Architecture design of a reinforcement environment for learning sign languages

Luis Naranjo-Zeledón[1,2], Mario Chacón-Rivas[2], Jesús Peral[1], and Antonio Ferrández[1]

[1] Department of Languages and Computing Systems, University of Alicante, Alicante, Spain
[2] Inclutec, Costa Rica Institute of Technology, Cartago, Costa Rica

Corresponding Author:
Luis Naranjo-Zeledón[1,2]
Cartago, Costa Rica
Email address: lcnz@alu.ua.es, lnaranjo@itcr.ac.cr

Abstract

Different fields such as linguistics, teaching, and computing have demonstrated special interest in the study of sign languages (SL). However, the processes of teaching and learning these languages turn complex since it is unusual to find people teaching these languages that are fluent in both SL and the native language of the students. The teachings from deaf individuals become unique. Nonetheless, it is important for the student to lean on supportive mechanisms while being in the process of learning an SL. Bidirectional communication between deaf and hearing people through SL is a hot topic to achieve a higher level of inclusion. However, all the processes that convey teaching and learning SL turn difficult and complex since it is unusual to find SL teachers that are fluent also in the native language of the students, making it harder to provide computer teaching tools for different SL. Moreover, the main aspects that a second language learner of an SL finds difficult are phonology, non-manual components, and the use of space (the latter two are specific to SL, not to spoken languages). This proposal appears to be the first of the kind to favor the Costa Rican Sign Language (LESCO, for its Spanish acronym), as well as any other SL. Our research focus stands on reinforcing the learning process of final-user hearing people through a modular architectural design of a learning environment, relying on the concept of phonological proximity within a graphical tool with a high degree of usability. The aim of incorporating phonological proximity is to assist individuals in learning signs with similar handshapes. This architecture separates the logic and processing aspects from those associated with the access and generation of data, which makes it portable to other SL in the future. The methodology used consisted of defining 26 phonological parameters (13 for each hand), thus characterizing each sign appropriately. Then, a similarity formula was applied to compare each pair of signs. With these pre-calculations, the tool displays each sign and its top ten most similar signs. A SUS usability test and an open qualitative question were applied, as well as a numerical evaluation to a group of learners, to validate the proposal. In order to reach our research aims, we have analyzed previous work on proposals for teaching tools meant for the student to practice SL, as well as previous work on the importance of phonological proximity in this teaching

41 process. This previous work justifies the necessity of our proposal, whose benefits have been
42 proved through the experimentation conducted by different users on the usability and usefulness
43 of the tool. To meet these needs, homonymous words (signs with the same starting handshape)
44 and paronyms (signs with highly similar handshape), have been included to explore their impact
45 on learning. It allows the possibility to apply the same perspective of our existing line of research
46 to other SL in the future.

47
48 **Subjects** Human-Computer Interaction, Computer Education
49 **Keywords** Sign language, Phonological proximity, Learning reinforcement, Similarity measures

50

Introduction

52 It is important to lean on learning reinforcement tools to enhance the learning process of a sign
53 language (SL), the knowledge obtained from class work seems to be insufficient to meet this
54 purpose. The use of technology becomes a great option to achieve the objective of learning a
55 sign language because the student faces a new language based on his visual abilities rather than
56 the spoken word. The use of technology can offer easy-to-use visual interfaces permitting the
57 interested party to compare and associate the meaning of signs more accurately. The interested
58 party has the possibility to access these applications if necessary.
59 A previous research (Naranjo-Zeledón et al. 2020), showed that phonological proximity
60 upgrades different areas within the study of a Sign Language. In relation to this particular
61 research, the fundamental characteristics of the Costa Rican Sign Language (LESCO, for its
62 acronym in Spanish) were disclosed regarding phonological proximity for clustering and
63 learning reinforcement purposes.
64 The main contributions of our proposal are:
65 1. The design of a modular and portable architecture of a learning reinforcement environment
66   for sign languages (it can be applied to different sign languages).

67 2. The inclusion of a graphical software tool, including a signing avatar and a phonological
68   proximity component meant to enrich the learning process.

69 3. The identification of homonym and paronym signs that illustrate the different degrees of
70   proximity between the signs.

71 4. The evaluation of the phonological proximity module at the implementation level, as well as
72   the usability and usefulness of this implementation in a software tool.

73 The architecture design includes the aforementioned software tool, containing a
74 phonological component so to make the learning process more complete. This tool was
75 developed by the Costa Rica Institute of Technology. At first, the tool showed concepts
76 classified into different categories (colors, alphabet, numbers, etc.). These classifications are
77 grouped into three levels: basic, intermediate, and advanced. If a sign is chosen by the user, an
78 avatar will reproduce it, interfacing at the same time with the PIELS (International Platform for

79 Sign Language Edition, for its acronym in Spanish). So far, it displays content from LESCO, but
80 the design of the tool allows for adaptation to any SL (Serrato-Romero and Chacón-Rivas, 2016).
81   Our phonological proximity study analyzes homonyms (signs with the same starting
82 handshape), paronyms (similar signs with different meanings), and polysemy which we have
83 determined is very rare in LESCO (same sign with different meanings). Some examples of these
84 phenomena are easy to find in spoken languages such as the paronyms 'affect' and 'effect', or
85 the homonyms of 'book' ('something to read' or 'make a reservation'). Sign languages require to
86 employ visual variables, like handshapes, their location at the pointing spot and facial gestures.
87 The software tool was broadened to examine these correlations and their impact on reinforcing
88 learning.
89   Conventional techniques in use, as will be seen in the Background section, have
90 drawbacks because they are specifically designed for some specific sign language. This situation
91 is very possibly since they do not use, or at least do not make explicit, a formalization of the
92 grammar of the specific sign language. This is in direct contrast to our approach, which takes as
93 a starting point the formalization of phonological parameters mapped to integer numbers and
94 their subsequent use by applying similarity measures.
95   We emphasize the difference between other methods to better understand the position of
96 this work. In this way, the research community can formalize their own parameters and adopt our
97 approach without the need for any change at the architectural level. In the field at hand, which is
98 education, the proposals revolve around the use of various techniques or approaches, each with
99 its rationale and justification, but at the same time revealing clear disadvantages, as explained
100 below:

101 • Self-assessment open-source software, with web-based tests for adult learners. These Yes/No
102   tests require important improvements to offer a more complete service, such as providing the
103   option to see translations directly after indicating whether the user knows or does not know a
104   sign.
105 • Using hardware devices (wearables, usually Kinect) with recognition of hand movements and
106   guidance to learners. As a general rule, the use of wearables is preferable to be left as the last
107   option, because it is unnatural, it is expensive and the equipment can be lost or damaged,
108   hindering the process.
109 • Educational games (who also use wearables). The same downsides identified in the previous
110   point are faced here.
111 • Incorporation of computer vision to indicate unnatural movements in the novice. While it is
112   true that computer vision is a very fertile field of research today, but it also requires the use
113   of additional equipment.
114 • Teaching fingerspelling in the form of quizzes. In general, fingerspelling presents a
115   communication technique that is too limited and should only be used when the signaling
116   person does not have any other resources to communicate their message at all.
117 • Lexicon teaching proposals. can be incomplete when the desired outcome is to produce real
118   communications, with syntactic connections that make sense to the other party.

119   Our main objective is to demonstrate that SL learning can be reinforced by technological
120   means incorporating the concept of phonological proximity. In turn, we will explain how the
121   phonological components of the SL in question should be parameterized, to incorporate them
122   into an architecture that provides a suitable interface with a signing avatar.
123   In conclusion, in this paper we provide elements that clarify how to deal with issues of
124   central importance in this type of technologies, hence making clear the advantages of the
125   proposed system, specifically:

126   • Modular architecture, to simplify the maintenance and the incorporation of new
127   functionalities.
128   • Applicable to several sign languages, to take advantage of the conceptual power of our
129   contribution in other languages and other tproypes of projects.
130   • Enrichment of learning environments, to take advantage of opportunities to accelerate and
131   improve the experience.
132   • Differentiation between homonyms and paronyms, to contrast the different degrees of
133   proximity between the signs and, therefore, the need to emphasize the practice where it is
134   most necessary.
135   • Applicable to other environments, offering a portable concept where researchers can
136   incorporate it and take advantage of it.
137   • Usability and usefulness validated through a standard test, to have a high degree of certainty
138   that the concept of proximity is properly supported by a real tool, which in turn is easy to use.

