# Development of Sign Language Communication Skill on Children through Augmented Reality and the MuCy Model

Jonathan Cadeñanes and Angélica González Arrieta

Department of Computer Science and Automation, Faculty of Science,
University of Salamanca, Spain
{cadenanes,angelica}@usal.es

**Abstract.** This paper shows a Sign Language Teaching Model (SLTM) called: Multi-language Cycle for Sign Language Understanding (MuCy). It serves as complementary pedagogical resource for Sign Language (SL) teaching. A pilot lesson with the Rainbow Colors was conducted at the Association of Parents of Deaf Children of Salamanca in order to determine the Percentage of Development of the Sign Language Communication Skill (SLCS) and others within a Collaborative Learning Environment with Mixed-Reality (CLEMR).

**Keywords:** Augmented Reality, Sign Language Communication Skill, Unity3D, Collaborative Learning Environment, pedagogical tool.

## 1 Introduction

To develop different Communication Skills (CS) on deaf children their individual learning readiness and intellectual capacities have to be taken into account. Teachers from preschool to secondary education sometimes need more creative teaching methods to develop the SLCS on deaf students [18]. And one suitable option for doing this (considering the educational curriculum) is the Augmented Reality (AR) technology, as it includes visual and interactive digital contents which are viewed in the real world.

Since deaf students are visual learners, they need to use images in order to understand the ideas and concepts from their surrounding environment. Teachers turn to consider the use of non-immersive and immersive Interactive Digital Learning Environments (IDLE) since they have shown to be effective methods for teaching Sign Language (SL) [1].

On IDLE two considerations are essential: The first, is a taxonomical framework that classifies the Mixed-Reality (MR). A Reality-Virtuality Continuum establishes the process to change between realities by using interfaces. The second (in accordance with the AR displays) [17] to move between those realities into a smooth transition, users have to employ a monitor-based (non-immersive) or Window on the World (WoW) device adapted for their learning needs.

This paper is organized as follows: In Section 2, we mention the two projects more similar to the one that we are proposing. In Section 3, the SLTM MuCy

and the Pedagogical Materials (PM) are explained in more detail as well as the criteria used to validate the model. Also we present a SL pilot lesson conducted at the Association of Parents of Deaf Children of Salamanca (ASPAS) [2]. In Section 4, we draw the conclusions. And finally, in section 6. The future research is mentioned.

## 2   Related Works

The MagicBook proposed by Billinghurst et al. [4,5,6,7,8]; is considered the best tool that allows users to move between Reality and Virtuality. This project covers three levels of MR within a Multi-level Collaborative Learning Environment.

The first level is the Reality. The use of an AR book as a tangible interface allows readers to interchange opinions while they are are sharing their learning experience. But if they want to learn on the second level (with the AR system), they have to use another interface (AR displays or PC screens). On this level, users can see digital worlds and avatars projected onto real objects (the physical books). Multiple learners can gather around the screen and still share information in both real and digital worlds.

By pressing a switch button on their AR displays, the users will no longer be in the real world because their view is totally immersive. This is the last level: Virtuality, on which multiple users can experience the AR learning scenes by being connected to workstations. The MagicBook supports collaboration on three levels: As a physical object (the book), as an AR object (avatars) and as an immersive Virtual Space (digital scenes).

The use of Immersive Learning Environments such as Mathsigner$^{TM}$allows deaf students to interact in real time with digital avatars by making signs through a Glove-based SL input recognition system [1]. As a result students can learn mathematical concepts and American Sign Language (ASL) terminology.

Mathsigner$^{TM}$can be displayed on immersive systems such as Flex$^{TM}$and reFex$^{TM}$. For these versions it is necessary to use glove and eye-wear displays in order to enter the system and interact with it. For the non-immersive versions a computer desktop program was created to be used at schools or at homes.

## 3   Multi-language Cycle for Sign Language Understanding, Pedagogical Materials and Pilot Lesson

We propose a Sign Language Teaching Model (SLTM) called: Multi-language Cycle for Sign Language Understanding (MuCy). It considers the diverse educational needs and individual communication development of deaf people from different ages. It also takes into account the fact that Education is considered as a part of social life [11] bearing in mind that deaf people lead social lives as well. It is important to offer them creative solutions for their social integration into a society based on communication. To the extent they learn to use different CS they will be more confident to express their ideas and feelings within diverse

socio-cultural groups. Therefore, the model helps to establish (at SL schools) an outline to create a Collaborative Learning Environment with Mixed-Reality (CLEMR).

