical protocol of each meeting was designed to allow a process of socialisation, collaboration, discussion and debate among all members of the CP, to promote the KC and exploration of the signs of the Libras based on the PSL model. The steps are as follows:

(1) Choose a sub-unit (parameter) of the PSL model;
(2) Select a value of the selected sub-unit;
(3) Ask participants about signs that contain the value in question;
(4) Discuss and debate each sign of the specified set;
(5) Reach a consensus on the form of each sign (in relation to the sub-units);
(6) Record each sign in video and store it in the KM tool;
(7) Describe each sign according to the PSL model and record it in the KM tool;
(8) Repeat steps 2–7 until all the sub-unit values have been discussed in CP.

As pointed out before, the authors of the present article were participants of such meetings, in order to ethnographically observe and derive the requirements for a KM system to address the issues of cultivating the CP.

4. Communities of practice, collaborative environments and their relations

Community of practice (CP) is defined by Wenger (2010a) as a group of people who share an interest or passion about a subject. Members of such a group try to interact regularly in order to augment their knowledge on the subject. According to Wenger (2010b, p. 179),

> 'The concept of community of practice was not born in the systems theory tradition. It has its roots in attempts to develop accounts of the social nature of human learning inspired by anthropology and social theory'. (Lave 1988, Bourdieu 1977, Giddens 1984, Foucault 1980, Vygostsky 1978)

A CP is a special organisational environment that favours learning through the interaction of their members as individuals with similar interests, projects, motivations and challenges (Terra and Gordon 2002). People bring different sets of skills, experiences and knowledge to the group, with each individual contributing in her particular manner to generate ideas, solve problems or make decisions. These opportunities to exchange knowledge and experience make learning and problem solving faster in relation to the correspondent time period in which an isolated individual would achieve the same goals (Wenger and Snyder 2001). Such learning interactions in a collaborative space can benefit from the use of Web platforms, like KM tools, to promote both formal and ad-hoc learning, as this article will show.

A CP is structured in three elements (Wenger 2001): (i) the domain (common interest of the group); (ii) the community (interaction and bonding dictated by the common interest); and (iii) the practice (process by which members of the CP learn about their subject of interest). CPs and collaborative environments are very similar, as both bring people together for a common subject and collaborate to achieve a common goal through interactive activities that contribute for KC in a specific domain.

Collaboration is a shared creation process in which two or more individuals, with complementary skills, interact to create a knowledge that they neither had previously nor they could obtain alone. Collaboration can also be considered a way of social interaction that creates a shared meaning about a process, product or event (Collis 1993). CP are spaces of collaboration that promote learning through physical or visual contact, 'with the purpose or need to solve problems, exchange experiences, build models techniques or methodologies, with the intent to cultivate the best practices' (McDermott 2000).

In collaborative environments, such as CPs, members must perform their tasks, discuss ideas, identify inconsistencies and failures in their reasoning; they must be able to explain the advantages and disadvantages of their strategies, to solve problems, among others. Therefore, it is paramount that the environment provides techniques, methodologies and tools for communication, coordination and cooperation.

5. Knowledge management and the CP

Knowledge management (KM) is a 'collection of processes that govern the creation and dissemination of knowledge [...]' (Lee and Yang 2000, p. 784). Cruz (2002) defines KM as a set of methodologies and technologies aimed at creating conditions to identify, collect, analyse, store, retrieve, disseminate and use knowledge that exists in all sorts of organisations. Collaboration can also be seen as helpful to KM in general and CP in particular.

As types of knowledge, Nonaka and Takeuchi (1997) think of the tacit knowledge as that related to the private experiences each individual has, the skills, beliefs and situations experienced in daily lives. As for the explicit knowledge, the authors refer to grammatical assertions, texts, manuals, graphics, spreadsheets and other sort of explicit material that may compose a database. The authors claim that both types of knowledge should interact and play complementary roles, in a process denominated knowledge conversion that often occurs in CP.

