



**Computer-assisted teaching of Sign Language using Computer Vision and
Machine Learning (CAT-SL)**

Ref. Project: 2020-1-EL01-KA203-079232

Intellectual Output 1: Analysis of Sign Language Teaching Methods and Challenges for an Automated Teaching System

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This project has received funding from Call 2020 Round 1 KA2 - Cooperation for innovation and the exchange of good practices, KA203 – Strategic Partnerships for higher education grant agreement 2020-1-EL01-KA203-079232.

Document history

Date	Name	Affiliation	Position/Project Role	Action/Description	Short
31/10/2023	D. Kosmopoulos	UPATRAS	Technical Manager/WP leader	Review of document template	
17/10/2022	K. Antzakas	UPATRAS	Content supervisor for UPATRAS	Reviewed & Validated. Modifications including expert's reviews.	
06/04/2022	K. Antzakas	UPATRAS	Content supervisor for UPATRAS	Initial version.	

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Executive Summary

The IO1 contains our results in the effort to capture all the requirements of developing a system for teaching of sign languages through an e-learning platform. The objectives of this study are:

- (a) To define the basic user groups
- (b) To analyze the similarities and differences among the European sign languages so that a common approach can be developed.
- (c) To identify the main challenges of that development.
- (d) To identify the requirements, which are structured to functional and non-functional.
- (e) To identify the use cases, from the user point of view.
- (f) To study the related policies at the EU level.
- (g) To analyze the Sign Languages status in the partner countries (Greece, Cyprus, Portugal and Netherlands).
- (h) The communication challenges between the Deaf and non—Deaf.
- (i) The Courses structure.
- (j) The certification and ECTS.
- (k) The scenarios and the evaluation.

The main conclusion from the report is that a system for teaching of sign languages through an e-learning platform addresses some real needs and that its implementation is feasible. The report is a useful guide for developers and policy makers who aim to contribute towards such systems.

List of abbreviations, acronyms and definitions

Abbreviation / Acronym	Definition
AI	Artificial Intelligence
API	Application Programming Interface
CERF	European Framework of Reference for Languages
CSL	Cypriot Sign Language
DSL	Dutch Sign Language
ECTS	European Credit Transfer and Accumulation System
ELP	European Language Portfolio
EU	European Union
GSL	Greek Sign Language
JSON	JavaScript Object Notation
LGP	Portuguese Sign Language
MT	Machine Translation
NLP	Natural Language Processing
PHP	Hypertext Preprocessor
SL	Sign Language
UI	User Interface
WebRTC	Web Real-Time Communication

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1. Introduction

According to the World Health Organization up to 5 out of every 1000 children are born deaf or hard of hearing. Those children obviously need a lot of support at school. Therefore, the educators need to receive appropriate training in Sign Languages, the native languages of the Deaf, so that they can communicate with them and to teach them how to develop linguistically.

Sign Languages in the curricula of Primary Education University Departments or schools dealing with Special Education are very useful and contribute towards this goal. However, it is hard for Higher Education Institutes to find experts in Sign Language and employ them as teachers; so many educators are not adequately trained as students to face the challenges of communicating with deaf children in the classroom. Similar considerations apply to other education levels as well.

The main Objectives of the CAT-SL project are:

- a. To develop an innovative and affordable system/service for interactive SL teaching for students in Special Education/Pedagogical departments and primary school education. It is based on computer-vision, machine-learning, linguistic technology, and avatars developed by all the involved partners in several national and EU-funded projects that are ongoing or recently completed. Thus, we aim at an exploitation of research results at European level that would not be possible without the contribution of the EU.
- b. To set up the CAT-SL infrastructure in four Higher Education Institutes (one for every partner), and one primary education one, based on open standards; to enable its practical use by teachers and students.
- c. To develop curricula and guides for teaching SL using the CAT-SL system for at least two multilingual courses, in Greece, Cyprus, Portugal and Netherlands; to support the social inclusion of the deaf children.
- d. To actively disseminate the project results through the promotion of workshops with stakeholders in the EU to raise awareness on the main challenges faced by the Deaf.

This document is the first step towards the realization of the above objectives. In section 2 we analyze the potential user groups that may benefit from CAT-SL and the respective roles. In section 3 we examine the similarities and differences among the EU SLs that we address and namely the Greek, the Dutch, and the Portuguese SLs. In section 4 we present an overview of the related challenges and how we plan to address them. In sections 5-6 we define the functional and non-functional requirements for the CAT-SL system. In section 7 we provide an overview of the use cases. In section 8 we give the EU policies and guidelines with respect to the SLs. In section 9 we present the current status in the partner countries. In section 10 we present the communication challenges between the Deaf and non-deaf in education and a related survey. In section 11 we give the structure of the courses that we aim to develop and in section 12 we present the ECTS certification guidelines. Section 13 mentions how we plan to handle the quizzes and games, which are expected to make the system more appealing. Section 14 described the evaluation goals and procedures. The report concludes with section 15 where the results and the future steps are summarized.

2. User Groups

The project aims to serve different user groups, which are identified in the following:

- a. The students of Special Education university departments, aiming to learn how to use and teach SLs to deaf children. The students can access educational material asynchronously. The students are also able to access educational material with synchronous feedback.
- b. The primary school pupils who aim to learn how to use the SLs. Occasionally some of them may be deaf. The pupils are able to access educational material asynchronously. They are also able to access educational material with synchronous feedback.
- c. The course administrators, who may be university professors teaching SLs in Special Education departments, as well as educators in public or private organizations involved in SL teaching or Deaf education. The course administrators are able to access educational material asynchronously, introduce new material, edit previous material, define exams, etc. They are given access to visual feedback mechanisms through the avatar.
- d. The teachers, who may be university professors or educators, as in the previous case. However, they have a restricted role, as they don't have permission to add or modify the course material and exams. They are allowed to use existing material, assign exams, and collect exam results.
- e. The system administrators, who are able to set up and maintain the system.

The users are required to have a user account for system access. There is an opportunity for guest accounts for users who wish to verify a limited amount of the system functionality.

3. Similarities and Differences among Sign Languages in the EU

In order to develop a multilingual teaching system for SLs it is important to identify the similarities and differences between the respective languages and to follow an approach that capitalizes on those similarities and does not overlook their different aspects.

The diversity of the world's languages is extraordinary and fascinating. Sign languages are considered as natural languages having the same status as spoken languages. As minority languages, sign languages are in contact with spoken languages of the hearing community. However, they are not derived from or related to the spoken languages of the surrounding hearing communities. On the contrary sign languages have their own linguistic structure, often very different from the dominant spoken language.

Prejudice against sign language and the Deaf people had a negative impact on sign language and the communities who use it. Sign language and Deaf communities have faced linguistic oppression for a long period of time and as a result research on sign language didn't start until the late 1950s.

According to Woll (2013) typological differences between signed and spoken language arise mainly from the interaction of language form with modality. Signed and spoken languages are produced and received in very different ways. Spoken languages are produced by the upper respiratory system (lungs, vocal tract, mouth) and perceived by the auditory channel. On the other hand, sign languages are produced by the hands and other non-manual articulators like the head, face, and body, and are perceived visually. Therefore, linearity is the only path of expressing linguistic items in spoken languages where spoken words follow one

after the other. On the other hand, sign languages can use simultaneous to linear sequence of signs (one sign after the other) features like facial expression (as adverbials, negation marker, interrogative marker, etc), head movements (negation, affirmation) and body movements.

However, spoken and sign languages as natural languages share common features and properties. Natural languages have a specific structure and are analyzed on different linguistic levels, phonology, morphology, syntax, semantics and pragmatics.

