Augmented Reality: An Observational Study Considering the MuCy Model to Develop Communication Skills on Deaf Children

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Abstract. To develop different Communication Skills (CS) on deaf children (such as making signs, reading, writing or speaking) we propose a Sign Language Teaching Model (SLTM) called Multi-language Cycle for Sign Language Understanding (MuCy). Also, we conduct an observational study at the Association of Parents of Deaf Children of Salamanca (ASPAS) in order to measure the development of CS on deaf children by using a kit of Sign Language Pedagogical Materials (SLPMs), as well as the use of Augmented Reality (AR) as complementary tools for teaching Sign Language (SL) within a Collaborative Learning Environment with Mixed-Reality (CLEMR).

Keywords: Augmented Reality, Sign Language, MuCy model, Mixed-Reality Learning Environment, Unity3D.

1 Introduction

To teach SL in preschool and primary education it is essential to identify the different individual learning needs of each deaf student in order to improve their school achievement and social integration [18]. Teachers have to adapt their classes to develop Sign Language Communication Skills (SLCS) on deaf children. An adequate alternative teaching tool that suits these needs is the AR, since it allows teachers and students to collaborate towards gaining knowledge in a Teaching-Learning Process [14].

One of the most important features of the AR is the overlay of images in the real world. This allows interaction with digital media in real time through tangible devices such as PCs screens, AR eye-wear displays or glove-based input recognition systems. With all this, deaf students can learn interactively. First, they can visualize within their minds the SL concepts given in their classes. Second, they can explore the motions of signs in a 3D view, so they can reproduce those signs and learn by imitation from the body, face and lips.

This article is presented as follows: In Section 2 we mention two current educational projects based on AR to analyze their technical features, since they are appropriate references to design our kit of SLPMs. In Section 3 we describe

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two SL pilot lessons implemented at ASPAS [2]. The observational study design, the methodology and the results are also presented here. Then, in Section 4 we draw conclusions. Finally, in Section 5, a brief description of future research is mentioned taking into account possible alternatives to improve our approach technologically.

2 Related Works

Mathsigner™[1] is an AR project aimed to teach SL that can be used for non-immersive or immersive systems such as Flex™and reFex™, so deaf students can learn mathematical concepts and American Sign Language (ASL). This technology has several advantages: First, it is able to produce a highly realistic and fluid environment where 3D characters perform signs in real time. Second, it promotes interaction between users and 3D avatars via a simple glove-based gesture control system. Finally, a desktop version can be used at homes or at schools.

Another tool that can be considered a standard teaching method based on AR is the MagicBook [5,6,7]. It can be adapted to teach SL because it covers three levels of collaboration [15]: The first, is the Reality. A group of users can gather around to learn and interact with a book by changing its pages and by sharing their learning experience.

The second level is Augmented Reality (AR). A networked application is installed on several PCs where animated avatars and virtual environments can be seen projected on PC screens. The users' interactions are with AR devices and tangible books. The last level is Virtual Reality (VR). The AR device allows users to be connected within the workstation. Their learning experience is no longer in the real world, their digital interactions (through virtual avatars) are by sharing information within the immersive and interactive system.

With Mathsigner™and the MagicBook, teachers have the possibility to design their classes with different topics by adapting them to their students' learning needs. They can choose the learning experience through moving from one reality to another according with the specific skills or knowledge they want to develop in their students. What is missing in these two AR educational projects regarding deaf children is the existence of statistical data demonstrating the level of SL learning achievement in students. To solve this, we conducted two SL pilot lessons at a local deaf people Association in the province of Salamanca (Spain) in order to determine the Percentage of Development of SLCS and other CS such as reading, writing and speaking.

3 Study Design and Method

The objective of the observational study is to measure the development of CS on deaf children by the use of AR as a complementary tool for SL teaching based on the SLTM MuCy. The study was conducted at the Association of Parents of Deaf Children of Salamanca [2] along with a kit of Sign Language Pedagogical Materials (SLPMs) designed for this purpose (Fig.2).

3.1 SLTM MuCy, SLPMs, Software Architecture and Pilot Lessons

The Multi-language Cycle for Sign Language Understanding (MuCy) (Fig.1) is a continuous psychomotor cycle to teach SL to deaf people (signers and non-signers) and to students that require knowledge of SL because they have similar communication disabilities.

The theoretical background of the MuCy model is based on the Lev'*s* Semionovich Vigotsky Zone of Proximal Development (ZPD) [9,12], the Principles of Social Education of deaf and dumb children [18] and the Milgram'*s* Reality-Virtuality Continuum [15]. To design the model we are based on the neuropsychological findings that have shown that deaf children can develop reading and speaking skills by training at an early-age [13]. The criteria to validate the design are according to The Principles of Learning and Teaching [11] and on the Danielson'*s* Group Teaching Framework [10].