Takeuchi and Nonaka (2008) explain four ways in which tacit and explicit knowledge are intertwined in the knowledge conversion process, SECI: (i) *Socialisation* (where tacit knowledge is shared): consists in

sharing a tacit knowledge in order for others to create tacit knowledge through direct experience; (ii) *Externalisation* (from tacit to explicit): articulation of the knowledge tacit by means of dialog and debating; (iii) *Combination* (explicit to explicit): knowledge is collected and systematised; and (iv) *Internalisation* (explicit to tacit): knowledge acquired is used in practice. The process described is the core of the SECI spiral of knowledge model of the mentioned authors, used to help KM to create knowledge.

KM requires a new work culture named CP (Lave and Wenger 1991, Wenger 1998, Carroll *et al*. 2003). KM is a continuous social process of goal clarification that requires commitment, constant encouraging of mutual learning and the increasing development of skills (Carroll *et al*. 2003). According to Picchiai *et al*. (2007), CPs are important tools for learning that favour the development of intellectual capital and consequent individual competences. CPs integrated to KM tools promote the creation and dissemination of knowledge (Picchiai *et al*. 2007). KC, one branch of KM, has been recognised as strategically important for knowledge and innovation; several works about KC are centred in the organisation of learning, with the goal to facilitate conversion and transfer of knowledge in its forms (tacit and explicit) (Nonaka 1991, Nonaka and Takeuchi 1994).

KC in a CP occurs in various situations during collaboration, through information and experience exchanges, through observation and assimilation of specific intrinsic skills from each participant, by the exchange of ideas for decision-making and problem-solving. In the CP, information exchange may occur tacitly or explicitly. KM (as support for KC, sharing, storage, retrieval and use) and the use of the SECI model will be used to effectively account for the diverse people from all walks of life that formed the CP studied – different skills and experiences, constantly interacting, collaborating in projects, sharing and creating knowledge.

6. System design and KC process

Additionally, knowledge refers to beliefs and commitments; it is related to action and, as such, it is a function of attitude, perspective or specific intention (Nonaka and Takeuchi 1997). The authors also consider that 'knowledge is a dynamic human process of justifying the personal belief in regards to the truth'. These concepts emphasise knowledge as essential to human action.

Dubberly and Evenson (2011) related Nonaka and Takeuchi's SECI model and the Dubberly *et al*. (2008) analysis–synthesis bridge model as models for system design. Dubberly and Evenson (2011) claim that the system design process leads to the acquisition of new knowledge through observation, consideration and repetition of the steps in the process. Mutatis Mutandis, the authors also claim that learning is also a form of designing. This way, 'if we can find robust models of learning, they might prove useful in designing and might suggest ways to improve the design process' (Dubberly and Evenson 2011, p. 75). Figure 1 shows the innovation model that relates the SECI and the Bridge Models.

Dubberly and Evenson (2011) tell us: 'Observing the current situation is a form of socialisation'; 'Modelling the current situation is a form of externalisation', 'modelling a better situation is a form of combination' and 'instantiating a model is a form of internalisation'. Thus, it can be seen that knowledge eliciting from stakeholders is a way of socialisation in which tacit knowledge is obtained by means of interaction and observations of such interactions (the research phase). The 'analysis' process articulates tacit knowledge into explicit so that it may be shared by others to become new knowledge. During the 'synthesis' phase, the concepts are explored and processed, creating a new explicit knowledge. Finally, during the 'delivery' phase, a new level of knowledge is created, mainly because the concepts are formally established, opening up, then, space for new tacit knowledge – in a similar manner in which the 'spiral of knowledge' of the SECI model works. The SECI and the innovation model served as basis for the analysis presented here, allowing verifying the process of KC within the CP and