Meier (2002) refers to shared properties between signed and spoken languages. In particular:

- Conventional vocabularies learned pairings of form and meaning.
- Duality of patterning, meaningful units built of meaningless sublexical units, whether units of sound or gesture.
- Productivity of new vocabulary: new vocabulary may be added to signed and spoken languages.
- Syntactic structures.
- Acquisition, similar timetables for acquisition.
- Lateralization, aphasia data point to a crucial role for the left hemisphere.

Although sign languages are unintelligible to each other, many researchers point out that the grammars of unrelated sign languages are more similar than the grammars of unrelated spoken languages. Johnston (1989) and Woll (2003) proposed a number of reasons for the patterns of similarities among sign languages:

- The relative youth of sign languages (including creolization). Sign languages are relatively young languages.
- The relatively low percentage of signers who are themselves the children of signers results in continual recreolization with resulting similarity of grammar (Fischer 1978).
- Iconicity as an organizing factor may result in greater similarity at all linguistic levels.
- The linear syntax found in spoken languages may intrinsically allow greater differences than spatial syntax.
- Sign languages are fused linguistic/gestural systems.

Typological similarities on sign languages are mostly based on modality and affect the levels of linguistic analysis. The visual-gestural modality allows many aspects of morphological and syntactic processes to be expressed simultaneously. In terms of phonetics and phonology, sign languages share a lot of common features. The use of the articulators is commonly classified dyadically. The use of the hands is forming the “manual” features and use of the face and upper body comprises the “non- manual” features.

Sign language phonological units include the use of hand/palm, orientation of hand/palm, movement of hand/palm and location on the face/body where hand/palm is placed. Movement, location and orientation are almost identical for all sign languages. A great number of handshapes (formation of the hand/palm) is also common among sign languages. Thus, we have handshapes like, open palm – 5, fist, fist with the index extended, fist with thumb extended, etc. The great number of handshape similarities can also be traced on the manual alphabet of sign languages. Even a common reader can easily conclude on the use of identical

handshapes in the majority of sign language having a glance at the manual alphabet of these sign languages.

According to Woll (2012), iconicity and its relation to phonology and morphology is a similarity factor with impact on grammatical features of sign languages. Thus, sign languages make use of space along with the use of hands (phonology) in order to construct sentences articulated over the space in front of a signer. Referents are arbitrarily located in space. These locations represent specific grammatical relations of the referents according to sign syntax. Specific moments of the hand attribute the syntactic status of subject or object for these referents. So, sign languages employ a spatial morphological process for inflecting transitive verbs, whereby the verb is directed in space away from the source of the action and towards the goal of the action. Location in space can also represent different time slots where an action or an event takes place. Sign languages also use space as a representation of the real world. Thus, space can be used in order to give information of how things are placed in a room/flat/house or to give directional information in general (where is the location of a particular building).

Movement change of a sign can be used on morphology in order to show degree (BIG, VERY-BIG, FAT, VERY-FAT). Furthermore, movement change can indicate temporal aspects. Repeated actions are indicated by repeated moments, duration is indicated by a temporal extension of the movement and an interrupted event by a movement interruption.

Handshape change in signs like WEEK or YEAR is used as a derivational morphology process in order to incorporate numbers, producing signs meaning 3-WEEKS, 5-WEEK, 3-YEARS, 5-YEARS, etc. Handshape change is also used in signs meaning give, carry, open and others so that the direct object is indicated. As a result, sign pairs like GIVE-BOX/ GIVE-PEN, CARRY-FLOWER/ CARRY-BAG, OPEN-DOOR/ OPEN-DRAW, are articulated using different handshapes.

Iconic impact can also be seen on the formation of plurals or the use of facial expressions as adverbials in sign languages.

Similarities are also found in specific grammatical constructions. Zeshan and Palfreyman (2017) presented typological issues on sign languages. They reported similarities in the formation of interrogatives, negation and possession. Similarities concern the use of facial expressions and uniformity on specific syntactic structures. In the case of possession, the use of analogous handshapes has also been reported.

3.1. The case of Greek, Dutch, Portuguese SLs

In order to proceed it is needed to note that there is no published descriptive grammar for any of Greek, Dutch and Portuguese sign languages. Therefore, based on the above it is expected that project's sign languages differ in terms of vocabulary and some particular phonological features -handshapes. So, for each sign language there is a different vocabulary corpus based on a common corpus of meanings. The basic mechanisms of phonology, morphology and syntax are expected to be almost identical.

3.1.1. Phonology

In relation to phonology, it is expected that mechanisms of sign construction are identical for all sign languages. All three sign languages form a sign based on four major parameters:

handshape, location, movement and orientation.

Handshapes are almost identical for the project's sign languages. Only minor differences on the handshapes are expected. Locations, movements and orientations are also identical for the three sign languages.

3.1.2. Morphology

Similarly to phonology, sign languages share common morphological mechanisms. Sign languages make use of simultaneous combinations of handshapes, locations and movements. These features are used in derivational morphology. By changing the handshape in order to reflect a number (1, 2, 3 etc.) a sign language can form expressions like number-WEEKS, number-O'CLOCK or number-YEARS-OLD. Furthermore, sign languages have pairs of noun-verb signs which only differ in the movement of the sign. For example, the pair SEAT / I-AM-SITTING is distinguished by a different movement of the sign. The verb has a single long movement whereas the noun has a short, repeated movement.

Sign languages manifest also inflectional morphology by changes in movement and location. Degree is shown through movement differentiation. Changes on size, speed, speed onset or length of a movement indicated degree differences. In the same way movement changes are used for expressing temporal aspects. Sign repetition is used for repeated actions or events; changes in the length of the movement (shorter/longer movements) indicate the length of an action or event (shorter/longer action or event).

In addition, handshape change indicates how a direct object is handled. Thus, signs like HAND-OVER-A-FLOWER-TO-YOU and HAND-OVER-A-BOX-TO-YOU have the same movement but different handshape.

Therefore, modulations of the movement is a major tool that sign languages employ in order to manifest various types of inflections. Common inflection illustrations in sign language are related to a) argument encoding in verb agreement, b) verb aspect: durational, gradual, continuative, etc. and c) plurality in nouns.

3.1.3. Syntax

As with phonology and morphology, shared mechanisms and modulations are also used in syntax.

Sign languages use space in a binary way. Syntactically so that clause arguments are represented in space and topographically by mapping the real world in space or by depicting spatial relationships.

In syntactic uses of space, referents are assigned a location in space and path movement of the verb indicates the start and the end point of the action, manifesting who does something to whom. Therefore, verbs of transfer such as GIVE, ASK, TELL, etc, indicate their referents through path movement.

In topographic space path movement of the verb indicates specific spatial relations. Therefore, verbs of location movement such as TRAVEL, indicate the start and the end point of the action through path movement of the verb.

All the above indicate that although there is not a detailed descriptive grammar for Greek, Dutch and Portuguese sign languages, there are mechanisms and modulations common for

sign languages. These mechanisms and modulations provide a scaffold for the development of a common sign language curriculum in this project.

4. The Challenges

The basic challenges in implementing a sign language teaching system are presented in the following. We also give indications on how to handle them.

4.1. Datasets

The inadequacies of publicly available sign language datasets restrict the strength and generalizability of systems trained on them. In data-rich circumstances, modern, data-driven machine learning approaches perform well. Success in voice recognition, which is similar to sign recognition in many aspects, has been made feasible by training on corpora containing millions of words. Sign language corpora, on the other hand, which are required to fuel the growth of sign language recognition, are several orders of magnitude smaller. Because of the short amount of current signing datasets and their reliance on interpretation material, existing datasets often lack signer variation.

We plan to use available corpora e.g. the ones produced in our HealthSign project (www.healthsign.gr) and enhance them with a variety of users.