139   The next section provides a background of previous work on the subject matter. Then, we
140   present the proposed architecture of the learning reinforcement environment ('Architecture for
141   SL learning reinforcement environment' section). After that, we illustrate details of its
142   deployment in a software tool showing the experiments carried out with the phonological
143   proximity module and the users' validation ('The SL Learning Reinforcement Tool module'
144   section). Finally, we draw our conclusions, depicting our contribution to the sign language
145   learning process and the future work ('Conclusions' section).
146

147   ## Background

148   This section presents the antecedents of the object of study. They have been classified into three
149   groups of great significance, each one explained in the following subsections. First, the
150   importance of phonological proximity is addressed, which is a crucial matter in this study. Then,
151   the similarity measures for phonological proximity are examined, which are the computational
152   mechanism to determine similarity between objects to be compared. Finally, we go over the
153   proposals for teaching tools that have been made for the student to practice sign languages. We
154   believe that based on the exhaustive search performed in scholarly repositories, this literature
155   reflects an up-to-date state of the research on these topics.

The importance of phonological proximity

156 **The importance of phonological proximity**

157 According to Baker et al. (2016) the main aspects that a second language learner of a sign
158 language finds difficult are phonology, non-manual components, and the grammatical use of
159 space. These features are specific to sign languages and do not take place in spoken languages.
160 Moreover, the phonological inventory of sign languages is completely different from that of
161 spoken languages. Another salient observation of the authors has to do with how among the
162 different phonological parameters, the handshape has the largest number of distinctive
163 possibilities. In the sign languages that have been studied, the number of different handshapes
164 appears to be larger than the number of locations and movements. Iconicity is also to be
165 considered since signs commonly portray iconic features, which means that the handshape
166 resembles parts of the meaning, a phenomenon that is extremely rare to find in spoken
167 languages.

168   Williams, Stone & Newman (2017) have studied the importance of phonological
169 similarity to facilitate lexical access, that is, the process by which individuals produce a specific
170 word from their mental lexicon or recognize it when it is used by others (American
171 Psychological Association, n.d.). This study, rooted in this psycholinguistic aspect, has
172 determined that lexical access in sign language is facilitated by the phonological similarity of the
173 lexical representations in memory.

174   Keane et al. (2017) have demonstrated that for fingerspelled words in American Sign
175 Language (ASL), the positional similarity score is the description of handshape similarity that
176 best matches the signer perception when asked to rate the phonological proximity. The positional
177 similarity approach is superior when compared to the contour difference approach, so in order to
178 define similarity when fingerspelling, it is more important to look at the positional configuration
179 of the handshapes than concentrating on the transitions.

180   An eye-tracking study on German Sign Language (Wienholz et al., 2021) recorded eye
181 movements of the participants while watching videos of sentences containing related or unrelated
182 sign pairs, and pictures of a target and some unrelated distractor. The authors concluded that
183 there is a phonological priming effect for sign pairs that share both the handshape and movement
184 while they differ in their location. The results suggest a difference in the contribution of
185 parameters to sign recognition and that sub-lexical features can influence sign language
186 processing.

187   An experiment conducted by Hildebrandt & Corina (2002), revealed that all subjects,
188 regardless of their previous exposure to ASL, categorize signs that share location and movement
189 (and differ in handshape) as highly similar. However, an ulterior examination of additional
190 parameter contrasts revealed that different degrees of previous linguistic knowledge of the
191 signers influenced the way they perceived similarity. So, for instance, the combination of
192 location and handshape is recognized as carrying a higher level of similarity by native signers
193 than by late deaf learners or by hearing signers.

Similarity measures for phonological proximity

194 With regard to measuring the phonological proximity in a sign language, different similarity
195 measures can be used. They can be categorized into five categories: Edit-based, Token-based,
196 Hybrid, Structural (Domain-dependent), and Phonetic (Naumann & Herschel, 2010; Bisandu,
197 Prasad & Liman, 2019).
198
199 Similarity measures can be used, as long as the characteristics of the data used as
200 phonological parameters have been properly characterized. For instance, if the parameters are
201 strings of characters, then the edit-based similarity measurements can satisfy the objective. If the
202 parameters are token sets (this is our case), then token-based measures can be used successfully.
203 Hybrid approaches strive for a balance regarding the response speed of other known measures
204 and the robustness of comparison between all the tokens, so as to find the best matches, both to
205 deal with named entities and to solve problems of misspelling in big data contexts (this fact does
206 not point them as good candidates for sign languages). Phonetic measures, due to their very
207 nature, have been extensively used for spoken languages, so they are not a good choice for sign
208 languages. Finally, the domain-dependent measures use particularities of the data, which do not
209 fit well in corpora of sign languages.
210 The current similarity measures have been widely welcomed by the research community
211 and many of them are long-standing, hence the literature on the matter can be classified as
212 classical. Coletti & Bouchon-Meunier (2019) note that a complete review or even a simple
213 listing of all the uses of similarity is impossible. They are used in various tasks ranging from
214 management of data or information, such as content-based information retrieval, text
215 summarization, recommendation systems, to user profile exploitation, and decision-making, to
216 cite only a few. Among the many similarity measures proposed, a broad classification may be of
217 use: the classical crisp context (Choi et al., 2010; Lesot et al., 2009) and the fuzzy context
218 (Bhutani & Rosenfeld, 2003; Bouchon-Meunier et al., 1996; Li et al., 2014; Couso et al., 2013).
219 Due to the nature of our research, we concentrate on the classical crisp context, since the fuzzy
220 scenario does not apply to our object of study. The main characteristics of these predominantly
221 classic measures are:

222 • Edit-based focusing on the calculation of the changes necessary to produce one string from
223 another, weighing the number of necessary changes (insertions, deletions or modifications) to
224 produce the new string. Hamming distance (Hamming, 1950) and Levenshtein distance
225 (Levenshtein, 1966) are the best known.
226 • Token-based approaches measuring the number of matches between two sets of parameters,
227 (n-gram tokens), where tokens are words or numbers. In this category we can mention
228 Jaccard distance (Jaccard, 1912) and Cosine distance (Singhal, 2001).
229 • Hybrid strategies comparing strings, using an internal similarity function (Jaro or
230 Levenshtein, for instance). Monge–Elkan (Monge & Elkan, 1997) and Soft TF-IDF (Cohen,
231 Ravikumar & Fienberg, 2003) are examples of these techniques.
232 • Structural proposals focusing on data particularities (Domain-dependent). Dates (Naumann &
233 Herschel, 2010) is the best-known example.

234   • Phonetic measures matching similar sounds in spoken languages (for example, they give
235   maximum qualification to pairs of words such as 'feelings' and 'fillings'), applying pre-
236   established rules of similar sounds. Soundex (Russell & Odell, 1918) and Kölner–Phonetik
237   (Postel, 1969) follow this strategy.

238   **Proposals for teaching tools**

239   Currently, studies for LESCO seem to be insufficient. That is why this section goes into
240   software-based proposals, despite the fact they do not consider this foremost linguistic concept.
241   Also, some researchers focus on the study of sign languages they can relate to more easily, be it
242   their own country or workplace sign language in use; this situation is very common in the
243   research community. Because of this situation, it seems relevant to mention the authors findings
244   and proposals in this section. The education for deaf people or interpreters of sign language is
245   out of the scope of this research. Our main focus stands for reinforcing the learning process for
246   hearing people as final users.
247   In (Haug & Ebling, 2019) a report about the use of open-source software for sign
248   language learning and self-assessment has been made. Another finding has been the web-based
249   test for Swiss German Sign Language (DSGS, for its acronym in Swiss German), designed for
250   adult learners. They gave important feedback on the appropriateness of the DSGS vocabulary
251   self-assessment instrument. This feedback arose inputs for the system improvement. The
252   innovation of this study relies on the fact about using existing open-source software as a starting
253   point to develop and evaluate a DSGS test for self-assessment purposes.
254   The target of the study in (Álvarez-Robles, Álvarez & Carreño-León, 2020) is to bring
255   forward an interactive software system (ISS) making use of a hardware device (Leap Motion) so
256   that average users had fluid communication with deaf people. The objective is to allow a natural
257   recognition of hand movements by helping the average users learning Mexican Sign Language
258   (MSL) at the same time. Also, through gamification techniques, it would permit the user to learn
259   and communicate with deaf people.
260   Related to British Sign Language (BSL), there is a lack of games available in the
261   marketplace for teaching purposes indicating that minimal efforts have been made to meet this
262   objective (Kale, 2014). The intention of the study is to develop a prototype using the Microsoft
263   Kinect, to help teachers educate young students. This prototype would teach basic BSL, by using
264   JavaScript and HTML5 in a web browser. Positive feedback coming from interviews and
265   playtests among 10 sign language experts unfamiliar with games technology to teach sign
266   language, was also collected. They indicated that this prototype could be used as complement for
267   those conventional teaching methods.
268   Another research (Huenerfauth et al, 2016) revealed there is a lack of interactive tools for
269   those students learning ASL. These tools might provide them feedback on their signing accuracy,
270   whenever their ASL teacher is not available for them. A software system project was also
271   performed by utilizing a Kinect camera. By incorporating computer vision, this software can
272   identify aspects of signing by showing non-natural movements so to provide feedback to the
273   students in their won practice. This tool is not supposed to replace feedback from ASL teachers.