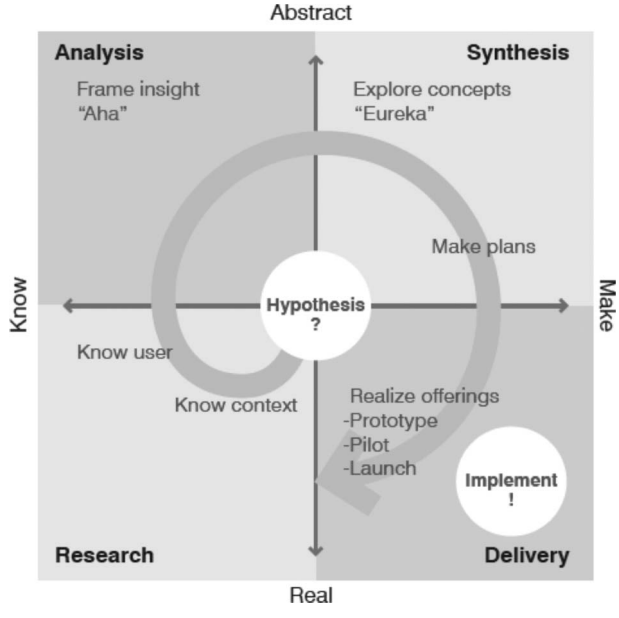

Figure 1. Innovation model. Source: Dubberly and Evenson (2011).

the further requirements for an effective learning system.

7. Computational description model of the PSL as an intellectual artefact

One of the tools the deaf have to grant the effectiveness of their tasks is the SL. The Brazilian sign language (Libras) is used by the target community for communication, information access and identity (the feeling of belonging to a cultural community). Libras, as is the case for most SL, is a legitimate linguistic system with rules and structure (phonology, morphology, syntax, semantics and pragmatics) of gestural spatial-visual manner (the communication is performed by movements and non-manual expressions perceived through vision). SL is capable of expressing feelings, psychological states, concepts (concrete and abstract) and thinking/reasoning processes.

Members of the deaf communities are proud of their own identity, culture and capabilities, and welcome tools and environments that promote communication (especially in SL) among themselves and with the society in general. The imposition of the use of the spoken/oral language (Portuguese) of the country in which the deaf are located (Brazil) as the only option, is seen by the deaf community as dominant and oppressive, making the personal relations among the deaf and between the deaf and the non-deaf difficult.

The PSL is an intellectual artefact created by a process that deeply investigated the literature and the deaf community's use of Libras to incorporate a maximum set of representative parameters of the SL. (Guimarães *et al*. 2010a, 2010b, 2011, Antunes 2011). Such an intellectual artefact was the instrument that brought the CP together.

The PSL is a computational description model based on a compilation and adaptation of phonological models (developed within the applied linguistic field) that aggregates a high degree of details for signs description in a computational context (many variables and parameters incorporated in the model are naturally and unconsciously used by fluent users of the SL, but are necessary for further results in the computational processing) (Antunes 2011). Figure 2 shows a synthesis of the basic structure of the model with some of its main parameters.

The model was validated in the researches presented by Antunes (2011) and Guimarães *et al*. (2011) as helpful in teaching Libras, evaluating knowledge of Libras, standardising it, to help designers to build future computational tools.

The proposed model is an important element of a conceptual human–computer interaction (HCI) architecture that takes several aspects of the deaf needs into consideration. The architecture is designed to serve as basis for the development of effective tools in SL to aid social inclusion and citizenship rights for the deaf communities. Figure 3 presents an abstraction of such architecture.

The architecture proposes several frameworks, services and APIs (application programming interface) with which the various areas of computer science should work in order to build more adequate applications. The PSL model is a module of Internal API layer used, for example, to describe each sign in relation to its phonological parameters and to share the descriptions with other services and applications. Some uses for seen by the architecture are: 3D processing (automatic generation of 3D avatars), computer vision (automatic recognition of signs via video camera) and natural language processing – all to be used as services to assist the design of education tools, environments of KM and creation, among others.

8. Cultivating CP involving non-deaf and deaf people: the requirements and challenges

8.1. Analysis of collaborative meetings: what are the variables that influence KC?

In order to verify whether the KM system used in a CP environment had indeed promoted the gathering, storage, retrieval, analysis, dissemination and use of information necessary to allow the flow of information