4.2. Recognition

Despite the major advancements in recent years, there are still several significant and unresolved recognition issues that limit real-world usefulness.

Depiction refers to visually representing or enacting content in sign languages and presents particular obstacles for recognition and translation. Understanding portrayal necessitates experience to Deaf culture and languages, which is typically lacking in the populations driving advancement in computer vision. As a result, conventional methodologies are incapable of dealing with portrayals. It is also tough to write notes for depictions. There are several ways to describe the same notion, yet annotation systems lack a common mechanism to represent this richness.

Producing sign language annotations, which are machine-readable inputs required for supervised training of AI models, takes time and is prone to mistake. There is no common annotation system or granularity level. As a result, researchers cannot combine annotated datasets to boost power and must deal with poor inter-annotator agreement. Annotators must also be thoroughly trained in order to get appropriate skill in the desired annotation system. Training is costly, and it limits the number of persons who can offer annotations beyond the already limited number of fluent signers. The lack of an uniform written style also makes it difficult to learn from created material – e.g., NLP systems that assume text input, use parallel text corpora to learn appropriate grammar and vocabulary, and leverage ubiquitous text resources in general.

We plan to stick more to the tracking part and ensure the adherence to presented motion patterns by teachers, thus bypassing for the time being the problem of expressing the same notion in numerous different ways.

4.3. Modeling the language

Many MT and NLP approaches for spoken/written languages have been created. Sign languages, on the other hand, vary structurally from these languages. Because of these variations, simple applications of MT and NLP methodologies either fail to capture some parts of sign languages or simply do not function. Many approaches, in particular, presume that only one word or notion is performed at a time. Many sign languages, on the other hand, are multi-channel, transmitting an item and its description at the same time. Many approaches also presume that context has no effect on the word being spoken; yet, in sign languages, content may be spatially structured and interpretation is directly reliant on that spatial context.

In our approach we consider the multiple channels (hands, arms, head, facial expressions) by using efficient tracking methods. We differentiate between signing and punctuation and consider spatial context where necessary.

4.4. Avatars

The development of avatars faces a number of technical challenges in creating avatars that are acceptable to Deaf users (i.e., pleasing to view, easy to understand, representative of the Deaf community, etc.).

Avatars that are either very cartoonish or very human-like are fairly pleasing, but in-between can be disconcerting. For example, in addition to providing semantically meaningful non-manual cues (e.g., raised eyebrows indicating a question), avatars must also have varied, natural facial expressions (i.e., not a robotic, stoic expression throughout). It can be difficult to design avatars that fall outside of this valley.

We aim to incorporate the design by the IPP, which is under development for several years and is aware of these problems and tries to mitigate them.

5. Functional Requirements

The CAT-SL system should contain modules for: System administration, Course administration, Content management, Evaluation, Body Tracking, Sign Learning, Avatar for visual feedback.

The requirements are extracted by reviewing the related literature (i.e., linguistic requirements by each of the involved SLs) and the technical capabilities offered by state of the art technology. These requirements are written by the experts in our consortium and will be validated by real users and will be eventually updated.

The requirements from the users' perspective are described in the following. Some of them were adapted from (Yoshinov et al, 2014).

5.1. System administration

The system administration includes a full range of functions for the management and configuration of system parameters and attributes, data, users, courses and interactivity settings. The following basic functions shall be included, which cover: authentication, management of rights and roles, user management, import and export of users and resources, management of language packs and log, etc.

SA1: The system supports a number of standard roles (e.g. Administrator, Teacher, Student, Guest) and have the potential to create additional roles.

SA2: The system is able to create user groups to collaborate, communicate and share content. These can also accommodate different groups of users attending different courses.

SA3: The platform enables users to access resources from external websites.

SA4: It is possible to access all administrative tools and functionalities from a single interface.

SA5: System Administrators are able to set quotas on the disk space for individual users, courses and organisations.

SA6: The administrator is able to set specific settings for the rights of users based on user roles, including settings for bandwidth on e-resource access.

SA7: The administrator is able to monitor visits and other statistics of the platform (i.e. number of users, time period, etc.).

SA8: Event log storage and log analysis functionality are available for the needs of system administrators.

SA9: The administrator is able to install and maintain the interactivity modules (body tracking, sign modeling, avatar).

SA10: The following Language packs should be available: Greek, Portuguese, Dutch, English.

5.2. Course administration

Course administration provides tools for synchronous and asynchronous e-learning, creating, editing, saving and deleting e-learning courses, encouraging student participation in the learning process and ensuring better interactivity within the teaching process. It also provides an opportunity to test, assess and oversee the student and teacher performance, as well as the opportunity for self-assessment.

CA1: Course administrators are able to assign different roles and rights to the different users, as well as assign access rights to various e-resources within the system.

CA2: Course administrator is able to produce standard user activity and system access reports and create customised reports without the need for additional programming.

CA3: The system disposes of available tools for communication and interaction such as a calendar, messages and announcements, email service, tasks, and chat.

CA4: The system allows the upload of syllabuses that are accessible through students' specific access rights.

CA5: The system allows to create course catalogues and to search and view training courses according to specific rights and roles of individual users in the system.

CA6: The system allows to integrate and embed images, presentations and video content.

CA7: Course administrators are able to set an order for accessing educational materials with a view to their utilisation in a particular sequence.

CA8: Course administrators are able to define access to different content, depending on individual performance and student progress.

CA9: Course administrators are able to change the course settings and make certain tools and parts of the course content (in)accessible on specific dates and at specific times.

CA10: Course administrators are able to archive a portion of the course or the entire course.

CA11: Course administrators are able to automatically notify users about new activities, publications, assignments, examinations, tests, or changes in the course.

CA12: Course administrators are able to create groups, to control a group's membership by assigning specific rights to users, and to determine what tools are available to certain groups.

CA13: Course administrators are able to publish information related to the teacher and the course.

CA14: Course administrators can enable online submission of assignments and tests.

CA15: Course administrators can conduct surveys among users in the system.

CA16: Course administrators can enable the possibility of self-assessment especially for interactive content in SL.

CA17: Course administrators can enable anonymous evaluation of students by the teacher.

CA18: Course administrators can import and export tests and questionnaires.

CA19: Course administrators can create a repository of questions, allowing repeated use of the questions in different courses and tests without the need for recreation.

CA20: Course administrators can set different weights for the automatic evaluation of questions and award partial credit.

CA21: The system gives the possibility for personal feedback by the teacher or the system itself by using automated methods.

CA22: The platform possesses a built-in system for sending and receiving emails among the course administrator and the students.

CA23: The system supports the import and export of courses, and the accepted standards.

CA24: The course administrators are able to check the student view of the course without logging out of the system and logging in as a student, or switching from one interface to another.

CA25: The teacher is able to choose a language pack for certain groups of users, or for a particular course, regardless of the system's language settings.

CA26: The teacher is able to create a personal portfolio of courses.

CA27: The teacher is able to create a reference body motion.

5.3. Content management

Content management requirements address the learning content of all users on the platform in order to facilitate work with the learning material.

CM1: The system allows to store and manage any type of multimedia content from a centralised location where it can be administered, updated and shared.

CM2: The system allows users to set different access rights to content.

CM3: The system allows to track the history of each file or directory from the content management system, i.e. to check which user accessed it, when and from where.

CM4: Teachers are able to quickly and easily view and manage all the files related to their courses.

CM5: The students are able to create a personal portfolio of courses.

5.4. Evaluation

The evaluation part concerns the means for evaluating the students who have already taken a course and the respective evaluation test.

E1: The assessment can be anonymous or not.

E2: It is possible to automatically add marks for homework, examinations, tests and other student assignments.

