Proceedings of the 9th Workshop on the Representation and Processing of Sign Languages, pages 171–176
Language Resources and Evaluation Conference (LREC 2020), Marseille, 11–16 May 2020

Design and Evaluation for a Prototype of an Online Tool to Access Mathematics Notions in Sign Language

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Abstract

Our project aims at giving access to pedagogical resources in Sign Language (SL). It will provide Deaf students and teachers with mathematics vocabulary in SL, this in order to contribute to the standardisation of the vocabulary used at school. The work conducted led to Sign'Maths, an online interactive tool that gives Deaf students access to mathematics definitions in SL. A group of mathematics teachers for Deafs and teachers experts in SL are collaborating to create signs to express mathematics concepts, and to produce videos of definitions, examples and illustrations for these concepts. In parallel, we are working on the conception and the design of Sign'Maths software and user interface. Our research work investigated ways to include SL in pedagogical resources in order to present information but also to navigate through the content. User tests revealed that users appreciate the use of SL in a pedagogical resource. However, they pointed out that SL content should be complemented with French to support bilingual education. The last version of our prototype takes advantage of the complementarity of SL, French and visual content to provide an interface that will suit users no matter what their education background is. Future work will investigate a tool for text and signs' search within Sign'Maths.

Keywords: Deaf Education, Sign Language, ICT in Education

1. Introduction

Sign Language (SL) started becoming a full-fledged language in few countries in the late 1980s. In France, it is only in 2005 that the Handicap Law gives a legal recognition to French Sign Language (LSF), underlining its educative, pedagogical and cultural legitimacy (Dalle, 2003). Since then, Deaf have access to education in Sign Language. However, though teaching is provided in their mother tongue (*i.e.* LSF), the majority of the pedagogical resources uses written French. Thus, an important part of the learning process relies on students' ability to read and understand French as their second language. Moreover, when learning new concepts, Deaf students have to learn the related French vocabulary in order to understand the given examples and exercises' instructions. Consequently, their knowledge of French will likely impact their learning in all disciplines. This is particularly true in science education where Deaf students have difficulties in visualising abstract concepts (Megat Mohd Zainuddin et al., 2009). Moreover, there is a real lack of vocabulary in SL for mathematics education and dissemination in higher education. In this difficult context, the online tool Sign'Maths aims at supporting Deafs in mathematics learning. The project raises the following research questions:

- How to present mathematics notions and navigate among them ?
- Does SL alone allow sufficient understanding for the user to efficiently access the definitions ? What about the user's satisfaction ?
- Is the use of SL in an educational website appreciated/preferred or disliked by Deaf users ?

We used our team experts' knowledge on education of mathematics using Sign Language and a user evaluation of the interface to address these questions.

2. Related work

In the 21st century, we have observed numerous attempts to give Deaf Community access to ICT (Information and Communication Technologies) and e-learning. Many online dictionaries for Sign Languages exist associating words of vocal language as textual and the video of the corresponding sign, like `www.sematos.eu/lsf.html`, `dico.elix-lsf.fr`, `www.spreadthesign.com`, `nzsl.nz` ... Information is organized by alphabetic order of words or by topics like *food*, *colors*, *numbers*... Search in the dictionnary can be made by word or key-word, and some propose search by phonological parameters (from (Stokoe, 1965)) : handshape and sign' location, like in (Kristoffersen and Troelsgård, 2012). In (McKee, 2017), they also propose a search by topic domains or by tags for usage status : obscene, archaic, neologism, informal and rare. These resources are meant to be used as a support to learn Sign Language. Some like in (McKee, 2017) are made for E-learning purpose. One thing worth noting about most of these dictionaries is the lack of actual definitions for the notions, except for EU funded ELIX (`dico.elix-lsf.fr`) an online dictionary for French SL learning, that provides the learner with definitions in both SL and French. These dictionnaries are not meant to learn a discipline like mathematic in Sign Language, so very few notions are presented and they don't provide definition for these notions.