The theoretical background of the SLTM we are proposing is based on Lev Semionovich Vigotsky's Principles of Social Education for deaf and dumb children [21], as well as the Zone of Proximal Development (ZPD) [11,14] and the Milgram's Reality-Virtuality Continuum or Mixed Reality (MR) [17].

The model's design is supported by the neuropsychological findings that have shown that deaf children can develop good reading and speaking skills by learning these concepts at an early-age [15], as well as the fact that their spoken language development (as the result of reading processes) serves to increase other CS mentioned before. Teachers as the mediators between learning interfaces and students regulate the learning experience through the ZPD and by promoting information exchanges between realities and users [16].

Deaf children can learn by using interfaces and digital content according to their intellectual capacity. Then with the help of others they imitate signs, interact with information and share knowledge within technological and Socio-cultural influences. In brief, the SLCS is enhanced by technology, people, and information (knowledge).

The MuCy model establishes two psycho-motor teaching levels of Education for SL Communication (Fig.1). On the first level of education, the objective is to teach the proper use of signs in relationship with their visual references and their written words to establish a logical connection of meanings between them.

By *signs*, we refer to the standardized group of body movements in a logical sequence that has been established by the educational authorities or professionals in the field. The *visual references* are the words or written sentences that correspond in meaning to the specific signs performed. The *written words* refers to the action of writing down on paper the meaning of that word.

On the second level of education, we present the *verbalization of the written word*. It is believed that deaf people can not speak, but that is not true. The process of reading books at home at an early age as a primary language skill has enabled the development of speech [15]. Furthermore, some deaf children have successfully acquired the ability to read from the face, lip and tongue movements, so there is no need to use SL to communicate [21].

To create the Unity3D AR desktop application for SL, first we used Blender 2.69 for the modeling and animation process [3]. Next, to build the AR scenes which can be displayed on PCs screens, tablets or AR displays we used the Cross-platform Game Engine Unity3D V4.3 [19] and the Vuforia-AR Extension [20].
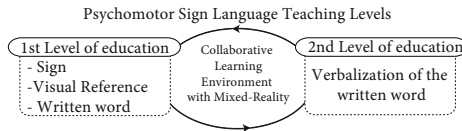


Psychomotor Sign Language Teaching Levels

1st Level of education
- Sign
-Visual Reference
- Written word

Collaborative Learning Environment with Mixed-Reality

2nd Level of education
Verbalization of the written word

**Fig. 1.** Multi-language Cycle for Sign Language Understanding (MuCy model)
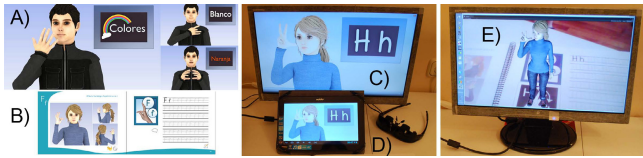
**Fig. 2.** Sign Language Pedagogical Materials (SLPMs) as learning interfaces based on the VR-Continuum. A) Some signs for colors, B) SL Book with sections for reading and writing exercises, C) Avatar making signs on WoW-Videos, D) Vuzix AR display, E) A Unity3D AR avatar making signs.

The use of an FBX format allowed us to view on the screens (in high-definition) the avatar's face and body animations.

The Sign Language Pedagogical Materials (SLPMs) (Fig.2) as learning interfaces presented in tangible and digital formats were designed to be used with the MuCy model in accordance with the RV-Continuum. The aim is to teach concepts to children from a basic to complex levels of understanding (knowledge). They also can choose the interface that better suits their learning needs. The SLPMs developed to be used together with the MuCy model are:

1) *The SL book* as a tangible interface for reading and writing exercises facilitates the adequate understanding of text and images (visual references) that correspond to specific SL positions. With this material, students can train their minds by making associations between signs and their correspondent words or phrases.

2) *The animations* as intermediate interfaces between Reality and digital contents (WoW) allow children learn by imitation while animated avatars perform the appropriate SL positions.