E3: It is possible to generate reports on student progress and analyse the level of acquisition of various elements from the learning material.

E4: The system allows import and export of the electronic register in xls and csv format for students and teachers.

5.5. Body Tracking

The body tracking system concentrates on identifying the pose of the human parts in each frame acquired by the camera viewing the student. The respective requirements are provided in the following.

TR1: The system is able to track both hands in such a way that the hand-shape and hand orientation could be extracted unambiguously.

TR2: The system is able to track the face so that the most common non-manual markers could be extracted unambiguously.

TR3: Motion elements like arm motion, head motion, body motion are extracted.

TR4: Deviations from ground-truth motions are identified.

TR5: The motion is calculated in about 10 seconds for small or medium-size sentences.

5.6. Sign recognition

The recognition part concerns the abilities of machine learning systems to represent and identify the motions performed by hands or other body parts, in order to facilitate feedback to the students.

RE1: The system is able to tell if the identified motion corresponds to the desired glosses

RE2: The system is able to tell if the identified motion corresponds to the desired punctuation.

5.7. Avatar for visual feedback

The avatar is a visual mechanism for sign representation and visual feedback to the students.

The basic requirements are:

AV1: The avatar is able to display the required hand trajectory.

AV2: The avatar is able to display the required hand shapes embedded in the trajectory.

AV3: The avatar is able to display the required body motion.

AV4: The avatar is able to display the required facial expressions.

6. Non - functional Requirements

The system should meet the following quality requirements:

NF1: Productivity – the system has the capacity to serve a reasonable amount of simultaneous (concurrent) sessions, depending on class size.

NF2: Scalability and flexibility – the system is modular to expand and serve more users, and to allow for additional settings, as more users might be interested in using the provided services.

NF3: Compatibility – the system is compatible with current Web standards (HTML, XHTML).

NF4: Accessibility – the system is installed centrally on one or more servers, and should be accessible via http or https over the Internet.

NF5: The system has a web-based user and administrative interface for public and protected sections

NF6: The system is compatible with the most popular Internet browsers, such as Internet Explorer v.8 and higher, Mozilla Firefox v.3.6 and higher, Safari v.3 and higher and Chrome v.10 and higher.

NF5: Functionality and easy access – the system follows accessibility standards (e.g. WCAG [W3C2021]) for ease of access and use.

NF6: Stability – the system guarantees a secure and reliable learning process.

NF7: The automated evaluation is done within 20 seconds for medium size sentences.

7. Use cases

The Use cases offer a representation of what the system is able to do from the users' perspective. In the following we provide a brief description and visual representations using the UML use-case diagrams.

The main idea is that the teacher and/or the content developer should be able to add material to the course. When it is necessary to add some activity related to the learning of hand signs, this should be an automatic process reachable through a few steps:

The teacher uploads the correct (target) video so the student can see what he/she must do.

When the student is ready, (s)he starts capturing video (his/her answer) through his/her webcam.

Next the video is processed and evaluated through a procedure (transferring, extracting features/keypoints, etc.), which runs in the background and is not visible to the student.

After completion of the process described under (c) the student is informed about the (degree of) correctness of his production.

It is a web-based environment (user's side). The user is not required to install anything (software, browser add-on etc.) to complete the course. A camera can be available on the user side.

The employed technologies are:

- WebRTC for downloading and transferring video and audio.
- JSON, REST services for communication between the various points of the application.
- PHP for the development of the Moodle plugin (qtype).
- MySql for the plugin and Moodle database.
- docker.io to deploy the application.
- kubernetes so that the application becomes autoscaling.

A first approach regarding the architecture is shown in the following figures. In Figure 1 appears the diagram of actions that constitute the use case of the Course Administrator. In Figure 2 appears the diagram of actions that constitute the use case of the Teacher. Finally, in Figure 3 appears the diagram of actions that constitute the use case of the Student.

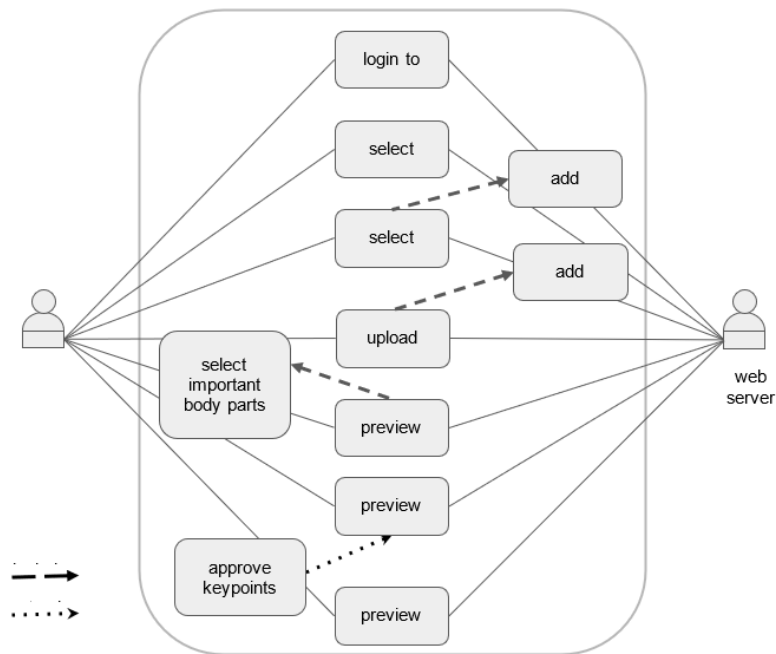


Figure 1: The diagram of actions that supported by the platform, to fulfil the needs of the Course Administrator.

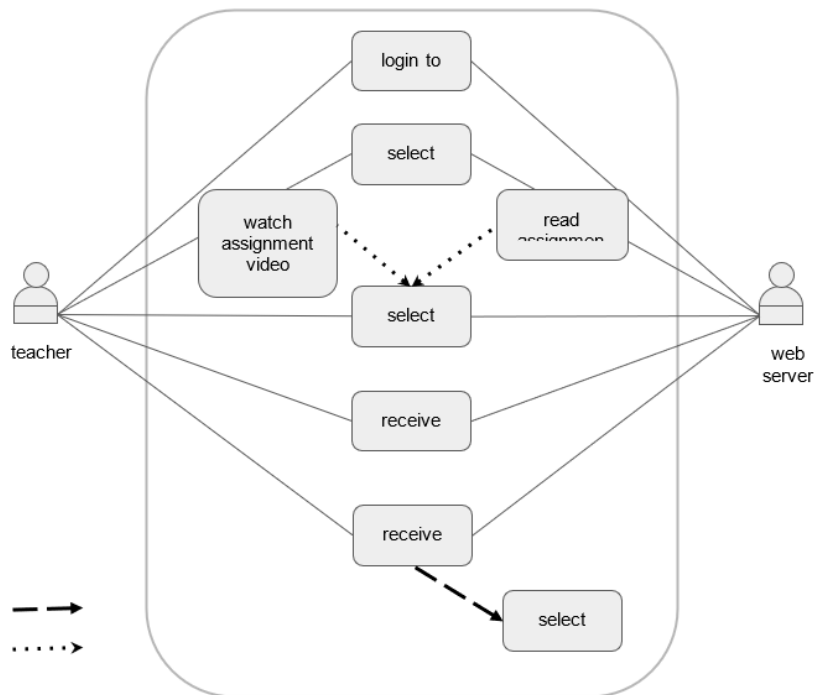


Figure 2: The diagram of actions supported by the platform, in order to fulfil the needs of the Teacher.