In 2004, Straetz *et al.* (2004) created a bilingual web-based

learning system for Deaf adults which allowed to retrieve a German SL video translation for each text block of the page. The same year, Debvc and Peljhan (2004) provided a web-based tool that allowed the students to watch video clips of lectures along with slides and subtitles. In 2007 in Jordan, Khwaldeh *et al.* (2007) developed interactive content and interactive tools to enable "interactivity between teacher and Deaf pupils". This included online conferences and chatting rooms where pupils can communicate with teachers or with one another. Augmented Reality was first investigated by Zainuddin *et al.* as a means to support Deaf Education. They created in 2010 an AR Science book (Zainuddin et al., 2010) to help Deaf students in visualizing abstracts concepts. In 2014, Jones *et al.* (2014) studied how a head-mounted display could help pupils in learning to read by visualizing both signs and words. Another study conducted by Adamo-Villani and Anasingaraju (2017) based on the use of Augmented Reality was carried out in 2017. It focused on mathematics learning for the Deafs and used 3D holograms to translate lessons in real time.

In the light of that, a website offering education support for abstract concepts learning in SL would be an interesting approach to explore. Our project is aimed at students, teachers, and any Deaf person who wish to learn mathematics concepts. Access to the information should be easy and should not require the use of expensive or cumbersome material. As only video technology satisfies these criteria, we chose this form for educational content within Sign'Maths.

3. Presentation of the project

Sign'Maths consists of an interactive tool that gives access to mathematical notions and their definition in Sign Language. We wish to make it freely available online. It is firstly addressed to Deaf students enrolled in high school or college, or to Deafs interested in learning mathematics definition at this level of education. This tool is also addressed to teachers and interpreters who have to translate from and to SL mathematics notions taught in these years. Another set of users that must be considered is the family and relatives of Deafs. Indeed, they can be interested in learning mathematics signs to support their Deaf relative or friend in learning lessons or practising exercises. By introducing and disseminating new signs among students, teachers, interpreters and families, Sign'Maths will participate in the harmonisation of SL vocabulary for mathematics.

3.1. The project team

We have noticed that very few Deaf people come to our university whereas they are ten a year to reach the high-school degree in our town. And those that comes don't finish the first year. We can assume several reasons for this including : the loneliness of Deaf students; the lack of interpretation service (only one third of the courses are translated); or the gap between high-school and university work methods.

In order to improve this situation, we decided to start by setting up a collaboration with secondary and high school teachers and to focus on mathematics. So we assembled a team made up of a researcher in Mathematics and a researcher in Computer science (both signers) on the side of the university, a Deaf professor (PhD in mathematics) teaching in high school (Paris), two mathematics teachers (both fluent signers) in high school in classes for Deaf students (Toulouse and Lyon), a secondary school teacher (fluent signer) in a class for Deaf pupils, two Deaf teachers in primary school for Deaf pupils, and finally two Deaf students former pupils of the high-school. Teachers in primary, middle and high school have already worked together for projects on the creation of signs for educational support. This team meets every month to develop proposals for signs for mathematics notions and their definition, and to work on the software user interface. As results, they produce all the material for the website: videos of signs of mathematics notions, their definitions and sometimes examples, as well as the corresponding texts in French and some diagrams.

3.2. Prototypes and evolution of the design

The first activity carried out is the identification of users' needs. As the access to end users was very limited, the members of the team with extended experience in Deaf education identified the main users' needs. This permitted to initiate the design of prototypes.
The information is organized as follows : notions are grouped in chapters by mathematical domains like geometry, analysis... themself divided in sub-domains, from general to specific notions with videos of signs for each and their definition. The Figure 1 shows an example of the chapter for *Sequences* ("*Suites*" in French, a part of Analysis Domain) with the sub-chapters *Generation*, *Particular sequences*, *Variations* and *Limits*.

In this paper we focus on the question of design of the prototypes' interface and its evaluation. Regarding the visual aspect of the interface, its design is based on the use of tiles, which shape permits a good visualisation of the videos and a tidy organisation of the notions. We had many options to illustrate notions, like textual, diagram, signs in video or static image of sign, and different mixtures of these.

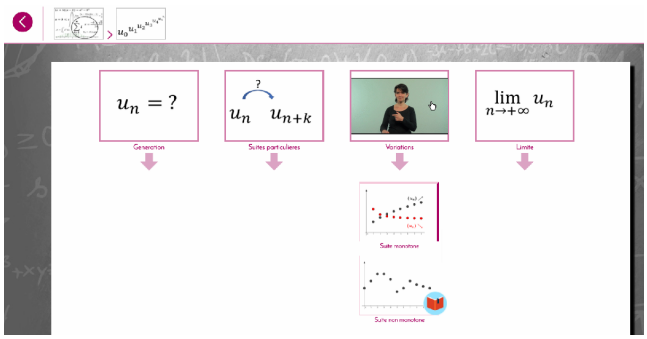

Figure 1: Home page with access via diagrams and text, with an example of SL video launched on mouse-over in the tile for the *Variation* sub-chapter