274 However, the tool can detect errors. Students state it is better for them to have tools able to
275 provide feedback like videos helping with error minimization, mainly time-aligned with their
276 signing.
277   Learning sign language is a task, commonly performed in peer groups, with few study
278 materials (Joy, 2019). According to their opinion, fingerspelled sign learning turns into the initial
279 stage of sign learning used when there is no corresponding sign, or the signer is not aware of it.
280 Since most of the existing tools are costly because of the external sensors they use, they
281 suggested SignQuiz, a low-cost web-based fingerspelling learning application for Indian Sign
282 Language (ISL), with automatic sign language recognition. This application has been the first
283 endeavor in ISL for learning signs using a deep neural network. The results reveal that SignQuiz
284 is a better option than printed medium.
285   There is another available proposal for Chinese Sign Language, by Chai et al. (2017).
286 They indicate that using a computer-aided tool known as SignInstructor can offer an effective
287 and efficient learning means. Even they go far beyond stating that the intervention of human
288 teachers is no longer needed, and that the sign language learning is highly effective showing an
289 outstanding score, even higher than the one obtained with face-to-face learning. The system has
290 three modules: 1) a multimodal player for standard materials, including videos, postures, figures,
291 and text; 2) online sign recognition by means of Kinect; 3) an automatic evaluation module.
292   There is a proposal for a Ghanaian Interactive Sign Language (GISL) Tutor (Osei, 2012).
293 This interactive tutor becomes the first computer-based for this sign language. It was specifically
294 designed to teach vocabulary of Ghanaian-specific signs. Those Ghanaians who were involved
295 with this tutor and tested it, said they would even like to have more available signs. The GISL´s
296 Tutor main purpose is letting Ghanaian-specific signs be accessible to anyone interested in using
297 this tool, by displaying pre-recorded lessons with the help of a computerized avatar.
298   We can conclude this section affirming that, to the best of our knowledge, there are no
299 documented proposals regarding software-assisted learning of sign languages that exploit the
300 concept of phonological proximity. After having studied the background of this topic, it is clear
301 that this research and its corresponding proposal is pertinent, insofar it explains in detail the
302 mechanisms that can be used to incorporate a component of phonological proximity to reinforce
303 the learning of any sign language.

304

Architecture for SL learning reinforcement environment

306 The architecture of the tool has been conceived to show a high level of modularity, as well as to
307 separate the logic and processing aspects from those associated with the access and generation of
308 data. Obviously, by relying on several existing components, the design must show all the
309 interdependencies that this implies.
310   Figure 1 shows the general architecture of the SL learning reinforcement environment,
311 which consists of four layers, ranging from those interacting with the users to those providing
312 signs and processing modules reflecting logically derived similitude relations. These layers are:

313   1) A graphical user interface, both for web browsers and mobile devices.

314   2) The SL Learning Reinforcement Tool.

315   3) An interface with a Phonological Proximity Submodule and a Signs and Discourses

316   repository.

317   4) A semantic disambiguation module.

318

319   **Figure 1: SL learning reinforcement environment architecture.**

320   The user interface provides access through any device that allows running a conventional

321 web browser or running an application on a commonly used mobile device. The users can play

322 different roles, which is relevant in the next layer, to determine the views and actions they can

323 carry out with the tool.

324   The SL Learning Reinforcement Tool can be used in web or mobile environments. It

325 consists of a sublayer called the learning module, which in turn classifies users into three roles:

326 user (a learner), administrator, and instructional designer. These roles exist to strike a balance

327 between separation of duties and flexibility. The user role of the tool provides access to the

328 practice, assessment and statistics modules. The administrator role also has access to these

329 modules, while the instructional designer role can use the practice, assessment and lesson

330 modules. This lesson module is where the instructional design is carried out, that is, the design of

331 each lesson, practice and evaluation mechanisms.

332   The other sublayer is the Phonological Proximity Component. This sublayer is in charge

333 of interfacing with the following architectural layers, sending requests for signs in phonological

334 close proximity every time that any of the users from any of the mentioned roles require it, as

335 well as reproducing signs through the avatar.

336   Then we find two parallel layers, actually based on the already operational PIELS

337 platform: first the Phonological Proximity Submodule and aligned to this same level the Sign and

338 Discourses Repository. These layers interact with each other and also with the layer of the SL

339 Learning Reinforcement Tool, previously explained.

340   The Phonological Proximity Submodule is responsible for receiving requests of similar

341 signs, using a unique sign identifier. The Top-ten Petitioner Component processes these requests

342 and returns the ten signs with the greatest phonological proximity with respect to the one

343 received as a parameter. To do this, a repository called PIELS Similitude Matrix is queried, in

344 which all the signs that make up the LESCO lexicon have been pre-processed. To keep this

345 repository updated, there is a New Signs Similitude Evaluation Component, which receives each

346 new sign included in the PIELS Sign Database from the parallel layer and applies a similarity

347 measure between all the signs (the measure that has worked best is the cosine formula).

348   The Signs and Discourses Repository contains the database with the LESCO lexicon up-

349 to-date and a collection of discourses built through the use of the PIELS platform. It also

350 contains the signing avatar, which is in charge of visually reproducing the signs that it receives

351 by parameter, as well as complete discourses. Naturally, to build these discourses the previously

352 existing signs are used or new signs may be created in its built-in editor as needed. This layer

353 provides a mechanism to embed the visual display of the avatar in the upper layer of the SL
354 Learning Reinforcement Tool, in the modules that so demand it: lessons, practice and
355 instructional design.
356   Finally, there is the layer called Semantic Disambiguation, which is intended to be used
357 in future work. The Disambiguation Container works through a big data Web corpus and a
358 cognitive computing module (Naranjo-Zeledón et al., 2019). It will be used to provide additional
359 functionality to the tool, consisting of determining semantic proximity, that is, signs whose
360 meanings are similar, regardless of whether or not they are similar in shape.
361

The SL Learning Reinforcement Tool module

363   In this paper, we focus on describing the architecture and carefully detailing the SL
364 Learning Reinforcement Tool module, to emphasize the feasibility of our proposal from a
365 practical point of view and to ensure that this has been validated by a group of users with a
366 suitable profile for this task. The use of the tool seeks to demonstrate in a tangible way that it is
367 feasible to incorporate the concept of phonological proximity in a learning reinforcement tool
368 serving as the basis for validating this concept with sign language learners. The tool description
369 and the performed experiments are explained in the two following subsections.
370

Tool description

372 The interface classifies signs into five categories (alphabet, numbers, greetings, Costa Rican
373 geography and colors), displaying a new screen when choosing one of them with a list of
374 available signs. Sequentially, the set of signs pertain to learning levels, ranging from the simplest
375 to the most complex ones. Figure 2 exhibits the interface once logged into the system.
376

377   **Figure 2: The software basic level interface with signs classified into categories.**

378   The adaptation of the software tool is achieved by adding a functionality when choosing a
379 signal. Whenever the user clicks on it, a list of its paronyms is shown, so the avatar reproduces
380 the sign, then the user can request to reproduce the similar signs. In this way, the small
381 differences can easily be determined, fact that alerts the user about how careful they should be
382 when having a conversation with a deaf person.
383   Figure 3 exhibits the graphical display once the alphabet lesson module is chosen and
384 clicked on 'Letter-D'. The system shows the top-ten similar signs, the first sign displays a
385 homonym 'Where' (from the starting handshape), and the rest of them are paronyms: 'Letter-K',
386 'Desamparados' (the name of a crowded city), 'Sunday', 'Dangerous', 'Dog', 'Mouse',
387 'Nineteen', 'And', 'Ministry/Minister'. If the user clicks on the suggested signs, then the avatar
388 reproduces them. Figure 4 shows the avatar pointing at 'Letter-D', while Figure 5 shows
389 paronym 'Sunday'.
390
391

392
393 **Figure 3: Top-ten homonyms/paronyms for 'Letter-D'.**

394

395 **Figure 4: Avatar signing homonym 'Letter-D'.**

396
397 **Figure 5: Avatar signing paronym 'Sunday'.**
398   When practicing, the system displays the avatar making a sign. This task can be repeated
399 at will. Then, the student chooses the right word corresponding to the four listed options. Figure
400 6 illustrates this stage.