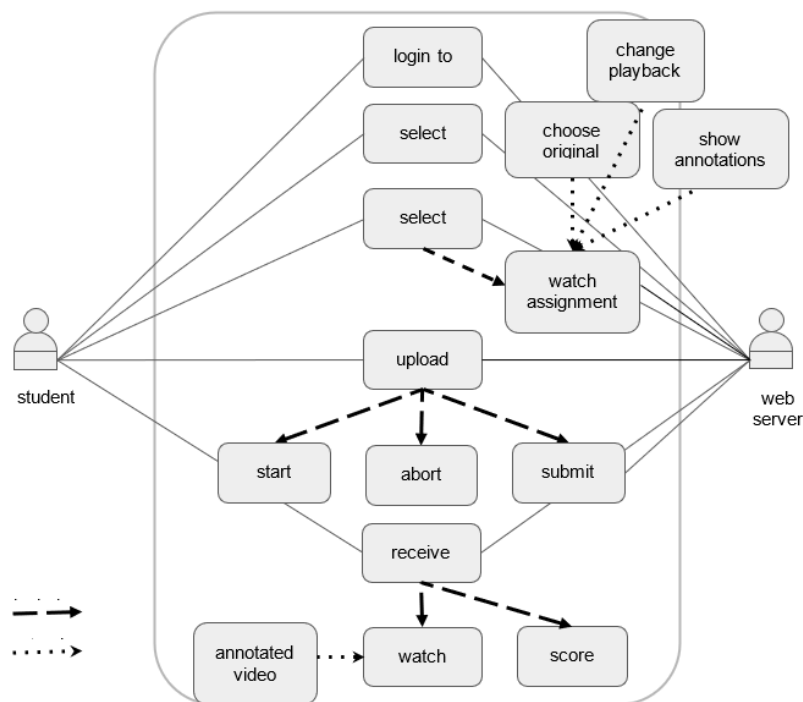


Figure 3: The diagram of actions that supported by the platform, in order to fulfil the needs of the Student.

8. EU Policies and guidelines

The European Parliament in its Resolution on Sign Languages for Deaf People (1988) called upon member states, in cooperation with the European Commission, to support pilot projects aimed at teaching sign languages to hearing children and adults, using deaf people trained for the purpose and to back research in this area.

The European Parliament in 1998 called on the European Commission to make a proposal to the Council concerning official recognition of the sign languages used by deaf people in each member state, and to ensure EU funding programmes in the field of education and employment training including training of sign language teachers and interpreters.

The European Charter for Regional or Minority Languages (1992) aims to ensure, as far as reasonably possible, the use of regional or minority languages in education and the media and to permit their use in judicial and administrative settings, economic and social life, and cultural activities.

Language education has been part of the Council of Europe's concerns for many years. This interest focuses on the protection of linguistic and cultural diversity, promotion of plurilingual and intercultural education, reinforcement of the right to quality education for all and enhancement of intercultural dialogue, social inclusion and democracy. For this reason, the Council of Europe has implemented the Common European Framework of Reference for Languages (CEFR) – (Council of Europe, 2020). CEFR is one of the best-known and most used Council of Europe policy instruments. Through the European Cultural Convention European countries commit to encouraging “the study by its own nationals of the languages, history and civilisation” of other European countries. Together with its related instrument for learners, the European Language Portfolio (ELP), CEFR has been a central feature of the Council of Europe's intergovernmental programmes in the field of education, including their initiatives to promote the right to quality education for all. Language education contributes to the Council of Europe's core mission “to achieve a greater unity between its members” and is fundamental to the effective enjoyment of the right to education and other individual human rights and the rights of minorities as well as, more broadly, to developing and maintaining a culture of democracy.

The CEFR is intended to promote quality plurilingual education, facilitate greater social mobility and stimulate reflection and exchange between language professionals for curriculum development and in teacher education. CEFR provides basic guidelines for the elaboration of syllabuses, curriculum, examinations, textbooks, etc. across Europe. It also describes what language learners have to learn to do in order to use a language for communication and what knowledge and skill they have to develop to be able to act effectively and covers the cultural context in which language is set. CEFR framework includes sign languages (ProSign) and defines levels of proficiency and includes sign languages.

9. Sign language status in partner countries

In the following we describe the language status in each of the partner countries. This gives the legal and educational background of the countries in which the proposed system is being implemented and will become operational. The data have been mainly extracted from the study of (Tupi, 2019) where the reader can refer for more details and situation in other member states.

9.1. Cyprus

9.1.1. Education

Since the creation of the School for the Deaf in 1953, the oral method has been used to educate hearing-impaired children in Cyprus, with natural gestures and body language used where appropriate. In Cyprus, major developments in the education of hearing-impaired people happened in the early 1990s.

The Ministry of Education and Culture implemented a policy of including children with special needs in normal education, which became law in 1999. As a consequence, the great majority of hearing-impaired students are mainstreamed, attending ordinary schools from preschool through postsecondary education, with just a few remaining at the School for the Deaf.

In the mainstream, which is a pure auditory-oral education context, sign language is not employed. Specialist instructors who work with hearing-impaired kids in the mainstream, on the other hand, may use natural gestures and body language to communicate with their pupils more effectively.

The oral technique is still employed at the School for the Deaf, but it has grown more flexible by including more free and open means of communication based on the idea of Total Communication, a system that incorporates sign language and is used at the School for the Deaf primarily with children who have failed to become oral or who have low chances of becoming oral.

Nonetheless, there is still a need for instructors of hearing-impaired pupils to be trained as skilled signers.

9.1.2. Sign language and deaf adults

Adult deaf persons have been the most vocal in their support for sign language as a viable means of communication. The impact on deaf adults in Cyprus of the trend in Europe and the United States to recognize sign language as a linguistically complete and therefore autonomous language, on the one hand, and the recognition of the deaf's right to have and use their own language within their own culture, on the other, has been strong enough to raise their self-awareness and enable them to feel positively.

The methodical efforts of deaf organizations, as well as Cyprus's membership to the European Union, have boosted interest in sign language at all levels, and the situation is today as follows: The Cyprus Broadcast Company bulletin is translated into sign language. A request for a separate bulletin for the deaf has been made to the C.B.C. The Pancyprian Organisation of Deaf People organizes sign language classes for deaf and hearing people, and the Ministry of Labour and Social Insurance provides financial aid to these people. Similar classes are provided by the Ministry of Education and Culture as part of the further education program.

Interpretation into sign language is provided for deaf people who must appear in court or participate in seminars. Furthermore, deaf organizations seek that the Cyprus government recognize Cyprus Sign Language as the official language of the deaf through legislation. Remarks in general Cyprus Sign Language is now in a state of change. It was heavily influenced by, and continues to be influenced by, the American Sign Language and the Greek Sign

Language. It is true that the Cyprus Sign Language is constantly being linguistically extended and updated.

Although it has not yet become a fully developed language, it appears to be in the dynamics of becoming an effective mode of communication, especially for the adult deaf. It also appears to be the central constituent of the emerging concept of Cyprus Deaf Culture.

Although it has not yet completely grown into a language, it looks to be on its way to becoming an effective form of communication, particularly for the adult deaf. It also appears to be a key component of the developing idea of Cyprus Deaf Culture.

9.2. Greece

9.2.1. Education

The government recognized Greek Sign Language as natural language for the deaf and hard of hearing school children and therefore its use in education since 2000 (PL 2817/2000). Furthermore, the particular law set as a prerequisite teacher's proficiency on sign language in order to be eligible working with deaf and hard of hearing students. In addition, bilingual education for the deaf and hard of hearing pupils was established by Public Law in 2008 (PL 3699/2008). Both laws also set inclusion central policy in special education. As a result the majority of deaf and hard of hearing students are in mainstream schools.