A first version used diagrams illustrating the notions, textual and video of SL indications – on tiles mouse-over

(Fig. 1). A framed tile represents a chapter and an arrow points at the notions it covers (see *Variations* in the figure). A notion that could be expanded into sub-notions is represented by a stack (for example "*Suite monotone*" - *monotone sequence*). Clicking on the book icon (over "*Suite non monotone*" diagram for instance) open the notion's definition. On the top left of the screen, Ariane's thread and back button allow easy return to previous chapters.

As we had limited time and means for the user evaluation part of the project, we decided to focus the user test part of this work on a radically Sign Language oriented Interface. So in order to investigate if SL alone allow sufficient understanding for the user to efficiently access the definitions, another version relying on SL only was realised (Fig. 2). We chose to make videos play in a loop, an approach supported by Jean-Louis Brugeille (Leroy and Brugeille, 2015), a Deaf expert in SL[1].

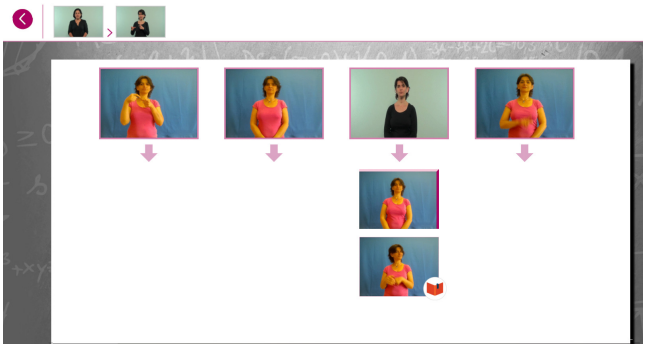

Figure 2: Home page with access via Sign Language

Finally, the definition page is shown in Figure 3. The definition video may include hypermedia links redirecting to prerequisites' definitions when needed. In this example, the prerequisite *Number* is associated with this notion. The moment that it is mentioned (*i.e.* signed) in the definition is represented by a range with white background and blue frame on the progress bar (see the orange circle and arrow). Moreover, the rectangle on the right part of the page shows the indication "Associate notion" and the French translation of the prerequisite. On mouse-over, the rectangle shows *Number* in SL, and on click, the definition page of *Number* opens in a new tab.

[1]Jean-Louis Brugeille has a permanent position in French Ministry for Education as academic inspector in Toulouse for teaching in SL and as national reference for education in SL.

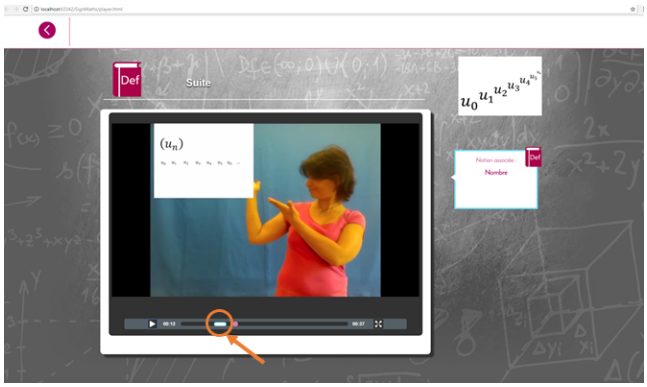

Figure 3: Page definition for *Convergent sequence*

4. User tests on a prototype entirely in Sign Language

The version entirely in SL was put on test with users, which aimed at evaluating if the interface was adapted for the different target audiences: students, teachers and families.

4.1. Participants and goal

The panel of participants we managed to gather was small but matched the user profiles we were looking for: four Deaf high-school students, two bilingual teachers of mathematics in SL, and two Deafs adults. The tests permitted to assess if the education backgrounds of users (*i.e.* education received in SL, French or in both language) triggered significant differences in their performance when using Sign'Maths. At that time the prototype was composed of a few videos (34 mathematical concepts, 17 definitions and 2 examples).

4.2. Test protocol

Very few literature addresses the question of user testing with Deafs. A study conducted by Slegers *et al.* (2010) gives recommendations for involving "target groups with whom researchers and designers cannot communicate as they are used to". However, this study focuses on children. As our participants were older and as we were limited in time, we couldn't follow the same guidelines (*e.g.* spending a whole day with the students at school). More time would have been needed to investigate how to conduct user tests with Deaf teens and adults. Nevertheless, we tried our best to produce a protocol adapted to the situation.