**Table 1.** Likert's scale survey to validate the MuCy model and the SLPMs

| i | Question | Mean | Std.Dev. | % |
|---|----------|------|----------|---|
| Q1 | The SLPMs help deaf children to remember information through memorization. | 4.00 | 1.414 | 80% |
| Q2 | The two educational levels of the MuCy model help deaf students to cognitively understand relevant information from the SL. | 5.00 | .000 | 100% |
| Q3 | Teaching Communication Skills such as reading, writing and speaking help deaf students to create solutions to the socio-cultural problems they face. | 5.00 | .000 | 100% |
| Q4 | Learning with a CLEMR helps deaf students to understand a complex situation in parts in order to create diverse learning solutions. | 5.00 | .000 | 100% |
| Q5 | Learning with interactive technology helps children increase their learning achievement. | 4.50 | .707 | 90% |
| Q6 | I would like to use these pedagogical materials as complementary teaching resources either at home or at school. | 5.00 | .000 | 100% |
| Q7 | The MuCy model helps deaf children to organize their learning process according to their educational needs. | 5.00 | .000 | 100% |
| Q8 | With these pedagogical materials it is easier to explain the SL positions to the children. | 4.00 | 1.414 | 80% |
| Q9 | Learning with AR avatars increases the interest in speech and makes the children feel more confident that they will learn to speak. | 5.00 | .000 | 100% |
| Q10 | The SL book is an adequate tool for teaching the reading and writing for an specific topic. | 4.50 | .707 | 90% |

3) *The Unity3D AR desktop application for SL* as intermediate interface uses a marker-based tracking system which can be adapted with AR display devices such as Vuzix for immersive learning experiences [22].

In order to validate the MuCy model and the SLPMs we are founded firstly, on the Principles of Learning and Teaching P-12 which are established by the Department of Education and Early Childhood Development [13]. Then, on the Danielson's Group Framework for Teaching [12], and finally on the Bloom's Taxonomy of Educational Objectives [9]. With these references we considered the most relevant aspects of each of them to design a likert's scale survey of five points [Table 1]. The respondents were two teachers from ASPAS.

The topic chosen for the SL pilot lessons is the Rainbow Colors. The SL lesson with the Colors was conducted in order to measure the Percentage of Development of SLCS and other CS reached by three deaf children (Fig.3A). This lesson had a duration of one hour with students located in different classrooms. A six-year-old student (Group A) learnt SL without using the MuCy Model and the SLPMs. The other two students aged six and seven (Group B) attended the lesson together with the materials within a CLEMR (Table 2).

For the Colors lesson we made 16 videos (including the signs for the concepts of light, dark and color). The duration of each video was approximately 6 seconds. For every minute each student watched and imitated an average of 8 to 10 SL positions. The lesson was divided into four activities. Each of them corresponding to a specific SLPMs.

Activity one corresponded to the animated videos. The children watched the avatars performing signs on the Tablet (Case A) and on the PC screen (Case B). All the students had to imitate the SL positions right after the avatars. For Activities two and three, the children had to use the SL book to practice the reading of the words for each color or concept. Next, they had to write those words down on the book. Finally (immediately after the writing exercises) they had to perform the SL positions corresponding to those words.

At the last Activity, the children first had to use the markers printed on the pages to display the animated avatars on the PC screen. Then, teachers taught
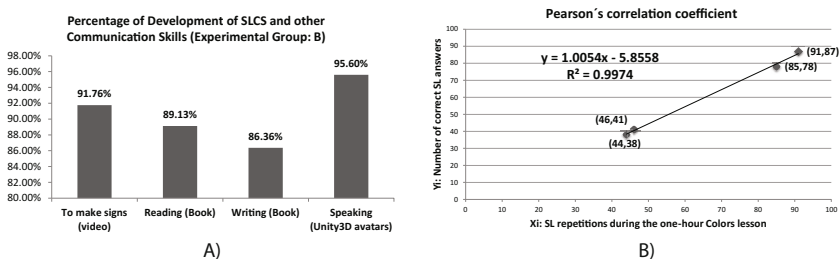


**Fig. 3.** A) Percentage of Development of SLCS and other Communication Skills of the Experimental Group. B) Correlation analysis between the SL repetitions during the one-hour Colors lesson and the students' correct SL answers.