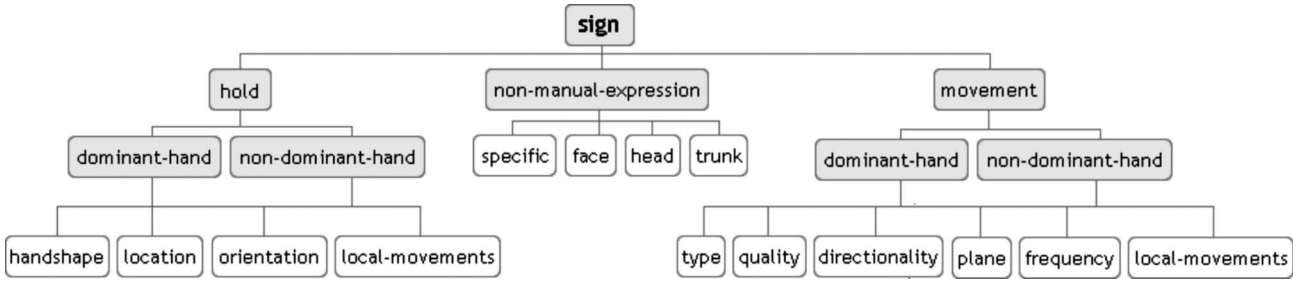

Figure 2. Conceptual structure of sign computational description. Source: adapted from Antunes (2011).

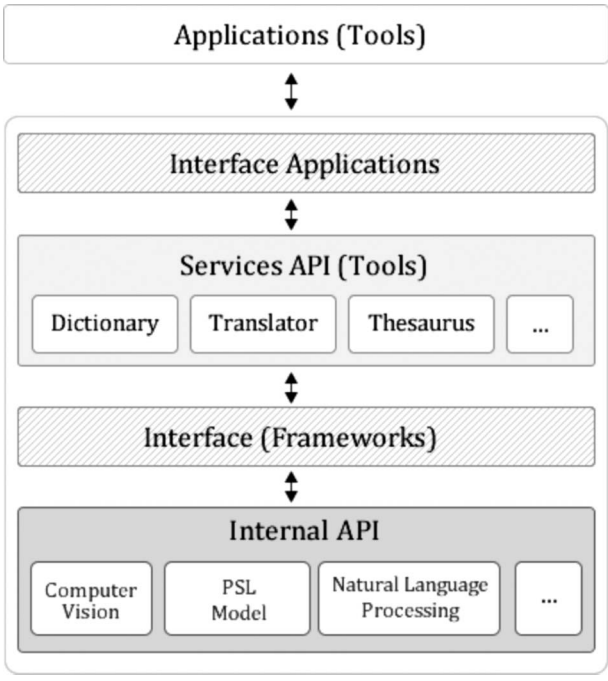

Figure 3. Services and applications in the abstraction of an HCI architecture to support development of effective tools for the deaf community. Source: Antunes (2011).

(i.e. that would permit KC), the KM system was analysed according to the SECI (Nonaka and Takeuchi 1997) and innovation models (Dubberly and Evenson 2011). These models served to verify how socialisation, externalisation, combination and internalisation of knowledge had occurred. The relationship with innovation model was analysed due to the fact that the KC can also happen within the design process, and in fact it occurred during the meetings, to the intellectual artefact (the Libras phonological model).

The analyses of the variables were carried out based on the tasks performed to promote collaboration during meetings. Some of the tasks that had to be executed during the meetings were: introduction, disclaimers, explanations the goals of the CP, instructions on how to perform the tasks, among others. Table 1 presents some results of the analysis.

The tasks performed during the meetings using the KM tool allowed for knowledge conversion, by both the SECI and innovation models, thus validating the KC expected to happen and observed to occur. Table 1 shows how all the studied variables came together during the analysis of the cultivation of the CP.

Thus informed, the main tasks performed during the meetings allowed for the improvement of the flux of tacit knowledge to explicit and vice-versa. There occurred many instances of information exchange among the members, as well as moments of discussion and reflections that lead to learning. During the interactions among the members, individual knowledge was collected, disseminated and used in order to achieve the desired goals. Some additional resources were used, such as books, Internet and dictionaries among others.

8.2. The analysis of the process. What the impacts caused by the use of tool for KC?

Carroll *et al*. (2003) describe the three characteristics a KM system must have in a CP:

(1) It must be attractive and accessible in order to stimulate the users to make effective use of it and thus gain critical mass;
(2) It must include interaction tools rich in authoring and material re-use;
(3) It must help the users is identifying the specialists and mediate the interaction with them.