At the beginning of each test session, the participant was asked to fill a pretest questionnaire:

- participant's age: as education for Deafs has significantly changed in the recent years, this information is relevant to understand the background of the participant.
- participant's city of residence and city of his/her studies: as the signs used by Deafs depends on the geographic location, this may bias results.
- if participant followed mathematics lessons on sequences and in which language: this would assess his/her knowledge of the maths vocabulary used during the test.

To reproduce real life cases of use, we asked participants to complete three types of tasks in finding the definition of a mathematical notion. These tasks differs in the way the notion is presented to the participant :

1. signed to him;
2. written in French on a paper;
3. illustrated by a diagram on a paper.

These tasks represent the different situations where students may be searching for a notion's definition in Sign'Maths. These situations are among: they know the sign for the notion (1), they know the French word for the notion (2), or they have encountered a diagram in an exercise (3).
Each task was timed and observations/remarks of the participant were noted down. After each task, the participant was asked to rate the difficulty of the task on a Likert scale (1932) and to explain what changes he/she would make on the interface.
At the end of the test, the participant was asked to fill a SUS questionnaire. Ideally, the SUS questionnaire would have been in SL. However, no official translation existed and our participants did not have sufficient English knowledge - which is understandable as it is their third language - to fill it in the original version. Thus, we chose to use the French version detailed in (Yharrassarry, 2011): even if there is no official French translation yet, this one is the most used of the existing translations.
Finally, we asked the participant if he/she had global remarks on the interface or any propositions of change.

4.3. Setting up and special precautions

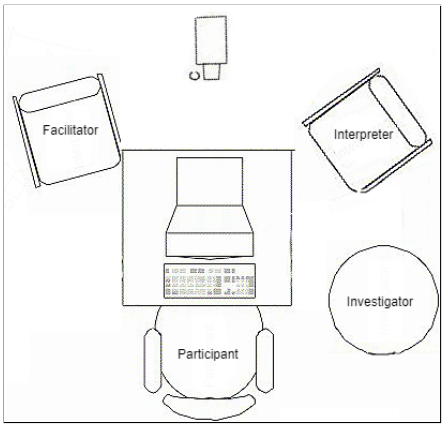

Figure 4: Experimental set-up

The experimental set-up we used for the tests can be seen in the Figure 4. User testing was done on a computer running on Windows 10 on which a stable version of the interface had been set up. The investigator having developed the prototype and having experience in user testing, she was in charge of observing, taking measures and notes, but she had no interaction with the participants during the test.
A person was needed to conduct the test sessions. As most of our participants were Deaf - and all being fluent in SL - this person - the "facilitator" - should communicate in SL. For no other person in our group was familiar with conducting tests, a preliminary training was necessary. This role could not be played by an interpreter as we were not of his/her availability. Thus, a Deaf member of the team was trained to play the facilitator. Work on the different parts of the protocol used has been conducted:

- When asking to open the definition of a signed notion, we chose to provide the sole sign for the notion. If the participant didn't know the sign, we would ask him to find what he/she found the most similar to it.
- For questions on notions in French or illustrated by a diagram, the facilitator gave the user a piece of paper with either the printed word or the printed diagram for the notion. This in order to avoid the misunderstanding of handwritten information and to give all the participants exactly the same information.
- SL being very visual, description of the tasks may include elements of response. For example, when asking for opening a definition, the signer may mime elements of the interface and the interaction needed to open the definition. This visual way to describe an action being intrinsic to SL, there was no other possibility to sign the questions. It is precisely why we had to work on which signs to use to describe elements of the interface. For example, the word "tile" had no translation in SL in this context. The sign which expression was the nearest to the concept of tile was the sign for "rectangle".

To guarantee a fluid communication during the tests, an interpreter SL↔French had been hired. Thus, the investigator could follow the test's progress and write down the participant's comments. Finally, as the interpreter's live translation may not highlight the emotions conveyed by the participant's signs, we chose to record his/her facial expression and body attitude.