9.2.2. Sign language and deaf adults

Deaf clubs and associations have been reported in Greece since the late 30's. Greek Federation for the Deaf was founded in 1968. However, sign language was not used for public services for the Deaf since the 1980 decade. During the 80's vocational programs for deaf adults were provided for the first time. At the same period news on the tv was also provided in sign language for the first time. In 2012 Greece ratified the United Nations Convention for People with Disabilities. UN Convention for People with Disabilities was further integrated in public law in 2017 (PL 4488/2017). The particular law recognizes sign language as equal to spoken Greek and states that sign language should be promoted in order to meet the communicational needs of the Greek deaf and hard of hearing citizens. Nowadays the National Institute of the Deaf provides interpretation services, remote (relay services) or live by interpreters.

9.3. Netherlands

9.3.1. Education

The government recognized that Dutch Sign Language is an important communication tool for many persons who are deaf or hard of hearing. Those with hearing impairments should benefit from an enhanced social status as a result of this. The Cabinet has also stated its preference for a single standard Dutch Sign Language. Standardization is critical for the implementation process, such as designing a school curriculum, instructional materials, activities, and goods given by the Dutch Sign Language Centre, and training courses for deaf interpreters.

9.3.2. Sign language and deaf adults

The Dutch Sign Language Committee was created in March 1996 by the State Secretary for Education. The committee believes that the recognition of a Dutch Sign Language must result in guarantees for learning the Dutch Sign Language, guarantees that people who use the Dutch Sign Language are not discriminated against, facilities for the use of the Dutch Sign Language in communication between the deaf and the hearing, and guarantees that the deaf can learn the Dutch language insofar as this is possible.

Only since 1995 has the General Administrative Law Act mandated that administrative bodies utilize the Dutch language. It is also until recently that education legislation specifies the language in which education is offered.

The Dutch Sign Language has now been officially recognized by law on March 16, 2021 (<https://zoek.officielebekendmakingen.nl/stb-2021-165.html>).

9.4. Portugal

9.4.1. Education

The Portuguese Republic's Constitution guarantees everyone the right to free and obligatory education. The right to special education, as well as the conservation and valuation of Portuguese Sign Language as a cultural expression and educational access tool, is likewise guaranteed by the constitution (Article 74, section g and h).

To that purpose, the National Department of Education and Innovation has set the requirements for the establishment, operation, and operation of school units for deaf children and adolescents enrolled in public primary and secondary schools (Official Bulletin, series II, no. 104, 1998.06.05, p. 6094).

In Portugal deaf children have attended bilingual education, Portuguese Sign Language (LGP) and Portuguese, since the second half of the 1980s. Bilingual education intends to make deaf students fully competent in both languages: their natural language and the official language of the country.

The LGP curriculum maintains some parallelism with the curricular guidelines for pre-school education, the national curriculum of primary education and the specific curricular organization for each of the three cycles in elementary school, in particular Portuguese as a mother tongue and History.

This LGP curriculum as a first language cannot be confused with a curriculum of LGP as a second language to teach non-deaf learners. Teaching a language that is acquired naturally during childhood is totally different from teaching a second language to which has never had contact with it.

The curricular program for the Portuguese Sign Language course is intended to be a regulatory instrument for its acquisition and development as the first language of the deaf community. It considers four nuclear areas: Interaction in LGP, Literacy in LGP, Study of Language, LGP and Community and Culture.

9.4.2. Adults

The profession of sign language interpreter was not formally recognized for a long time. The profession/occupation of Portuguese Sign Language interpreters is already listed in the National Classification of Professions, although it is only currently in the research phase in preparation for regulation.

In terms of deaf people's access to the justice system, the Ministry of Justice, the National Secretariat for the Rehabilitation and Integration of People with Disabilities, and the Portuguese Federation of Associations for the Deaf have signed an agreement that allows any deaf person who has been summoned to court or needs to contact any service within the justice system to do so.

Since 1999, there has been an agreement between the National Secretariat for the Rehabilitation and Integration of People with Disabilities and the same Association of Interpreters on Portuguese Sign Language with the goal of facilitating deaf people's access to information available within the framework of meetings, conferences, seminars, and other events promoted by this Secretariat.

There has been an attempt to ensure that the bulk of Portuguese-language television programs are followed by a sign language interpretation service or a caption service on the screen.

10. Communication Challenges Between Deaf and Non-deaf in Education

The communication challenges between Deaf and non-deaf have been studied by the consortium member IPP in Portugal, however, the situation is similar in other countries. In Portugal, deaf students enrol in bilingual teaching that is offered in several reference schools until the level of secondary education. These schools centralize the required resources for bilingual teaching in Portuguese and Portuguese Sign Language (LGP). Nevertheless, deaf students are frequently a minority that faces challenges in education, including:

- The competences and the knowledge of LGP is not the same for all students; these competences depend on the frequency of previous contact with other deaf friends and family;
- The age when the student acquired deafness is also a key factor; students born deaf and those who became so after acquiring speech face very different barriers to communicate with deaf and non-deaf friends;
- Technical vocabulary has to be explained using terms/signs the deaf student can understand;
- New concepts have to be explained before introducing written materials that refer to these concepts;
- Coordination of the activities at the school to assure that visual attention is not required in parallel with other tasks; for instance, reading a PowerPoint and explaining at the same time;
- Content should be provided in sign language;

- Information, mainly in written form, should be accompanied by images and/or examples of real cases/examples;
- Any spoken intervention must be preceded by a warning so the deaf students can under-stand who is intervening;
- All speech that cannot be provided in sign language should be done in front of the deaf students to facilitate lip reading;
- The efficiency of lip reading is approximately 30%, i.e., only approximately 30% of the information is captured by a receiver used for lip reading. The remaining 70% are assumed/inferred;
- Beard, moustache and objects in the mouth, like a pen, compromise the perception of oral communication;
- When writing, deaf students have difficulties in the use of synonyms, verb conjugations, con-junctions, morphological agreements and syntactic structures;
- When reading, deaf students may face difficulties to understand vocabulary, idiomatic expressions and complex syntactic structures.

10.1. Survey

The survey was conducted online through a Google form. The students (approximately 19.000) and the academic staff (approximately 1.500) of the Polytechnic of Porto were invited to participate by email. We received a total of 252 answers from which 246 are validated. Two respondents are deaf.

- Approximately 86% of the respondents have no regular contact with deaf colleagues while 13% do have.
- 66% believe that deaf people can read fluently and understand written Portuguese.
- 15% know sign language.
- 21% think sign language is the same in any country.
- 93% would like to learn sign language.

Clearly there is a gap between the Deaf community and the non-deaf. Any education course and tool should consider it and find ways to bridge it. The CAT-SL apart from its technical goals, aims to raise awareness among the non-deaf about the problems the Deaf community faces.

11. Courses Structure

Language education has been part of the Council of Europe's concerns for many years. This interest focuses on the protection of linguistic and cultural diversity, promotion of plurilingual and intercultural education, reinforcement of the right to quality education for all and enhancement of intercultural dialogue, social inclusion and democracy. For this reason, the Council of Europe has implemented the Common European Framework of Reference for Languages (CEFR). CEFR provides basic guidelines for the elaboration of syllabuses,

curriculum, examinations, textbooks, etc. across Europe. It also describes what language learners have to learn to do in order to use a language for communication and what knowledge and skill they have to develop to be able to act effectively and covers the cultural context in which language is set. CERF framework includes sign languages (ProSign) and defines levels of proficiency and includes sign languages.

Course structure and course outline have been based on this framework. The current project provides users with A1 sign language proficiency level.

In the following we present some outlines of courses teaching SLs. The first one regards guest users of our system, i.e., for people interested in getting acquainted with the SLs. The second one is for university students and the last one is for school pupils.