401
402
403 **Figure 6: Avatar signing 'Letter-U' for practice sessions.**

404   The system guides the student´s learning process by following a sequence of steps. This
405 feature makes possible for the student to take lessons, save his progress status and, have access to
406 new levels within the application to learn new concepts. The system also allows the theme to be
407 changed, so to increase contrast levels facilitating accessibility for low-vision individuals.
408 Besides, the student can access statistics to measure his daily progress.

409 **Experimentation**
410 The objectives of our experimentation consisted of evaluating the similarity measure used in the
411 proposal and the validation of the tool. Therefore, the methodology was oriented to achieve these
412 objectives. First, each sign was defined using 26 phonological parameters (13 for each hand),
413 and then a similarity formula was applied to compare each pair of signs. These previous
414 calculations were used to display each sign and its top-ten similar signs. Finally, the SUS
415 usability standard test and an open qualitative question were applied, as well as a numerical
416 evaluation to a group of students, to validate the proposal.
417   As will be seen later, in the user validation subsection, user research is a method that
418 naturally fits the type of research we are presenting. User research is meant to represent a strong
419 foundation for design decisions and general strategy. It helps in creating high-quality products
420 for end-users, with the necessary data to back the strategy and design decisions. It also helps to
421 identify early adopters of the product, hence discovering people who can give contextual
422 feedback from the early stages of development.
423   In the two following subsections, we explain the experiments carried out to evaluate the
424 similarity measure we have used in our phonological proximity module, and the validation with
425 different users regarding the usability and usefulness of the tool.

426 *Phonological proximity module*
427   A similar measure, applied to the phonological parameters of the signs, was implemented. It
428 produces a list ordered from highest to lowest for each one of them. To interact with the students,
429 whenever they select a sign, the system just displays the ten most similar results to avoid
430 overwhelming with huge outcomes Table 1 shows those similar scores gotten from sign 'Letter-

431   D'. As per the standard cosine formula, a higher number stands for higher similarity. As a matter
432   of fact, if a 100 score is obtained, it means that the signs are homonyms. We also present the 26
433   phonological parameters for sign 'LETTER-D' and its top-ten similar signs, those matching
434   parameters pop out in bold. As depicted in previous research (Naranjo-Zeledón et al., 2020), the
435   results achieved by the cosine formula are based on mapping the phonological parameters of each
436   sign to an array of numbers. These numbers are predefined and show different phonological
437   characteristics of the signs like the hand orientation, the handshape, and the hand spatial location.
438   Therefore, this standard formula is used to measure proximity among the orderings over the n-
439   dimensional space. The formula is shown in Eq. (1).

440
$$\cos(x,y) = \frac{x \cdot y}{||x|| ||y||}$$
(1)

441   Here x and y are two arrays, both of them containing 26 entries that map 13 phonological
442   parameters identified for each hand. If the cosine value is 1, then the two arrays are identical,
443   while a value of 0 means that they do not have anything in common.

444

445

446   **Table 1:**

447   **Phonological parameters for sign 'LETRA-D' and top-ten similar signs.**

448

449   *User validation*

450   This section is structured to first present the importance of user research, which leads to the
451   choice of subjects. Then, we proceed to explain what these subjects were asked to do. Then, we
452   provide a rationale for the concept of phonological proximity as the central axis of the validation
453   process. Finally, we explain in detail how usability and utility were validated.
454   User research is becoming more and more relevant in the field of education and learning,
455   which is why this research adheres to its principles, particularly for validation purposes. As Kao
456   et al. (2018) indicate, iterative user research for products has been conducted in over 50
457   educational technology companies at different stages of development. User research has been
458   used as a collaborative and interdisciplinary process gathering together experts from academic
459   fields, teaching and learning sciences, and human-computer interaction, along with software
460   developers, since developing effective educational products require an understanding of many
461   expertise fields.
462   The profile of the subjects to whom the survey was administered consisted of 12 regular
463   users of technological tools being involved in a process of learning a sign language, 10 of them
464   with a basic knowledge of LESCO and the other 2 in a more advanced level, not experts though.
465   Their ages range from 21 to 52 years, although the average is 31 years of age, with 8 men and 4
466   women. As for men, the average age is 29 and that of women is 35. A total of 10 individuals out
467   of 12 are novices, while the other 2 have a little more advanced knowledge of LS. Regarding
468   their professions and academic degrees, they are classified into a Doctor of Computer Science, a

469 Bachelor of Administration, an Industrial Design Engineer, four Computer Science
470 undergraduates, four Computer Engineers and an Industrial Production Engineer. All of them
471 used the web version of the tool, in order to facilitate remote interaction between the subjects and
472 the researchers, and to more expeditiously clarify any doubts that may have arisen. We have
473 found that when applying our proposal to these users, who are mostly novice sign language
474 learners, the results are very satisfactory, as will be discussed later.

475   The subjects had to do two tests, in preparation for which they interacted directly with the
476 tool, indicating in which cases they detected similarity between base signs and signs proposed by
477 the system as highly similar. After performing this exercise with 3 base signs and their 10 similar
478 signs, they were asked to complete the SUS test, as well as answer an open question about their
479 perception of usefulness. To complement the above, they were asked to also give a numerical
480 rating to the utility. Although the tests were carried out remotely, it was possible to observe how
481 the subjects decided relatively quickly if the suggested signs seemed similar or not, without
482 having to ask the avatar to reproduce them several times.

483   The results obtained in the evaluation of the phonological proximity module are deeply
484 analyzed in our previous paper (Naranjo-Zeledón et al., 2020. In our database, we have already
485 mapped each sign to a vector of 26 numerical parameters, each one with a precise phonological
486 meaning. The parameters follow this order: left index, left middle, left ring finger, left pinky, left
487 finger separation, left thumb, right index, right middle, right ring finger, right pinky, right finger
488 separation, right thumb, left rotation, left wrist posture, left interiority, right rotation, right wrist
489 posture, right interiority, left laterality, left height, left depth, contact with the left arm, right
490 laterality, right height, right depth, contact with the right arm.

491   For example, the array [1,3,2,2,1,3,1,3,2,2,1,3,3,3,3,2,3,3,2,4,15,3, 2,4,15,3,2] contains
492 the 26 parameters that phonologically describe the sign for "PROTECTION", while the subarray
493 [1,3,2,2,1,3,3,3,2,4,15,3,2] represents only the left-hand parameters. As explained above, the
494 cosine is a token-based approach, and it was selected because it is the most natural way to handle
495 numerical arrays of parameters, as is the case in this research. An edit-based measure of
496 similarity would force the arrays to be converted to strings, taking care that some parameters
497 have one digit while others have two. On the other hand, domain-dependent measures do not
498 apply to our data, and a hybrid approach presents unnecessary complications. Obviously,
499 phonetic similarity measures are specifically designed for spoken languages, so they are left out
500 in this discussion.

501   With regard to the user evaluation, we have conducted an extrinsic evaluation through the SUS
502 test, consisting of a questionnaire with ten items and a five Likert scale response for each option,
503 ranging from 'Strongly agree' to 'Strongly disagree' (Brooke, 1986). Among its benefits, we
504 can identify that it has become an industry standard, widely referenced in articles and
505 publications. By using SUS, one can make sure of these very desirable characteristics:

506 • It is extremely easy to administer to participants.
507 • It can be used on small sample sizes and yet attain reliable results.
508 • It is valid in effectively differentiating between usable and unusable systems.