Gimenez *et al*. (2010) developed an environment that offers tools to support KM that incorporate the above suggestions in its core design. This virtual environment proved to be useful to this CP considering the difficulties encountered by the deaf members in regards to locomotion and knowledge conversion. Such tool allowed for collaboration to occur remotely. Table 2 presents the main elements of the mentioned environment.

The KM platform used provided tools for sharing, storage and information organisation, as well as for KC, registration and project control, thus characterising the diverse possibilities for KC in collaborative spaces that occurred in our CP.

The KM environment was designed to receive information that aggregated value to the processes, with knowledge being stored in an information database that was accessible to all members of the CP. The members themselves inserted the data, according to predefined rules of hierarchies, cultivating collaboration and sharing of experiences and knowledge. By inserting the data and by using the tool, the members of the CP were, then, sharing and learning: the members externalised their knowledge by inputting data into the system; they also internalised by reading and making sense of the available data; and they combined and socialised by modifying and discussing the information with other members.

This storage module permitted that all the knowledge created by members could be shared to implement future activities in this CP. The forum and Wiki tools were also important to share this knowledge, as well as the questions and topics of interest to create new

Table 1. Variables that influenced in the knowledge creation (KC).

KC	Action – occurrence	Motivation/cause	KC × SECI	KC × Innovation model
Collecting	Exchange of experiences of Libras and the intellectual artifact. *Responsible*: CP	Establish communication in order to promote exchange of experience and to tighten the ties.	Tacit knowledge is collected by direct experience – socialisation	Collecting relates to research. Dubberly and Evenson (2011) research → socialisation
Storage	Register of selected signs. *Responsible*: co-authors	Perform the storage of signs to validate the intellectual artifact	Transfer, editing and storage of tacit and explicit knowledge – socialisation and combination	Storage relates to research and synthesis. Dubberly and Evenson (2011) research → socialisation and synthesis → combination
	Video recordings (by deaf) *Responsible*: co-authors	Perform the video recording of the signal for later description to validate the intellectual artifact	Video of tacit and explicit knowledge – socialisation and combination	
	Video recording of meetings. *Responsible*: co-authors	Perform the video recording of meetings to examine aspects of cooperation involved in the community of practice	Video recording of meetings – socialisation and combination	
Dissemination	Research *disclaimers* and goals explanation. *Responsible*: co-authors	Establish communication and coordination in order to motivate cooperation	Tacit knowledge is articulated – externalisation	Dissemination relates to research and analysis. Dubberly and Evenson (2011) research → socialisation and analysis → externalisation
	Hand-out of information about the tasks. *Responsible*: co-authors	Establish communication and coordination and provide means for task execution	Tacit knowledge is articulated – externalisation	
	Signaling of selected signs *Responsible*: deaf members	Sharing of knowledge with the CP	Tacit knowledge is articulated and translated – externalisation and socialisation	
Analysis	Comprehension upon the task to be performed. *Responsible*: deaf members	Analyse the information to generate the answers to the tasks.	Explicit knowledge is systematised and applied – combination-combination	Analysis (KC) relates to analysis (innovation model) and synthesis. Dubberly and Evenson (2011) analysis → externalisation and synthesis → combination
	Translation. *Responsible: interpreter*	Mediate communication between deaf and non-deaf	Explicit knowledge is systematised, applied and articulated – externalisation and combination	
Use	Responses to assigned tasks. *Responsible*: deaf members	Perform the task to achieve collaboration	Tacit and explicit knowledge are systematised and applied – Combination and Internalisation	Use relates to synthesis and delivery. Dubberly and Evenson (2011). Delivery → internalisation and synthesis → combination
	Video analysis and sign description. *Responsible*: co-authors	Describe the signs to validate the intellectual artifact	Tacit and explicit knowledge are systematised and applied – combination and internalisation	

meetings or materials within the CP, to serve as a basis for teaching and learning (in our case, the Libras) – using the distance learning tools for online classes or information retrieval tools for use in offline classes.