4.4. Analysis of the results

Before getting into the results' analysis, it is worth noting that our low number of participants didn't allow to generalise our results. However, it gave us useful insights on the interface tested and allowed us to retrieve design guidelines for the next version.
In this analysis, we compared the performance of 3 categories of users: Deaf students (*Students*), Deaf or bilingual maths teachers (*Teachers*) and Deafs who might use Sign'Maths in the family sphere (*Family*). Their performance was analysed for 3 types of tasks (cf. 4.2.) :

- **Open the definition of a notion signed**:
  The difference in performances is around 10 seconds for the 3 categories of users, *Teachers* being the fastest and *Family* being the slowest, and *Students* being in the middle.
- **Open the definition of a notion written in French**:
  Teachers were 1 minute faster that *Students*, who were 2 minutes faster than *Family*.
- **Open the definition of a notion illustrated by a diagram**:
  Students were 10 seconds faster than *Teachers*, who were 1 minute faster than *Family*.

According to these observations, we can conclude that, when it comes to searching a notion in SL, all users seem to succeed equally. However, users who received education in SL (*i.e.* *Students* and *Teachers*) seem to have fewer difficulties in searching for notions written in French or illustrated by a diagram.
To retrieve conclusions from the SUS scores, we used the article of Bangor *et al.* (2009). The SUS score of *Students* is 61, which is between *OK* and *Good*. The score of *Teachers* is 81 which is between *Good* and *Excellent*. However, the SUS score of *Family* is 33, considered as *Poor*. The global score of our panel of users is 63, meaning that our interface's acceptability falls within the category *Marginal High* - which is a step before the level acceptable.

Finally, the most frequent comment from users was that using the interface required being aware of the mathematics vocabulary used – several signs/words being unknown for some users, especially *Family*. They highlighted that the interface was clear and well organised, and *Students* and *Teachers* particularly appreciated the use of SL. All users agreed that French indications and illustrations of the concepts should be added to the SL content. They also proposed minor changes such as improving videos' quality and adding content to the interface which they found quite simple.

In conclusion, user tests have highlighted that work needed to be done to make our interface more inclusive and more adapted towards users who are not aware of the mathematics vocabulary used in Sign'Maths. Sign'Maths should allow users to find a notion, whether they know its translation in SL, French, or none of them. Eventually, we took advantage of participants' presence to perform a brainstorming session after the test sessions.

5. Final prototype of Sign'Maths

Following the user tests, a low-fidelity prototype has been realised. This prototype is a combination of the two previous versions, and it takes into account the conclusions of the tests and users remarks and propositions.

The chaptering is now materialised by a tree. The main topic is represented by a big tile in the centre (here "*Suites*"). The tiles above are previous chapters; the tiles below are chapters covered by the main one. Each tile:

- is composed of a diagram illustrating the notion;
- shows the notion in SL on mouse-over;
- and is accompanied by the French translation of the notion.

The following figures show the final interface obtained. The tree structure is flexible and automatically adapts to the number of notions displayed. As shown in Figure 5, on tile mouse-over appears the translation of the notion in SL.

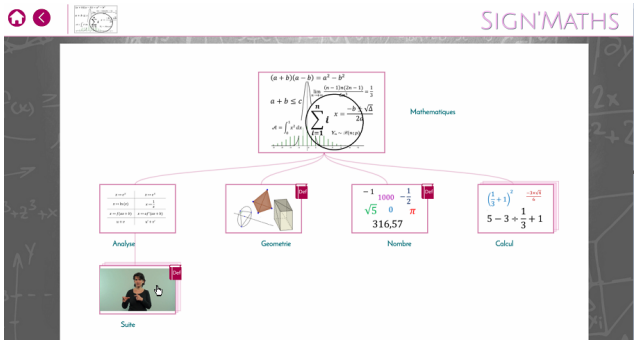

Figure 5: Home page of Sign'Maths

This interface takes advantage of the complementarity of Sign Language, French Language, and visual content. The chaptering is clear and navigation is allowed through several elements (tiles themselves, the Ariane's thread, and the back and home buttons).
Clicking of a tile - in the picture, clicking on the tile "*Suite*" - triggers the *Sequences* chapter expanding (Fig. 6). The tree nodes updates, as well as the Ariane's thread.