509   In addition to the SUS standardized test, we have considered it appropriate to include an
510   open question of a qualitative nature, where the participants had to answer in a mandatory
511   manner. The question is 'How do you think comparing similar signs has made learning easier or
512   more difficult for you?'. The objective of this question is to evaluate the usefulness of our tool.
513   Then, we proceeded with a last question, to assign a numerical rating to the previous question, on
514   a scale from 1 to 100, worded as follows: 'Based on your answer to the previous question, how
515   would you numerically rate the improvement in learning using similar signs? (1 is the lowest,
516   100 is the highest)'.
517   To carry out the test, each participant was summoned individually and given instructions
518   to enter the system so to become familiar with it. Then, they were asked to choose 3 signs
519   corresponding to the 'alphabet' group and analyze the similarity with their corresponding 10
520   most similar signs, to determine the precision threshold of the similarity formula used, as well as
521   the possible need to refine the initial configuration of the signs before doing validations. After
522   corroborating the levels of similarity, they proceeded to answer the SUS questionnaire, the
523   qualitative question, and assign the numerical rating. The SUS survey format used can be seen in
524   Figure 7.
525
526
527   **Figure 7: SUS (System Usability Scale) standard test.**
528
529

530   Table 2 shows the results of applying the SUS test to the participants, that is, the 12
531   participants in the rows and the 10 standard questions in the columns. There is an additional
532   column on the far right, which corresponds to the numerical evaluation of the usefulness of the
533   phonological proximity as perceived by the participants. Regarding the tone of the responses to
534   the qualitative question, Table 3 shows the opinions and their tone for each participant in the
535   study. This tone has been established by the authors as negative, mainly negative, neutral, mainly
536   positive, or positive. The next section provides a broader discussion of the findings presented in
537   both tables.
538

539   **Table 2:**

540   **SUS Test and Phonological Proximity Scores.**

541
542   **Table 3:**

543   **Opinion/Judgment of learning improvement by using phonological proximity.**

544

545 *Discussion*
546 The SUS usability standard test gives a score of 89, which indicates that the tool has an
547 extremely high level of usability, since the average of a large number of studies of this nature is
548 68 and from 84.1 to 100 the usability is located in the 'A+' percentile, which is the highest
549 (Lewis & Sauro, 2018).

550   Such a high ranking also has the desirable characteristic that the product is more likely to
551 be recommended by users to their peers. This characteristic is of particular relevance when it
552 comes to an innovative product, which presents an important differentiation compared to the
553 existing options, in this case in the educational field.

554   If we examine the extreme ratings, that is, the highest and the lowest, are removed and
555 averaged based on the remaining 10 ratings, the result is still very similar, increasing slightly
556 from 89 to 91, which is indicative that none of them have a greater weight in the overall result.
557 On the other hand, looking for an interpretation of these extremes, it should be noted that the
558 lowest score was 60, and it was awarded by a subject who experienced problems during the
559 reproduction of some signs by the avatar, due to a momentary synchronization problem on the
560 platform, which may have negatively affected her perception. The highest score, 97.5, was given
561 by one of the three subjects with the least experience in sign languages. In both cases it seems
562 that the extreme ratings have a fairly predictable explanation.

563   On the other hand, the phonological proximity score, which reflects a numerical
564 evaluation by each participant in a scale from 1 to 100, yields a very satisfactory average of 91.0.
565 The obtained score demonstrates that the tool is useful for our objective of reinforcing sign
566 language learning.
567   Carrying out the exercise of eliminating extreme ratings again, it can be seen the majority
568 grant a 90 or 100 and that only two subjects gave an overall rating of 70. These are the two
569 people who are not experts but have a little more advanced knowledge in sign languages. Again,
570 the results make sense.
571   The open question showed a positive tone in practically all the answers, which can be
572 synthesized in concepts such as "usefulness", "detection of differences" and "reduce confusion".
573 It is evident that these opinions are favorable and that they in fact reflect satisfaction with respect
574 to the improvement that students perceived when using a computer tool that incorporates the
575 concept of phonological proximity.
576   Obviously, the graphic display of the tool is very useful to match the visual nature of sign
577 languages. Although it is not the central focus of this research, it is important to highlight the fact
578 that the appropriate graphic design and an avatar that reproduces the signs as similar as possible
579 to what the students have learned in class is decisive for the proposal as a whole to be successful.
580   We are of the opinion that there is room for improvement in terms of the similarity of
581 some signs that did not seem to represent a contribution for the majority of subjects. The
582 phonological parameterization and the formula used work well for most cases, but in some
583 particular cases it may be that the rotation and location of the hand account for most of the

584   similarity, leaving aside the handshape, which is precisely what the novice student looks at first.
585   There was only one sign that gave this problem repeatedly, but it deserves attention in future
586   work. Validation was helpful in raising this possibility.
587   The general appreciation that we obtain from what it is stated in this analysis of results is
588   that both the tool used and the concept itself of phonological proximity to detect slight
589   differences have received the endorsement of the subjects of this study. Both from a quantitative
590   and qualitative point of view, the subjects who collaborated in the validation show a clear
591   acceptance of phonological proximity as a valuable concept to help reinforce their learning.
592
593   ## Conclusions
594   This paper presents an architecture to strengthen the sign language learning making use of
595   phonological proximity concept to improve results. As far as we know, this is the first time this
596   approach has been suggested in relation to reinforce the learning of sign languages and,
597   particularly applied to the Costa Rican Sign Language (LESCO, for its Spanish acronym). The
598   main contributions of our proposal are: (1) a modular architecture meant to reinforce different
599   sign languages learning; (2) the inclusion of a software tool with a phonological proximity
600   component to assist in the learning process; (3) the identification of homonyms and paronyms to
601   contrast the proximity levels between the signs; (4) a thorough evaluation of our phonological
602   proximity module and the usability and usefulness of the tool.
603   We describe the operation of our software tool with a graphical interface that classifies
604   concepts and reproduces those selected signs, broadening its current functionality through
605   phonologically similar signs, in other words, with similar handshapes. To meet this purpose, we
606   explore the incorporation of homonymous and paronyms.
607   By allowing the students to compare pretty similar signs, we have included the
608   phonological proximity component into an existing tool with a suitable interface. The value of
609   this improvement is to reduce the number of mistakes of those similar signs in a real
610   conversation with a deaf person since this can seriously impact the communication and hinder
611   the understanding between each other. A mapping of the signs with the other signs becomes an
612   essential requirement to dispose of the available lexicon in advance. To ease the use, we decided
613   that the interface should list only ten similar signs, so the user might not be confused, situation
614   which would be counterproductive.
615   We evaluated both the phonological proximity module and the usability and usefulness of
616   the tool. Thanks to the practical application of the concept of phonological proximity, learning is
617   reinforced, as has been validated through our experimentation with sign language students in this
618   research. We conclude that the incorporation of the phonological proximity concept to this
619   software tool can upgrade the reinforcement of LESCO learning, offering the possibility of using
620   the same approach of our line of research in other sign languages.
621   For future work, the use of standardized questionnaires for user experience, such as
622   AttrakDiff or UEQ (User-Experience Questionnaire), along with the SUS test, are to be
623   considered, encompassing a comprehensive evaluation of the tool. We will also study the effect
624   of using the similarity measure on separate phonological components of signs. This would

625   consist of validating the handshape, orientation and location of the hand as separate components,

626   to determine if this produces improvement in the results. Additionally, we will consider the

627   inclusion of facial gestures, head and trunk movements as possible elements that improve the

628   accuracy of the similarity.

629 **ADDITIONAL INFORMATION AND DECLARATIONS**

630 ## Grant Disclosures

631 The following grant information was disclosed by the authors:

632 This work was supported by the Spanish Ministry of Science, Innovation and Universities
633 through the Project ECLIPSE-UA under Grant RTI2018-094283-B-C32, the Spanish Ministry of
634 Science and Innovation through the Project AETHER-UA under Grant PID2020-112540RB-
635 C43, the Project INTEGER under Grant RTI2018-094649-B-I00, and by the Conselleria de
636 Educación, Investigación, Cultura y Deporte of the Community of Valencia, Spain, within the
637 Project PROMETEO/2018/089.

638 ## Acknowledgments

639 The authors thank the School of Computing and the Computer Research Center at Costa Rica
640 Institute of Technology for the financial support, as well as CONICIT (Consejo Nacional para
641 Investigaciones Científicas y Tecnológicas), Costa Rica, under grant 290-2006. Our colleague at
642 Inclutec, Víctor Romero, provided valuable access to data and feedback on the use of various
643 tools. We also appreciate the great support received by Lery Sánchez, Daniel Martínez, Alfredo
644 Campos, and Ana Zúñiga, at Costa Rica Institute of Technology for providing the software code
645 upon which we built the phonological proximity component. The help of Mario Chacón-Campos
646 to make the definitive deployment of the software on the Web was invaluable.