While the first one is of a more generic structure, the other two follow the structure of the respective education programs. More specifically, the courses are based on the same framework, i.e., both share a core vocabulary, basic knowledge of grammatical structures as well as basic communication skills. However, pupils' courses are presented in a more plain way in terms of content and are structured in a playful way. Furthermore, pupils' courses run under the supervision of an adult, for example the teacher of the class. Learning outcomes are also adopted to their age. On the other hand, students' courses include more theoretical material about sign language, sign language grammar, Deaf community and Deaf culture. Class content is richer and more demanding.

11.1. Course outline for users interested in learning SLs

Some general objectives concerning perceptive language:

- Can understand direct commands (e.g. “give me a book”).
- Can understand descriptions of clothes (pattern, color).
- Can understand information on quantities, size, shape.
- Can understand the content of a message / topic (thoughts, desires, opinions, etc.) in SL.
- Can understand basic grammatical structures of sign language and the reasons why they are used.
- Can understand simple negation.
- Can understand simple interrogatives.
- To know, understand and appreciate the culture, civilization and language of the Deaf community.

Some general objectives concerning expressive language:

- Can produce clear and unambiguous handshapes.
- Can use fingerspelling and spell names.
- Can produce direct commands (e.g. “give me a book”).
- Can describe clothes (pattern, color).

- Can describe physical shape (height, width, length).
- Use SL to effectively express basic thoughts, desires, views and feelings.
- Use appropriate types of SL for basic cognitive, reasoning, creative and informational purposes.
- Use of correct SL structures.
- Use elements from Deaf culture and Deaf community.

Teaching areas:

- Voiceless communication.
- Use of basic handshapes. Handshapes, location, movement.
- Basic vocabulary of everyday use in ENG.
- Formation of simple sentences in ENG.
- Basic communication skills in ENG.
- Deaf culture and Deaf community and terminology: Deaf, deaf, dumb, hearing.

Grammar:

- SL manual alphabet and fingerspelling
- Personal pronouns.
- Affirmation / negation.
- Interrogatives.
- Facial expressions. Affirmation, negation, interrogatives.
- Possessive pronouns.
- Plurals.
- Verbs.
- Basic description skills in space.
- Classifiers.

Vocabulary:

- Family and friends.
- School, profession, transport means.
- Face, body, clothes.
- Food, drinks.
- Animals, plants/trees.
- Numbers, time, weather.

- Sport, religion, politics.

11.2. University course outline

The aim of the course is to teach students basic communication skills in sign language. Students are also familiarized with issues related to sign language modality and sign language grammatical structures. Moreover, students have the opportunity to get aware about issues related to deaf community and deaf culture.

11.2.1. Learning outcomes

By the end of the course the students will be able to:

- To understand the different modality between sign and spoken language.
- To recognize basic sign language phonological features.
- To break down and recognize the phonological parts of a sign.
- To acquire a basic sign language vocabulary on various thematic areas related to everyday life such as friends and family, work-profession, color-numbers, etc.
- To develop receptive and expressive language skills in sign language.
- To understand the importance of head movements and facial expressions for sign language.
- To develop basic communication skills in sign language.
- To understand and produce simple negation.
- To understand and produce simple interrogatives.
- To describe and discuss basic grammatical aspects of sign language.
- To identify how sign language modality affects its structure.
- To identify grammatical phenomena/structures of spoken and sign language.
- Produce clear and unambiguous handshapes.
- Use fingerspelling and spell names.
- Produce direct commands (e.g. “give me a book”).
- Describe clothes (pattern, color).
- Describe physical shape (height, width, length).
- Understand direct commands (e.g. “give me a book”).
- Understand descriptions of clothes (pattern, color).
- Understand information on quantities, size, shape.

11.2.2. The course syllabus

- Introduction to sign language.
- Introduction to Deaf culture and Deaf community.
- Voiceless communication.
- Use of basic handshapes.
- Sign structure and sign formation: handshape, location, movement, orientation.
- Basic sign language vocabulary (number, color, environment, animals, plants, etc)
- Basic sign language vocabulary of everyday communication (family, friends, community, town we live, studies, profession, etc.).
- Formation of simple affirmative clauses in SL.
- Introduction to grammatical structures (pronouns, plurals).
- Introduction to interrogative clauses.
- Introduction to negative clauses.
- Introduction to imperative clauses.
- Formation of various types of clauses
- Communication skills in sign language.
- Communication skills and the Deaf community.

11.2.3. Course structure

Sign language course is going to be part of a major course (i.e. part to a deaf studies course). It is developed as an asynchronous online learning. Students have to follow the presentation and do additional homework. There are going to be 13 class-presentations. Each class provides students with new information and additional homework material. Students are expected to follow a class and then do the additional homework.

11.3. School course outline

The aim of the course is to teach elementary school pupils basic communication skills in sign language. Pupils are also familiarized with issues related to sign language modality and basic sign language grammatical structures. Moreover, students have the opportunity to get aware about issues related to deaf community and deaf culture.

11.3.1. Learning outcomes

By the end of the course the pupils are able to:

- To understand the different modality between sign and spoken language.
- To recognize basic sign language phonological features (handshapes, locations, movements).

- To break down and recognize the phonological parts of a sign.
- To acquire a basic sign language vocabulary in various thematic areas related to everyday life such as friends and family, color-numbers, school, etc.
- To develop basic receptive and expressive language skills in sign language.
- To understand the importance of head movements and facial expressions for sign language.
- To develop basic communication skills in sign language.
- To understand and produce simple negation.
- To understand and produce simple interrogatives.
- Can produce clear and unambiguous handshapes.
- Can use fingerspelling and spell names.
- Can produce direct commands (e.g. “give me a book”).
- Can describe clothes (pattern, color).
- Can describe physical shape (height, width, length).
- Can understand direct commands (e.g. “give me a book”).
- Can understand descriptions of clothes (pattern, color).
- Can understand information on quantities, size, shape.

11.3.2. Syllabus

- Introduction to sign language.
- Introduction to Deaf culture and Deaf community.
- Voiceless communication.
- Use of basic handshapes.
- Sign structure and sign formation: handshape, location, movement, orientation.
- Basic sign language vocabulary (number, color, environment, animals, plants, etc)
- Basic sign language vocabulary of everyday communication (family, friends, school, community, town we live, etc.).
- Basic communication skills. Give information about ourselves.
- Formation of simple affirmative clauses in SL.
- Formation of pronouns and plurals.
- Formation of interrogative clauses.
- Formation of negative clauses.
- Formation of imperative clauses.

- Basic communication skills. Give information about our school and neighbor
- Information about how to communicate with a deaf pupil.

11.3.3. Course structure

The Sign language course is going to be part of an educational program. It is developed as an asynchronous online learning. A teacher introduces each presentation to school students. Pupils have to follow the presentation and do additional practice. There are going to be 13 class-presentations. Each class provides students with new information and additional practice material.

12. ECTS & Certification

CAT-SL is being incorporated in courses developed for students wanting to become teachers in special education, SL interpreters, or any other profession that requires advanced productive as well as receptive skills in Sign Language. As part of these courses CAT-SL will automatically be part of the ECTS system.

Non-university students who may want to follow SL courses because they are interested in learning a particular SL without the intention to make use of it professionally, will receive a certificate after successful completion of the course. These certificates may be handed out by the organization that gave the training. The level of the training may be indicated on the certificate. Yet, it will be important that these indicator levels will be adjusted to the levels determined by the organization of higher education.

13. Quizzes and Games

To make the courses and exercises in CAT-SL attractive, the inclusion of games and quizzes is considered.