**Table 2.** SL Repetitions, correct answers and total scores in One-hour lesson. A) Control Group: 1 student, B) Experimental Group:2 students.

**A) Control Group. The Rainbow Colors lesson.**

| Activity | T (mins) | SL Reps. Goal | MS | RD | WR | SP | Xi | Yi | Percent | Score |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Session SL Reps.** | | | | | | | |
| 1 | 20 | 100 | 80 | 0 | 0 | 0 | 80 | 72 | 90.00% | 9.0 |
| 2 | 10 | 50 | 0 | 45 | 0 | 0 | 45 | 35 | 77.78% | 7.8 |
| 3 | 10 | 50 | 0 | 0 | 40 | 0 | 40 | 28 | 70.00% | 7.0 |
| 4 | 20 | 100 | 0 | 0 | 0 | 75 | 75 | 70 | 93.33% | 9.3 |
| **Total** | **60** | **300** | **80** | **45** | **40** | **75** | **240** | **205** | **85.42%** | **8.5** |
| **Mean Value** | 15 | 75 | 20 | 11.25 | 10 | 18.75 | 60 | 51.25 | **82.78%** | **8.28** |
| **Std. Dev** | | | | | | | | | | **1.08** |

**B) Experimental Group. The Rainbow Colors lesson.**

| Activity | T (mins) | SL Reps. Goal | MS | RD | WR | SP | Xi | Yi | Percent | Score |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Session SL Reps.** | | | | | | | |
| 1 | 20 | 100 | 85 | 0 | 0 | 0 | 85 | 78 | 91.76% | 9.2 |
| 2 | 10 | 50 | 0 | 46 | 0 | 0 | 46 | 41 | 89.13% | 8.9 |
| 3 | 10 | 50 | 0 | 0 | 44 | 0 | 44 | 38 | 86.36% | 8.6 |
| 4 | 20 | 100 | 0 | 0 | 0 | 91 | 91 | 87 | 95.60% | 9.6 |
| **Total** | **60** | **300** | **85** | **46** | **44** | **91** | **266** | **244** | **91.73%** | **9.2** |
| **Mean Value** | 15 | 75 | 21 | 12 | 11 | 23 | 66.5 | 61 | **90.72%** | **9.07** |
| **Std. Dev** | | | | | | | | | | **0.39** |

the students to move their lips and tongues to reproduce sounds and to practice speech.

## 4  Conclusions

We have presented in this article a SLTM called MuCy. It established two psychomotor teaching levels of Education for SL Communication. The main contributions of the model to the teaching of SL are the promotion of the development of several CS on deaf children, allowing them to acquire knowledge through social interactions within a CMRLE and SLPMs (designed for a Rainbow Colors SL lesson at ASPAS). And finally, the model can be adapted to specific SL learning needs and can be reproduced as a complementary SLTM at other schools or deaf people Associations.

Mindful of psychomotor relationships between knowledge and communication, it is observed that there is a strong correlation coefficient of 0.99% (Fig.3B) between the SL repetitions from the one-hour Colors lesson and the number of Correct Answers given by the children. It is established that the more they practice SL positions (reading, writing and speaking through the SLPMs) the more they learn to communicate.

According to the Percentage of Development of SLCS and other CS (Fig.3A). The use of SLPMs has shown the following results: The use of videos has shown a 91.76% improvement in the SLCS, and the use of AR to develop speaking skills has shown an improvement of 95.60%. The use of the SL book has shown an improvement of 89.13% for reading skills and 86.36% for writing skills. This demonstrates that by using AR avatars, there is an increased level of interest in speech and makes the children feel more confident that they will learn to speak (Table 1, Q9). It also has been demonstrated that learning in collaboration with others increases learning achievement. (Table 2B).

With all the above, teachers have on their hands a complementary and adaptable SLTM which ensures the full understanding of concepts, meanings or ideas in accordance to different communication learning needs of deaf children.

## 5    Future Research

We consider to add a new SLPM based on Blender and OpenKinect camera for motion capture. A project at Microsoft Research China [10] has proved the recognition in real time of translating signs at the same time a person is performing them in front of the Kinect. By adding another SLPM to be used along with the MuCy model, the Teaching-Learning Process will be faster and efficient, because feedback to the learners is immediately streamed on the screens.

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