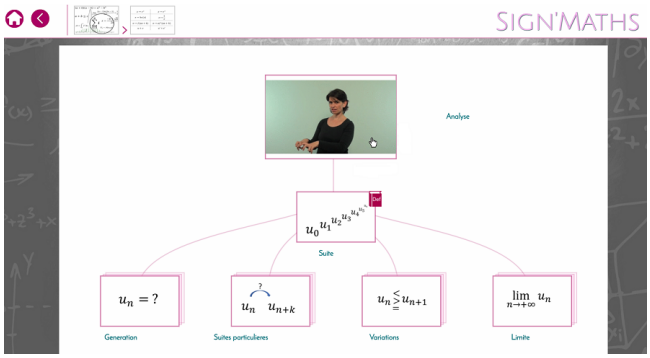

Figure 6: Example of tree exploration in Sign'Maths

Definition and example icons are represented respectively by a purple book with "*Def*" written on the cover and a green book with the indication "*Ex*". A click on these icons triggers the opening of either the definition page (Fig. 3) or the example page - which designs are similar.

6. Conclusions and prospects

Sign'Maths stands out by putting SL at the core of a pedagogical tool. Tests results show that participants appreciate the extensive use of SL in the interface. However, due to the ubiquity of written text in their Education, they agree that French indications are needed to support navigation and would be helpful for a search-by-word tool. Finally, participants appreciate the use of graphics to complement SL and written information. Because mathematics cover abstract concepts, the use of visual information such as diagrams and signs can have a positive impact on Deaf students' learning. The search of unknown mathematical words will be addressed by adding a text search function. Future work will investigate how an entry in SL can be used to search for signs in video definitions.

7. Bibliographical References

Adamo-Villani, N. and Anasingaraju, S., (2017). *Holographic Signing Avatars for Deaf Education*, pages 54–61. Springer International Publishing, Cham.

Bangor, A., Kortum, P., and Miller, J. (2009). Determining What Individual SUS Scores Mean: Adding an Adjective Rating Scale. *J. Usability Studies*, 4(3):114–123, May.

Dalle, P. (2003). La place de la langue des signes dans le milieu institutionnel de l'éducation : enjeux, blocages et évolution. *Langue française*, 137(1):32–59.

Debevc, M. and Peljhan, Ž. (2004). The role of video technology in on-line lectures for the deaf. *Disability and Rehabilitation*, 26(17):1048–1059, September.

Jones, M., Bench, N., and Ferons, S. (2014). Vocabulary acquisition for deaf readers using augmented technology. In *VAAT, 2014 2nd Workshop on*, pages 13–15. IEEE.

Khwaldeh, S., Matar, N., and Hunaiti, Z. (2007). Interactivity in Deaf Classroom Using Centralised E-learning System in Jordan. In *The 8^{th} Annual Postgraduate Symposium on the Convergence of Telecommunications, Networking and Broadcasting*, Liverpool.

Kristoffersen, J. and Troelsgård, T., (2012). *The Electronic Lexicographical Treatment of Sign Languages: The Danish Sign Language Dictionary*, pages 293–314. 11.

Leroy, E. and Brugeille, J.-L. (2015). Ressource en autoformation : Langue des Signes Française : quelle évaluation pour une langue sans écriture ? `https://goo.gl/C7fBbM`. Video in French SL, 2015-02.

Likert, R. (1932). A Technique for the Measurement of Attitudes. *Archives of Psychology*, 140:1–55.

McKee, R., (2017). *The Online Dictionary of New Zealand Sign Language: A case study of contemporary sign language lexicography*. 10.

Megat Mohd Zainuddin, N., Badioze Zaman, H., and Ahmad, A., (2009). *Learning Science Using AR Book: A Preliminary Study on Visual Needs of Deaf Learners*, pages 844–855. Springer Berlin Heidelberg, Berlin, Heidelberg.

Slegers, K., Duysburgh, P., and Jacobs, A. (2010). Research Methods for Involving Hearing Impaired Children in IT Innovation. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries*, NordiCHI '10, pages 781–784, New York, NY, USA. ACM.

Stokoe, W. (1965). Dictionary of the American Sign Language based on scientific principles.

Straetz, K., Kaibel, A., Raithel, V., Specht, M., Grote, K., and Kramer, F. (2004). An e-learning environment for deaf adults. In *Conference proceedings 8^{th} ERCIM workshop "user interfaces for all"*.

Yharrassarry, R. (2011). Une année d'ergonomie sur le bloc-notes. `http://blocnotes.iergo.fr/tag/sus/`.

Zainuddin, N. M. M., Zaman, H. B., and Ahmad, A. (2010). Developing augmented reality book for deaf in science: the determining factors. In *ITSim, 2010 International Symposium in*, volume 1, pages 1–4. IEEE.