647 ## Competing Interests

648 The authors declare there are no competing interests.

649 ## Author Contributions

650 - Luis Naranjo-Zeledón and Mario Chacón-Rivas provided the conceptualization, as well as
651   the methodological design of the research and the formal analysis.
652 - Luis Naranjo-Zeledón, Mario Chacón-Rivas, Jesús Peral and Antonio Ferrández scrutinized
653   thoroughly the software suitability.
654 - Luis Naranjo-Zeledón and Mario Chacón-Rivas conceived and conducted the validation
655   stage.
656 - Mario Chacón-Rivas, Jesús Peral, and Antonio Ferrández were in charge of managing the
657   research project, as well as reviewing the final version of the manuscript.

658 ## Data Availability

659 All the data used for experimentation as well as the implementation of the similarity formulas
660 used are available at Zenodo:

661

662 Luis Naranjo-Zeledón. (2021). Phonological proximity calculations and validation [Data set].
663 Zenodo. http://doi.org/10.5281/zenodo.4723992

References

Álvarez-Robles T, Álvarez F, Carreño-León M. 2020. Proposal for an Interactive Software System Design for Learning Mexican Sign Language with Leap Motion. In: *International Conference on Human-Computer Interaction*. Springer, Cham.

American Psychological Association. (n.d.). Lexical Access. In *APA dictionary of psychology*. Retrieved April 16, 2021, from https://dictionary.apa.org/lexical-access.

Baker, A., van den Bogaerde, B., Pfau, R., Schermer, T. 2016. The linguistics of sign languages: An introduction. John Benjamins Publishing Company.

Bhutani, K. R., Rosenfeld, A. 2003. Dissimilarity measures between fuzzy sets or fuzzy structures. *Information Sciences*, 152, 313-318.

Bisandu, D.; Prasad, R.; Liman, M. Data clustering using efficient similarity measures. *Journal of Statistics and Management Systems*. 2019, 22, 901–922.

Bouchon-Meunier, B., Rifqi, M., Bothorel, S. 1996. Towards general measures of comparison of objects. *Fuzzy sets and systems*, 84(2), 143-153.

Brooke, J. 1986. System usability scale (SUS): a quick-and-dirty   method of system evaluation user information. Reading, UK: Digital Equipment Co Ltd, 43, 1-7.

Chai X, Liu Z, Li Y, Yin F, Chen X. 2017. SignInstructor: an effective tool for sign language vocabulary learning. In: *4th IAPR Asian Conference on Pattern Recognition (ACPR)*. IEEE.

Choi, S. S., Cha, S. H., Tappert, C. C. 2010. A survey of binary similarity and distance measures. *Journal of systemics, cybernetics and informatics*, 8(1), 43-48.

Cohen, W., Ravikumar, P., Fienberg, S. (2003). A comparison of string metrics for matching names and records. In: *Kdd workshop on data cleaning and object consolidation* (Vol. 3, pp. 73-78).

Coletti, G., Bouchon-Meunier, B. 2019. A study of similarity measures through the paradigm of measurement theory: the classic case. *Soft Computing*, 23(16), 6827-6845.

Couso, I., Garrido, L., Sánchez, L. 2013. Similarity and dissimilarity measures between fuzzy sets: A formal relational study. *Information Sciences*, 229, 122-141.

Hamming, R. W. 1950. Error detecting and error correcting codes. *The Bell System Technical Journal*, 29(2), 147-160.

Haug T, Ebling S. 2019. Using Open-Source Software for Sign Language Learning and Assessment. In: *International Journal of Emerging Technologies in Learning (iJET)* 14.19: 188-196.

Hildebrandt, U., Corina, D. 2002. Phonological similarity in American Sign Language. *Language and Cognitive Processes*, 17(6), 593-612.

Huenerfauth, M, Gale, E, Penly, B, Hariharan, D. 2016. Designing tools to facilitate students learning American Sign Language. In: *Effective Access Technologies Conference, Rochester, New York, USA*.

Jaccard, P. 1912. The distribution of the flora in the alpine zone. 1. *New phytologist*, 11(2), 37-50.

704 **Joy J, Balakrishnan K, Sreeraj M.** 2019. SignQuiz: A quiz-based tool for learning
705   fingerspelled signs in Indian sign language using ASLR. *IEEE Access* 7: 28363-28371.
706 **Kale, A.** 2014. Using motion capture to produce learning software to aid teachers of sign
707   language. *The Computer Games Journal* 3.1: 62-94.
708 **Kao, Y. S., Matlen, B. J., Tiu, M., Li, L.** (2018). Logic Models as a Framework for Iterative
709   User Research in Educational Technology: Illustrative Cases. In *End-User*
710   *Considerations in Educational Technology Design* (pp. 52-75). IGI Global.
711 **Keane, J., Sehyr, Z. S., Emmorey, K., Brentari, D.** 2017. A Theory-Driven Model of
712   Handshape Similarity. *Phonology*, *34*, 221–241.
713 **Lesot, M. J., Rifqi, M., & Benhadda, H.** 2009. Similarity measures for binary and numerical
714   data: a survey. *International Journal of Knowledge Engineering and Soft Data*
715   *Paradigms*, 1(1), 63-84.
716 **Levenshtein, V. I.** 1966. Binary codes capable of correcting deletions, insertions, and reversals.
717   In *Soviet Physics Doklady* (Vol. 10, No. 8, pp. 707-710).
718 **Lewis, J. R., Sauro, J.** (2018). Item benchmarks for the system usability scale. *Journal of*
719   *Usability Studies*, 13(3).
720 **Li, Y., Qin, K., He, X.** 2014. Some new approaches to constructing similarity measures. *Fuzzy*
721   *Sets and Systems*, 234, 46-60.
722 **Monge, A., Elkan, C.** 1997. An efficient domain-independent algorithm for detecting
723   approximately duplicate database records.
724 **Naranjo-Zeledón, L, Ferrández, A, Peral, J, Chacón-Rivas, M.** 2019. Big Data-Assisted
725   Word Sense Disambiguation for Sign Language. In: *The International Research &*
726   *Innovation Forum* (pp. 441-448). Springer, Cham.
727 **Naranjo-Zeledón L, Chacón-Rivas M, Peral J, Ferrández A.** 2020. Phonological Proximity in
728   Costa Rican Sign Language. *Electronics* 9.8: 1302.
729 **Naumann, F., Melanie Herschel.** An introduction to duplicate detection. *Synthesis Lectures on*
730   *Data Management*. 2010, 2, 1–87.
731 **Osei, DD**. 2012. Enabling sign language instruction with technology: the case of developing a
732   computerized learning tool for Ghanaian Sign Language (GhSL). Doctoral dissertation,
733   Ashesi University College.
734 **Postel, H. J.** 1969. Die Kölner Phonetik. Ein Verfahren zur Identifizierung von Personennamen
735   auf der Grundlage der Gestaltanalyse. *IBM-Nachrichten*, 19, 925-931.
736 **Serrato-Romero J, Chacón-Rivas M.** 2016. Traductor LESCO: un esfuerzo puntual en el
737   apoyo al proceso de aprendizaje de estudiantes con discapacidad auditiva. *Investiga.TEC*
738   27: 4-4.
739 **Singhal, A.** 2001. Modern information retrieval: A brief overview. *IEEE Data Eng. Bull.*, 24(4),
740   35-43.
741 **Wienholz, A., Nuhbalaoglu, D., Steinbach, M., Herrmann, A., Mani, N.** 2021. Phonological
742   priming in German Sign Language: An eye tracking study using the Visual World
743   Paradigm. *Sign Language & Linguistics*, 24(1), 4-35.

744 **Williams, J. T., Stone, A., Newman, S. D.** 2017. Operationalization of sign language
745   phonological similarity and its effects on lexical access. *The Journal of Deaf Studies and*
746   *Deaf Education*, 22(3), 303-315.