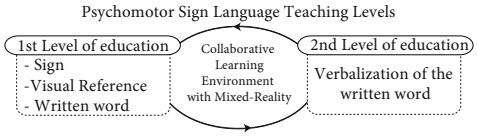

Fig. 1. Multi-language Cycle for Sign Language Understanding (MuCy model)

The first level of education in the MuCy model refers to learning the proper use of signs in relationship with their visual references (words or phrases) and their written versions. The second level refers to the practice of speaking those words by imitating the face, mouth and tongue movements. The SLPMs (Fig.2) are: 1) A *SL Book* which allows the use of the Vuforia marker-based tracking system for Unity3D [16,17]. A set of images of 3D avatars performing signs are printed on the book. Their respective meanings in words or phrases are presented in text format which makes possible to practice the reading and writing skills. 2) *Animated videos* that help deaf children to learn by imitation. 3) A Unity3D *SL AR desktop application* that displays on virtual scenes animated avatars which can be seen with AR devices such as the Vuzix eye-wear [19] or on PC screens. The modeling and animation process was made with Blender 2.69 [3].

Fig. 2. A) An Avatar performing the sign for the concept Colors, B) SL Fingerspelling Alphabet Book with sections for reading and writing exercises, C) AR Avatar in Unity3D, D) Vuzix eye-wear display for AR, E) Animations displayed on a Tablet

The AR SL application's architecture and design's flowchart explain the process we used to implement Unity3D for educational SL purposes (Fig.3). The two research instruments chosen to collect data for this study were observations and interviews. For the observations, the data collected was from two SL pilot lessons: The Fingerspelling Alphabet and the Rainbow Colors. For the interviews, we use a Smiley-face Likert's scale of five points to validate the SLTM and the SLPMs, as well as to know the parents and teachers attitudes about the usability, satisfaction and learning achievement they though the children reached by using our MuCy model and SLPMs (Table 2).

The two SL pilot lessons were conducted at ASPAS in order to measure the Percentage of Development of SLCS and other CS (such as reading, writing and speaking) reached by four children (two aged six and the other two aged seven) (Fig.4A). Each lesson had a duration of one hour with students located in the same classroom using the CLEMR (Table 1A,1B). For the Alphabet lesson we made 30 videos of words from A to Z and 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, and for every minute each student watched a video, they imitated an average of 8 to 10 SL positions.

The lessons were divided into four activities, each of them corresponding to a specific SLPM. The first activity was with animated videos. The children watched the avatars performing signs on the Tablet (Group A) and on the PC screen (Group B). Then, they had to imitate SL positions right after the avatars. The second and third activities were with the SL book with images of avatars showing the correct SL positions printed on it. The students practiced reading the words (colors and alphabet). Then, they had to write these words down on the book. Immediately after, they had to perform the SL positions corresponding to those words. For the last activity, at first the children had to use the markers printed on the pages to display the animated 3D avatars on the PC screen. After visualizing the avatars they had to imitate the SL positions individually and then in a group. Finally they practiced speech facing each other and their teachers. The students also learned to move their lips to make sounds similar to those we use to speak.

3.2 Data Analysis and Results

According to the Percentage of Development of SLCS and other CS (Making signs: MS, Reading: RD, Writing: WR and Speaking: SP) in relationship with the SLPMs as complementary tools within a CLEMR, the results were as follows (Table 1A,1B and Fig.4A):

1) *For the Rainbow Colors lesson.* The use of videos in Activity one had shown an 91.76% improvement of making signs, activities two and three showed a 89.13% increase in improvement of reading skills and an 86.36% improvement in writing skills. In Activity four, the use of AR to develop speaking skills while performing signs showed a 95.60% increase in improvement.

2) *For the Fingerspelling Alphabet lesson*, Activity one showed a 90.53% in improvement, the development of reading skills 87.93%, writing skills 90.48%, and speaking skills 93.68%.

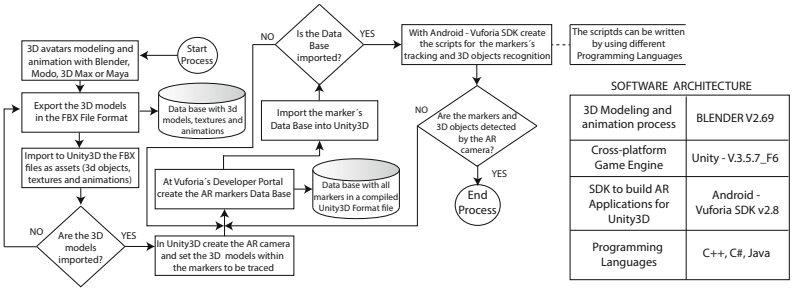

Fig. 3. AR SL application's architecture and design's flowchart

For the Colors lesson, the two students' Total Mean Value of SL Correct Answers was 90.72%, while for the Alphabet lesson 90.65%. These Mean Values has demonstrated that by using ICT Technology such as AR avatars increases the SLCS and the interest in speech on deaf children in primary education (Table 2, Q3 and Q9).