The environment was important to discuss the topic of interest of the CP, which socialised and created important knowledge about the Libras. In this case, the use of PSL model as an intellectual artefact served as the basis for the socialisation of the members at each meeting which collaboratively debated about the signs (from prior knowledge, experiences, etc.) creating a sound knowledge for all members of the CP.

Some discussion included the impact of each parameter of the model in communication (understanding, engagement, semantics, etc.), the understanding about the variations between each person in signalling (e.g. the degree of variation can influence the discourse analysis), the correctness of the signs (perception of the incorrect use of a parameter can completely change the meaning of a sign), among others.

Regarding the SECI and Innovation models, Table 3 shows the tools and its main processes. With the use of the models was possible to perceive that the tools, which are part from KM Environment, supported the KC at the CP. For example, in 'lessons learned' one can observe all the stages of knowledge conversion. The users registered mistakes in lessons learned and they argued how to solve them, to find a better solution, then all the members were able to consult the lessons and learn by them.

Table 2. Tools from the KM environment. Source: adapted Gimenez *et al.* (2010).

Function	Description
Project management	Complete project management tool with visualisation of several knowledge representations for better participation.
Chat	Real-time information exchange.
Forum	Sections for topic discussions.
Lessons learned	Record of Best problem solutions implemented.
Data base	Data base management. Users, skills, etc.
Distance learning/ moodle	Integration with moodle to create online courses, publish materials and knowledge evaluation.
Authoring knowledge repository	*Wiki-like* tool where members could upload their own documentation of knowledge. Also allows for collaboration and sharing.
Workflow	Tool to create fluxograms and workflows to represent the work processes.

9. Additional requirements for KM tools to empower learning in CP organisations formed by deaf and non-deaf members

9.1. Analysis of the KM tool. What are the requirements for KM tools to empower learning in CP organisations formed by deaf and non-deaf members?

The CP organisation studied, aimed at learning SL aspects and the design of an intellectual artefact, highly benefited from the use of an adapted Web KM platform for both formal and informal learning. The results of the learning experience mediated by Web platforms reported here may serve as a basis for other types of organisations that wish to consider their use within a similar context.

The tasks performed in the CP during the collaborative meetings allowed for interaction between deaf and non-deaf and the creation of knowledge in Libras, through experience exchange, task execution, meeting documentation among others. It is, thus, possible to demonstrate that the main goal of the research reported in the present article was achieved. The intellectual artefact was analysed, validated and accepted by the deaf community as well as by the researchers as a computational representation of Libras.

This study used the theoretical framework of SECI (Nonaka and Takeuchi 1997) and innovation models (Dubberly and Evenson 2011) to observe KC. These models allowed the researchers to investigate the

Table 3. Main integrated processes. Source: adapted from Gimenez *et al.* (2010).

Tool	S	E	C	I	KC	IM
Project management	X			X	Collecting, storage, dissemination, use	Research, delivery
Chat	X	X			Collecting, storage, dissemination, analysis	Research, analysis
Forum	X	X		X	Collecting, storage, dissemination, analysis, use	Research, analysis, delivery
Lessons learned	X	X	X	X	Collecting, storage, dissemination, analysis, use	Research, analysis, synthesis, delivery
Data base	X		X	X	Collecting, storage, dissemination, analysis, use	Research, synthesis, delivery
Distance learning	X	X	X	X	Collecting, storage, dissemination, analysis, use	Research, analysis, synthesis, delivery
Knowledge repository	X	X	X	X	Collecting, storage, dissemination, analysis, use	Research, analysis, synthesis, delivery
Workflow	X	X	X		Collecting, storage, dissemination, analysis	Research, analysis, synthesis

instantiantion of the processes (socialisation, externalisation, combination and internalisation from the SECI model, as well as research, analysis, synthesis and delivery from the innovation model). They were mostly performed during the execution of KM tasks.

By collaborating in the CP around the intellectual artefact, the deaf were able to formally apply and extend their knowledge of Libras. The artefact proved to be an educational tool that allowed for neologisms in Libras. As for the specific aspects of this article, the researchers were able to identify some difficulties that may also imply, directly or indirectly, in the cultivation of the kind of CP presented in this study. In this sense, these difficulties can be overcome with some improvements to augment efficiency in the use of such Web platforms for both formal and informal learning, specifically for the members of the deaf community in their relation to non-deaf.