Figure 1

SL learning reinforcement environment architecture.
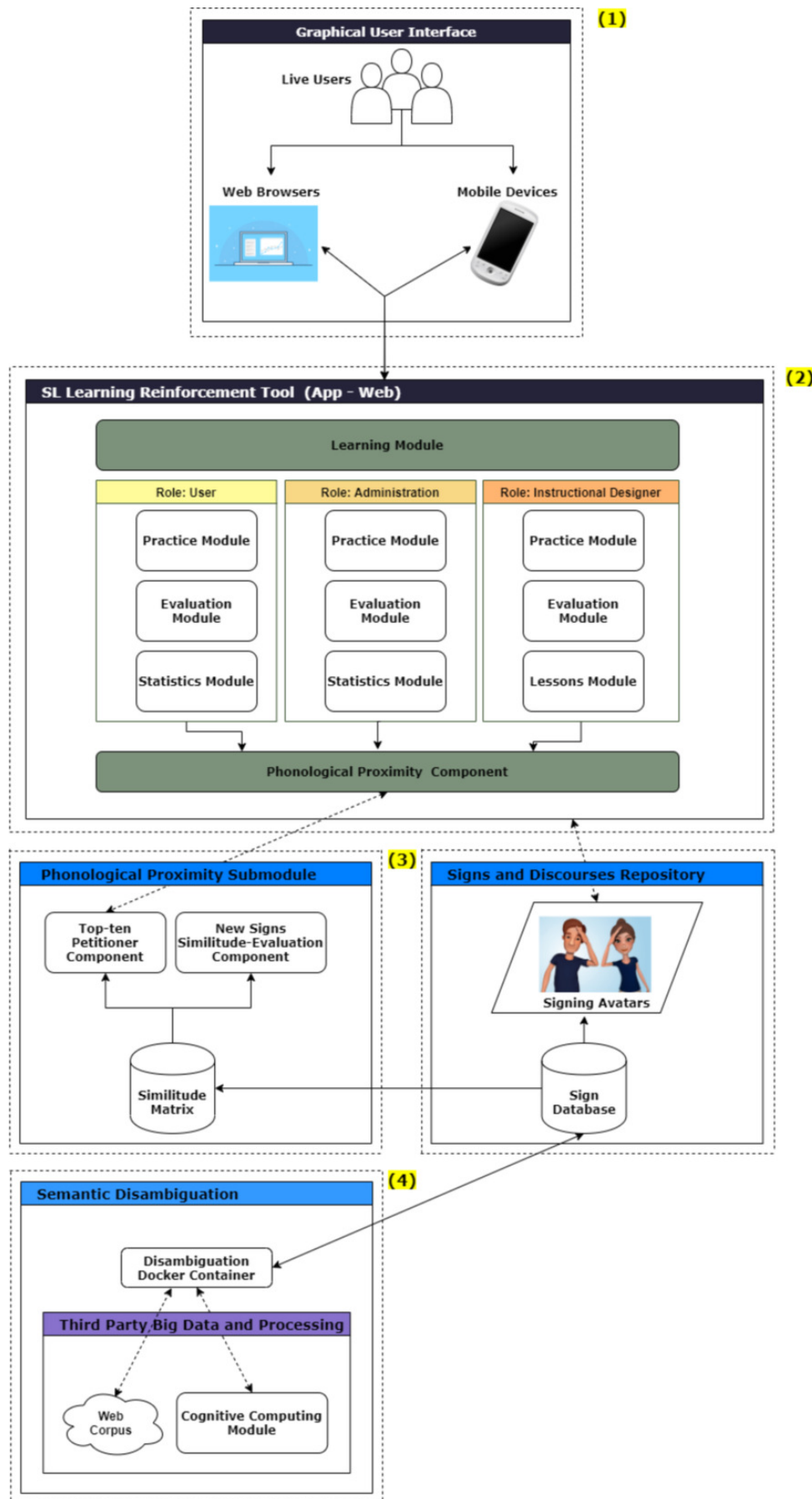
Figure 2

The software basic level interface with signs classified into categories.
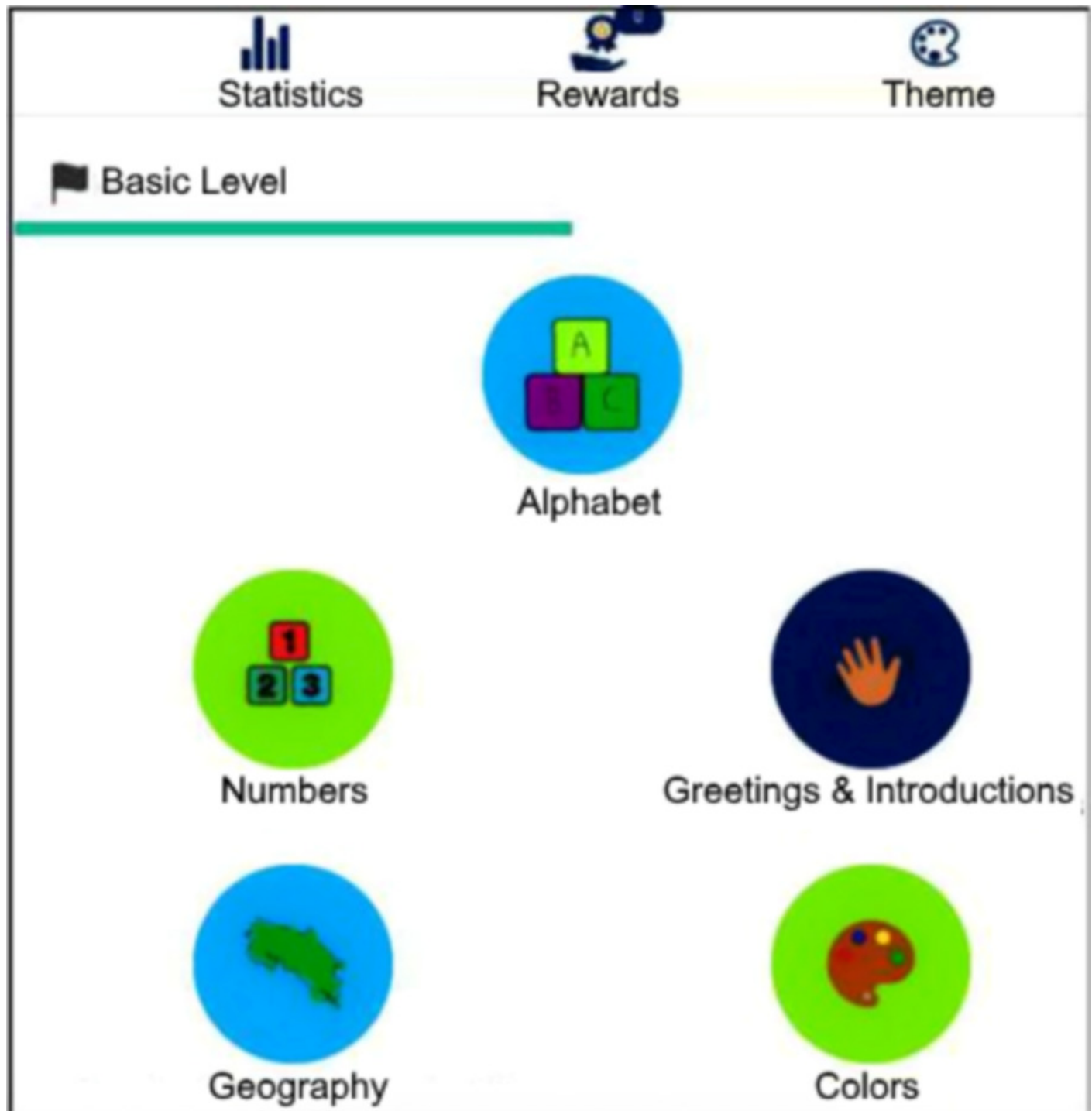
Figure 3

Top-ten homonyms/paronyms for 'Letter-D'.

Figure 4

Avatar signing homonym 'Letter-D'.

LETTER

LETTER-A

LETTER-B

LETTER-C

LETTER-CH

LETTER-D ✔

Figure 5

Avatar signing paronym 'Sunday'.