As the development of a successful game requires a number of different actions, such as thinking of a storyline, inclusion of characters, interaction with the user, etc., it is usually quite expensive. An example of such an extensive game, which still needs additional development, has been reported on by Economou et al. (2019). The development of CAT-SL primarily focuses on teaching and learning, and the budget of the project does not allow for developing an elaborate game along these lines.

There is a large number of scientific reports on the nature of educational games and their effects could be increasing learning results as well as motivational. Huizenga et al. (2017) cite a number of commonalities that can be found in digital learning games:

- a goal, an objective to achieve;
- game activity, i.e. a process, an event; the player is doing something;
- game rules;
- outcome(s), i.e. a numerical score depending on gaining or losing points;
- conflict or competition, i.e. some sort of contest, either with the system or with other players, or even with game players themselves by improving their own score.

The question that should be asked first and foremost, is whether end-users would really appreciate the inclusion of game-like elements in CAT-SL. It is expected that younger learners who might find structured training with CAT-SL a bit tedious. It ultimately depends on the type of end-user to determine what sort of game would be most effective (Nadolny et al., 2017).

Before actually beginning to develop a game or quiz it is therefore important to investigate what end-users would consider appropriate by offering them a number of possible game or quiz formats. In a learning situation gathering points might be an incentive for learners to try to improve their scores during consecutive learning rounds. A time-element is often employed to stimulate users to try and beat scores obtained earlier. Similarly, movies of signs could be covered with tiles that slowly disappear, urging users to indicate what they think was shown, scoring more points when giving a correct answer when more parts of the movie remain covered.

For quiz-type elements during a training session one option might be to show the avatar producing a gloss in Sign Language, and giving the student a (limited) number of words he can choose from for the correct answer. This can be made increasingly difficult, by giving only a handshape or hand movement that would be a distinctive feature between a number of given words.

These types of games and quizzes are relatively easy to develop without having to spend huge amounts of the project's budget for it, so the main focus can remain on the learning tool.

14. Evaluation

During the development of the CAT-SL system a number of evaluation cycles are run through. In these processes different aspects of CAT-SL are tested.

- These aspects can be categorized as follows:
- Functionality and user-friendliness of the user-interface, both from the point of view of the student as well as the teacher
- Robustness of the system
- Assessment of learning effects
- Type of feedback of CAT-SL to the student
- CAT-SL and the Deaf user

In the following sections each of these aspects is separately addressed.

14.1. Functionality and user-friendliness of the UI

A very important aspect of the CAT-SL system is the fact that it is used as a stand-alone learning tool for students of Sign Language, as well as the teacher who may fill the system with assignments, typically consisting of both written material, such as words or sentences that the student will have to produce in SL.

Additionally, the teacher may provide video files that will be used as input to control the

avatar, or as examples for the students to sign themselves. Feeding text and/or video files into CAT-SL should be a straightforward action, that teachers should preferably be able to do themselves without any necessary technical assistance.

The same holds true for students that have to work with CAT-SL. The UI should be self-explanatory with options for recording, playback (with adjustable speed) and storage of videos.

To determine whether the functionality of CAT-SL fits user requirements, it is essential to query future users and to incorporate user groups in evaluation and improvements of early versions of the UI design.

14.2. Robustness of the CAT-SL

On the input side of CAT-SL its robustness and reliability can depend on both on the quality of the video material as well as the way in which this is processed. Both robustness and reliability can be determined by comparing recognition scores of standardized SL stimuli, such as have been developed for Dutch SL tests to measure recognition proficiency with learners of SL, to recognition scores obtained from the same test stimuli processed through CAT-SL for learners with comparable proficiency levels.

On the output side the reliability of CAT-SL is influenced by the quality of the avatar that shows the SL sequences. The impact of recording conditions, such as light exposure of the student, the quality of the video camera, background conditions and maybe even the type of clothes people wear on the quality of the SL produced by the avatar should be ascertained. In case recording conditions may substantially influence the quality of the SL played back by the avatar, guidelines are set up that future users have to take into account in order to provide reliable video input.

14.3. Assessment of learning effects

In the final stages of the project the effect of CAT-SL on improvement of SL skills should be measured with students of SL. It remains to be seen at this point whether it is possible to set up an extensive (in time) experiment to establish the amount of progress made in acquiring SL skills. Additionally, it is difficult to enroll two groups of users of statistically relevant numbers to carry out a protracted training period. Instead it may be relevant to assign users randomly to an experimental condition without CAT-SL training (i.e. the current way of learning SL) and an experimental condition where students are asked to partake in a supplementary training with CAT-SL. To establish any progress, all students' starting levels are determined as a base-line. Hereafter their SL skills are measured at regular intervals, so that progress rates can be calculated and compared between the different groups, controlling for the initial starting levels. This type of assessment can be carried out for different types of SL learners.

14.4. Type of feedback of CAT-SL to students

The way CAT-SL provides feedback to the student could very likely be one of the most important factors contributing to the learner's success. In a field study learners in different

stages of acquiring SL are asked to comment on various ways of feedback that can be built into the tool.

Given an example of a sign or sign sequence to mimic, the student's own production input is recorded and stored. Students should be able to playback their own recording next to the output provided by the avatar. This recording should be given an acceptability rating score varying between 0 – 100 per cent correct. In addition the student should be able to playback the original example they were requested to copy and compare it to their own production. Ideally the duration of the target file should be adapted such that it matches the student's video. When the student receives a score < 70% correct, CAT-SL could require the student to provide another take, with a maximum of ten. In a small graph feedback could be given on the success rate of this particular production as a function of time.

To help the student improve the correctness of his production, the program should provide feedback on at least four different aspects that have been important in establishing the overall correctness score, viz. (i) handshape, (ii) position of the hand in relation to the body, (iii) type of movement and (iv) facial expression. Preferably incorrect production of each of these aspects should be indicated in the avatar by changing the colour during the relevant parts of the production.

To establish the intrinsic value of an acceptability rating score provided by CAT-SL, this score should be compared to a score based on a judgment given by a teacher. Items that have been scored automatically by CAT-SL should also be given to Deaf native signers, for a judgment on either acceptability or comprehensibility.

14.5. CAT-SL and the Deaf user

Finally, CAT-SL could also be employed as a tool for Deaf students wanting to acquire a second, i.e. foreign SL.

Although perhaps not the main target group in this project, it is an important user group to keep in mind, when it comes to the UI design and the naturalness of the avatar. Regarding the design of the UI, as little text should be used. CAT-SL UI should be self-explanatory, preferably making use of symbols to indicate the function of buttons or indicating what action should be required at a certain point in time by changing the colour of the buttons that should be clicked on (or deactivating the ones that would lead to incorrect actions if selected).

Even more so, the quality of the signs produced by the avatar should be acceptable to native signers. From the very beginning of the development cycles the acceptability of the avatar should be scrutinized by a team of Deaf persons, who can be asked to provide feedback on the quality of both UI and avatar. Preferably native signers having different SLs as their native SL should be incorporated in a judgment panel during the course of the project.

15. Conclusions and future steps

We have presented a document that is the basis for the development of an automated system for teaching sign languages. It can be used for any such development in the future.

We have presented the user roles and groups. We have presented the similarities and differences among the SLs of the consortium countries to offer a unified approach and the challenges of developing a system. We presented the functional and non-functional

requirements and the basic use cases, for use by the developers. We described the EU policies and guidelines and the situation for the SLs in the partner countries, so that we comply with them. We presented the basic curriculum structures for three categories of learners: university students, school pupils and the general audience. We presented the ECTS certification guidelines using the system. We made special mention to quizzes and games and ways to incorporate them. We finally presented evaluation criteria for the system.

In the next step we will capitalize on the results of this report to proceed with the development of the system and the courses. The report is not meant to be a static document, but a living one. It will be further validated by the interested parties and eventually updated, incorporating the users' feedback.

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