9.1.1. Needs and requirements for training and continuing education

One of the first difficulties encountered was the lack of social proximity of the interpreter with the targeted deaf community, which generated a series of communication problems during the process due to the distinct sets of lexical knowledge held by both. Some of other difficulties were: excessive time in communication, difficulties in abstraction and communication of ideas, tasks and questions (i.e. need for constant repetition) and difficulties in recording the signs (video) in the tool (the signs, listed in Portuguese, were wrongly executed by the deaf as per the interpreter and, thus, several signs needed to be recorded again).

These difficulties can be solved by the development of modules for training and continuing education of the interpreters in the Internet-based KM platform can minimise these problems. Some alternative solutions are: (1) module of controlled vocabulary (with specific signs of each topic of interest and culture of the CP); (2) a tool to continuing involvement through the participation of interpreters in collaborative activities in online platform (observing classes, activities, etc.); (3) Thesaurus systems of technical terms specific to the area of the non-deaf members, among others.

9.1.2. Needs and requirements for effective communication between deaf and non-deaf

The second great difficulty referred to the interpretation. The interpreter was responsible for the mediation of the collaborative meetings between non-deaf and deaf members and, thus, her absence made the communication very difficult: in the case of this study, the communication was: partial – when the deaf members were oralised (or used the Portuguese in the writing form) or non-deaf members had minimal knowledge of the Libras; almost non-existent – when non-deaf members had no knowledge of Libras and the deaf members were not oralised in Portuguese.

In order to resolve this problem, certain modules can be developed for the KM platform, such as: (1) a system of access and use of an online remote interpreter (i.e. the communication can be mediated in real time on Internet-based platform for through an remote interpreter from any location); and (2) a real-time translation tool between the spoken language (e.g. Portuguese) and SL (vice-versa), through the use of 3D processing and automatic sign recognition (computer vision) and natural language processing services, which demand long term research.

9.1.3. Needs and requirements for standardisation of SL

As a third problem, the lack of standardisation of SL (Libras) was also observed. For example, the regionalisms (specific signs defined by the culture of a region) were used constantly in meetings, especially since many members were from other states. This required an additional step in the methodological process, which was the recording in video of each sign discussed (for other members to have a correct reference in future meetings or discussions). Another problem observed was in relation to the variations of each person (some variations were due to pragmatism, but most of them characterised wrong signs), the accents and the neologisms, which generated difficulties in communication at times among the deaf members themselves and with the interpreter.

The PSL model proved relevant in this context of discussing the form and structure of the signs, can be used as the basis for the development of a dictionary tool (in SL) to support the maintenance of the Libras (providing resources for future documentation and standardisation of the language).

9.1.4. Needs and requirements for KM

The fourth difficulty observed occurred during the processes of storage and retrieval of the knowledge. The deaf members had some difficulties in using the systems because the KM tool was not in the language of the user (SL). In storage, the deaf were able to record the videos, but found difficult to describe the signs in Portuguese according to the PSL model. This problem also had an impact on information retrieval because the deaf members lacked proper knowledge of

how to search the signs (previously described) in the database.

In this case, (1) the development of new interface elements and interaction forms based on SL is a resource that can improve the use of the tools in the KM platform; (2) the use of visual aids for the explanation of the parameters of the PSL model had great acceptance and, thus, a visual interface should be designed in the tool to describe the signs. In the same direction (3), a service of gestural interaction based on SL can be developed, through the automatic recognition of signs by means of a video camera. Another feature that can improve the KM tool (4) is the use of signwriting (one of the writing systems of SLs) both for the storage and retrieval of the information.

9.1.5. General needs and requirements for social inclusion of the deaf

Last but not least we can mention the deaf's difficulties in regards to locomotion to and from the meeting venues, mostly due to the lack of accessibility and adequate information in Libras about location, directions and public transportation. Some of the issues: where and how to obtain information about public transportation? How to inform the target address to the taxi driver? How to get to the place of meetings? In addition, many deaf members live in other regions, which makes this displacement even more difficult.