The Pearson's analysis has shown in both lessons a strong correlation coefficient of 0.99 between the two variables (Fig.4B): 1) The total number of SL Repetitions (Xi:SLR), and 2) the number of the Correct SL Answers (Yi:CA) given by the children once they had taken the two lessons of one hour duration each. This indicates that a greater number of SL repetitions with SLPMs produce more Correct SL Answers and learning achievement.

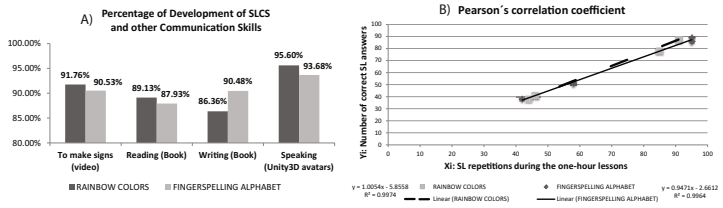

Fig. 4. A) Percent of Development of Communication Skills in relationship with the Pedagogical Materials, B) Correlation between the average of SL repetitions and the average of the Correct SL Answers given by the children

As for the Likert's scale, it is observed that all respondents strongly agree with our SL teaching approach (Table 2: Q2,Q6 and Q11). For the *Usability* variable (Table 2: Q3,Q4,Q6,Q7 and Q11) all the answers had a 100% approval which means that SLPMs promote the Collaborative Learning Experience, and that to learn in a CLEMR helps deaf students to understand complex situations in parts in order to create diverse learning solutions. Also both parents and teachers wanted to use these Pedagogical Materials at their homes or in schools

Table 1. SL Repetitions, correct answers and total scores in one-hour lesson for the A) Rainbow Colors and B) Fingerspelling Alphabet

A) The Rainbow Colors lesson.

Activity	T (mins)	SL Reps. Goal	Session SL Reps.				Xi	Yi	Percent	Score
			MS	RD	WR	SP				
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**

B) Fingerspelling Alphabet lesson

Activity	T (mins)	SL Reps. Goal	Session SL Reps.				Xi	Yi	Percent	Score
			MS	RD	WR	SP				
1	20	130	95	0	0	0	95	86	90.53%	9.1
2	10	65	0	58	0	0	58	51	87.93%	8.8
3	10	50	0	0	42	0	42	38	90.48%	9.0
4	20	110	0	0	0	95	95	89	93.68%	9.4
Total	**60**	**355**	**95**	**58**	**42**	**95**	**290**	**264**	**91.03%**	**9.1**
Mean Value	15	88.75	24	15	11	24	72.50	66	**90.65%**	**9.07**
Std. Dev										**0.24**

Table 2. 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	To learn 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%
Q11	The SLPMs promote the collaborative learning experience with Mixed-Reality (CLEMR).	5.00	.000	100%

because the MuCy model helps deaf children to organize their learning process according to their educational needs.

For the *Satisfaction* variable (Table 2: Q8,Q9 and Q10), Q9 had a 100% approval which shows that learning with AR avatars increases the interest in speech and makes children feel more confident. Also, Q8 with 80% in positive responses has shown that parents and teachers thought that using our SLPMs made it easier to explain SL positions to children. Q10 with 90% in positive responses demonstrated that the SL book is an adequate tool for teaching the reading and writing skill for an specific topic.

Finally, the *Learning Achievement* variable (Table 2: Q1,Q2 and Q5) has shown that the two educational levels of the MuCy model help deaf students to cognitively understand relevant information from the SL, that they can remember information through memorization (Q1) and that learning with interactive technology children increase their learning achievement (Q5).

4 Conclusions

We have presented in this paper a SLTM and a kit of SLPMs that have been implemented at ASPAS for two SL lessons. With the collected data we have demonstrated that by using ICT (such as AR) and by promoting the CLEMR deaf children have developed a high percentage of SLCS and other CS. Also, a brief explanation of the process we used to create the AR SL application based on the Cross-platform Unity3D is provided. So it can be reproduced by any teacher that wanted to use the MuCy model and AR as a complementary teaching resource.

With all the above, we have concluded that the Teaching-Learning Process within a CLEMR reinforces social interactions and CS in deaf children. Also, we have proved that teachers can adapt their classes to the educational needs of their students for a specific topic. The MuCy model along with the SLPMs also have proved to be an adequate complementary tool for teaching SL and developing different CS in a continuous psychomotor cycle.

5 Future Research

To improve technologically our model and to create an Interactive-networked desktop application with Mixed-Reality, we consider the convergence of technologies such as motion capture and voice recognition. Since they are appropriate to design collaborative and remote SL lessons.

For the motion capture of face, body and SL hands movements we will use the OpenKinect camera [8], and for the voice recognition system the Carnegie's Mellon Open Source *Sphinx Speech Recognition Toolkit* [4]. With these technologies interacting with each other synergistically in a desktop application, deaf people will be able to learn SL by translating movements and sounds into text and Animated-outputs (3D avatars in AR) within a remote CLEMR in real time.

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