LETTER

LETTER-A

LETTER-B

LETTER-C

LETTER-CH

LETTER-D ✔

Figure 6

Avatar signing 'Letter-U' for practice sessions.
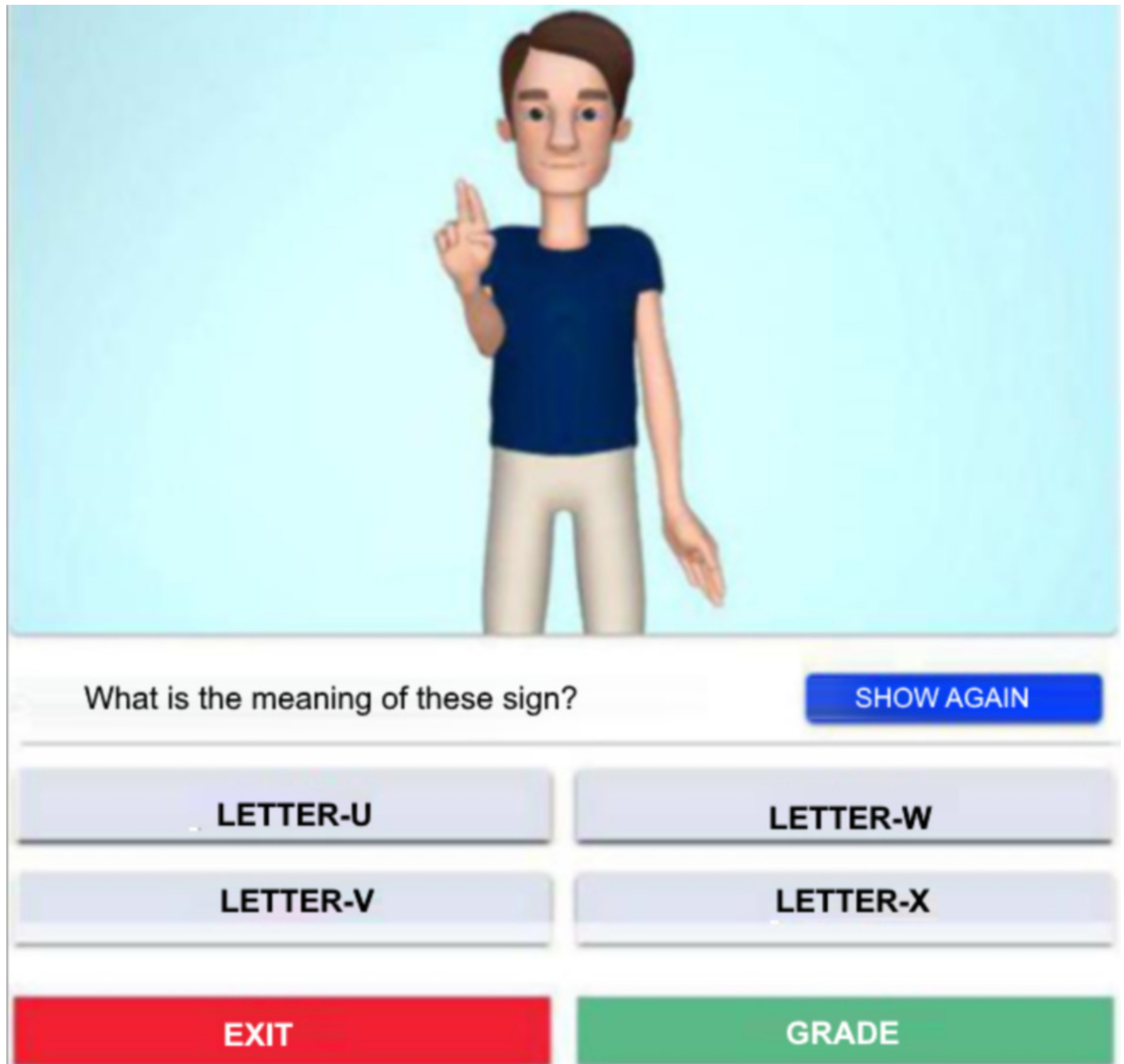
Figure 7

SUS (System Usability Scale) standard test.

LESCO learning reinforcement test, using similar signs

*Mandatory

Please rate your level of agreement with each of the following statements: *

	1 - Totally disagree	2 - Somewhat disagree	3 - Neither agree nor disagree	4 - Somewhat agree	5 - Totally agree
I think I would like to use this tool frequently.	O	O	O	O	O
I found this tool unnecessarily complex.	O	O	O	O	O
I thought this tool was easy to use.	O	O	O	O	O
I think I would need help to be able to use this tool	O	O	O	O	O
I found the various functions of this tool to be well integrated.	O	O	O	O	O
I thought there was too much inconsistency in this tool.	O	O	O	O	O
I imagine that most people would learn to use this tool very quickly.	O	O	O	O	O
I found this tool very cumbersome / awkward to use.	O	O	O	O	O
I felt very confident using this tool.	O	O	O	O	O
I needed to learn a lot of things before I could get started with this tool.	O	O	O	O	O

Phonological parameters for sign 'LETRA-D' and top-ten similar signs.

1 **Table 1:**

2 **Phonological parameters for sign 'LETRA-D' and top-ten similar signs.**

LETTER-D	1	4	4	4	1	3	1	1	1	1	1	1	4	3	2	3	3	2	2	15	1	3	4	22	1	2	
																											Similarity
WHERE	1	4	4	4	1	3	1	1	1	1	1	1	4	3	2	3	3	2	2	15	1	3	4	22	1	2	100
LETTER-K	1	3	2	2	1	3	1	1	1	1	1	1	4	3	2	3	3	2	2	15	1	3	4	22	1	2	99.48
DESAMPARADOS	1	4	4	4	1	2	1	1	1	1	1	1	1	3	2	3	3	2	2	15	1	3	4	22	1	2	99.42
SUNDAY	1	4	4	4	1	2	1	1	1	1	1	1	4	3	2	3	3	2	1	12	2	3	4	22	1	2	99.4
DANGEROUS	1	3	2	2	1	3	1	1	1	1	1	1	3	3	2	3	3	2	2	15	1	2	4	22	1	2	99.38
DOG	3	3	3	3	1	4	1	1	1	1	1	1	5	3	3	3	3	2	2	15	1	2	4	22	1	2	99.36
MOUSE	3	3	3	3	1	1	1	1	1	1	1	1	5	3	2	3	3	2	2	16	1	2	4	22	1	2	99.2
NINETEEN	2	2	2	2	1	2	1	1	1	1	1	1	4	3	2	3	3	2	2	15	1	3	4	22	1	2	99.2
AND	1	1	1	1	1	4	1	1	1	1	1	1	5	3	2	3	3	2	5	15	1	2	4	22	1	2	99.2
MINISTER	3	3	3	2	1	3	1	1	1	1	1	1	3	3	1	3	3	2	1	15	1	2	4	22	1	2	99.2

SUS Test and Phonological Proximity Scores.

1   **Table 1:**

2   **SUS Test and Phonological Proximity Scores.**

Participant	q1	q2	q3	q4	q5	q6	q7	q8	q9	q10	SUS Score	Proximity Score
p1	4	1	5	1	4	1	5	1	5	1	95.0	70
p2	5	3	5	4	2	3	4	1	3	4	60.0	90
p3	5	1	4	1	3	2	5	3	5	1	85.0	70
p4	3	1	5	2	5	1	5	1	5	1	92.5	100
p5	5	1	4	1	5	1	5	1	4	1	95.0	100
p6	5	1	5	2	4	1	5	1	5	2	92.5	90
p7	5	1	5	1	4	1	4	1	5	3	90.0	100
p8	5	1	5	4	4	1	5	1	5	1	90.0	100
p9	4	1	5	1	5	1	5	1	5	1	97.5	90
p10	4	4	3	2	5	1	5	1	4	1	80.0	100
p11	4	1	5	1	5	4	5	1	5	1	90.0	90
p12	4	1	5	2	5	1	5	1	5	1	95.0	90
										Average:	**89.0**	**91.0**

Opinion/Judgment of learning improvement by using phonological proximity

1 **Table 1:**

2 **Opinion/Judgment of learning improvement by using phonological proximity**

Participant	Opinion / Judgment	Tone
p1	'It helps me to locate possible signs with which I could be confused or improve the context of use'.	Positive
p2	'To be able to distinguish signs that can be confused at the time of a conversation'.	Positive
p3	'It seems very valuable to me, since with the same form, several signs can be practiced, then the hand becomes more skilled'.	Positive
p4	'I believe that having similar signs can make it easier for me to learn new signs, as long as I am interested in reviewing and comparing them thoroughly. Once you have mastered a sign, making the move to a similar one is much easier'.	Positive
p5	'At the beginning there are words that are similar and when you see them after a long period of time, these differences are not very noticeable, so it is useful to remember precise words well'.	Positive
p6	'The implementation of this section is useful and does not hinder the use of the application if it generates confusion as to why some are similar but this does not affect the flow of use'.	Positive
p7	'Yes, I think it is quite useful because it helps to know vocabulary similar to a letter / word, and it also helps to see the differences between each one so as not to be mistaken'.	Positive
p8	'The implementation of this section is useful and does not hinder the use of the application. It creates confusion as to why some are alike but this does not affect the flow of use'.	Mainly positive
p9	'I think it has facilitated because one sign is memorized and the small differences are noticed with respect to another'.	Positive
p10	'It has facilitated [*sic*] because by presenting similar signs, it helps to make their difference'.	Positive
p11	'Seeing similar signs allows me to learn some other signs more quickly, since I can associate them'.	Positive
p12	'It seems to me that in learning signs, having similar signs at hand allows me to find a better way to express the message with the correct signs. In addition, identify the differences and be able to apply it when using a specific sign'.	Positive