In order to minimise these problems of access and displacement, some modules can be developed in the KM platform, such as: (1) the improvement of the video-conferencing module to allow multiple users or groups (e.g. groups of each region in real-time, both with deaf and non-deaf members) as an alternative; (2) the development of an interaction resource through the videos (e.g. in real-time the user can point to and mark in the video, of visual manner, the parameters debated); and (3) the improvement of the collaborative modules (synchronous and asynchronous) with a translation system may be relevant in order for each member (deaf and non-deaf) to use the system in their language.

10. Weaknesses and future works

The section 9 (requirements) presented several problems found during the study. These problems impacted the development and the final result of the meeting. These problems also served to derive functional and non-functional requirements to improve KM tools in order to make the collaborative environment for KC among deaf and non-deaf members of a CP more productive and efficient in future researches (hypothesis). However, it is important to note that some of the weak points of this research, which must be addressed at future researches are mainly related to SL issues within the CP.

Although the CP goals for using the PSL model were attained, the scope of this research was restricted to the observation of requirements for KM tools as related to those goals. In other words, the PSL model is an intellectual artefact that is part of the general knowledge of the members of the studied CP, and it contains well-known properties (i.e. the model deals with the structure and sub-units the comprise the signs in Libras). Therefore, all members of the CP were able to actively interact, share and collaborate for KC. The use of another object of study may unravel different sets of obstacles and different results: (a) that would be the case when such object is not in the knowledge context of the CP members (e.g. specific areas of knowledge); or (b) a case where the objects might create a communication barrier in the interaction regarding the lack of lexicon in SL for that knowledge (e.g. in Brazil, Libras is very young, and has no signs for quantum physics, for example).

Another very important limitation of the study is that it was conducted collaboratively, but mostly co-local (i.e. the resources and the geographical concentration were conducive of a specific '*modus operandis*'). A more throughout investigation of the CP cultivation 'in the wild' (i.e. where members are really dispersed in time and place) is necessary. A vast geographical distribution, in such a big country as Brazil may bring forth some issues: (a) the interpreter will be remote, and will need aid tools regarding regionalisms, etc.); (b) the interface, as studied, was not in SL, a problem that would hinder it difficult to use 'in the wild' by the deaf members; the social and technical protocols must be revised to contemplate such environment (i.e. inclusion of new protocols for simultaneity, concurrency, synchronicity, etc.).

The results present on this article were obtained within a CP of deaf and non-deaf members from the deaf culture in Brazil. Special consideration should be taken into account when devising experiments and system development for other cultures (considering, for example, differences, such as the more advanced level of SL knowledge, etc.).

11. Conclusions

CP centred around learning, formed by members of the deaf community and non-deaf members proved to be a crucial environment for learning in such organisation types. The presently related research used a model of the phonology of SL as the central learning theme, classical theories of KC (such as the SECI model) as well as novel theories relating KC and design (the innovation model) and KM tools to aid the cultivation of the intrinsic interactions.

The combination of the above-mentioned tools was paramount for the success of the CP purpose. The research focused on the role the KM platform played within the CP process. The results showed that the KM tools were crucial in augmenting the overall performance of the necessary tasks.

Several problems arose during the studied process, which allowed for the definition of a set of additional requirements for the tool, such as: the use of SL in the system; a more adequate video-conference module; improvement in the usability of the interface, in order to contemplate the needs of both the non-deaf and the deaf members; a need for a translation system; a need for a social protocol to facilitate communication among the members, including a remote, virtual intervention of an interpreter; a system to serve as a vector of standardisation of SL, among others.

The methodological steps used in this research also proved to be an adequate choice because not only it allowed to analyse several specific aspects that motivated and cultivated the CP: the use of a KM tool and its impacts on the CP but also gave some insights about the identification of other needs of the deaf community for citizenship; the identification of computational tools to support the community promotion and standardisation of Libras; the practice of the deaf student's knowledge of Libras; the creation of new knowledge in Libras, such as how to form new lexicon; the manner in which the students can better standardise their knowledge of Libras; the creation of new methods for teaching SL as a second language, among others. Those findings should be the basis for future work.

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