Potential benefits in the learning process of Ecuadorian Sign Language using a Sign Recognition System.

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Potential benefits in the learning process of Ecuadorian Sign Language using a Sign Recognition System

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Abstract This paper presents the possible benefits of introducing technology into the teaching methodology currently used for teaching hearing impaired people the Ecuadorian Sign Language. The technological solution proposed in this paper is composed by a special glove; used to measure hand data for the recognition of signs and a graphical user interface designed following a blackboard metaphor aiming to provide a clear feedback. The system was designed to be usable independently of the age, experience with computers and literacy/numeracy level of the users. Nine teachers and three students were tested to obtain feedback about the usefulness of the system. The results indicate that even though the system is still lacking in recognition accuracy, it provides a more interactive and engaging teaching environment that could prove beneficial for the learning process. Among these benefits are the reduction of physical resources needed by the instructor, a tool for self practice/learning that produces a better use of resources and a possible promising tool to promote group teaching/learning.

1 Introduction

It is not a new idea that information and communication technologies (ICT) have given good results when applied to strengthening teaching/learning strategies. Recent examples of projects using ICT to improve learning are presented in [9, 21, 29, 31, 59], some of its advantages are presented as follows. By using multimedia to present content, the learning experience is enriched by exploiting more than one sense [1]. Additionally, other research [5] agrees that creativity is enhanced and self-esteem can be built as a result of applying ICT in education during the early ages. Other human features that can be strengthened by an ICT-powered learning process include the memory, auditory processing skills and listening skills, the last two influence directly on user attention [47].

This is different from students without disabilities, whose learning can be focused on any of their different senses, impaired students depend mostly on one or two senses or skills that are well developed as a consequence of their impairement. In the particular case of hearing-impaired students, hand signs and/or face expressions are used as means of communication. For this reason, the intensive use of their sense of sight since an early age gives them a higher visual perception making them more keen and adept at learning through visual data [32]. Currently, there are three methodologies that address the teaching/learning of hearing-impaired students: audio-verbal, cued speech and gestural.The gestural approach focuses on the communication using signs, postures and gestures of the hand. The word or phrase that is tried to be conveyed, is performed in an area limited by the head and the waist. In Ecuador, the set of postures and gestures used by hearing impaired people is known as the Ecuadorian Sign Language (ESL). Locally, the gestural approach is widely used because it is considered by teachers to be easier to be taught and learned than oralism, a cued speech approach based on lip reading.

Given the fact that more and more people have access to ICT, exploitation of its features makes them a powerful tool to be integrated in the learning process in every special classroom. This paper presents the potential benefits of using a sign language recognition system in the teaching/learning process (TLP) of the hearing impaired. This system is able to recognize 20 different signs divided into two different group terms: animals and colors. The system was tested on 12 individuals, nine were teachers and three students from two different centers for hearing impaired students. The test aimed to measure the usability and potential adoption of the system in the TLP.

This paper is organized as follows: Section two presents the processes used in the teaching/learning of hearing impaired students. Then, section three introduces some assistive technology used to improve the TLP of hearing impaired individuals. The next section presents the problem and its proposed solution. In section five, a test procedure to evaluate the potential of the proposed solution is described including tools and settings of the test procedure. Section six presents the results of the study. Section seven presents the analysis and discussion of the research. Finally, findings of the study and recommendations for future work are given.

2 Teaching/Learning Process for Impaired Students

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As mentioned above, as a side effect of having an impairment on a specific sense or ability, another sense develops to compensate it. For example, people with visual impairments often have a well-developed sense of hearing and sometimes also a heightened sense of touch. In the case of hearing impaired people, the sense of sight in conjunction with attention are developed [6, 7, 32, 42]. To provide an effective methodology that will allow students with disabilities to gain knowledge, the TLP should be focused on the developed senses/skills of the student.

2.1 The case of the Hearing Impaired

Like other people with impairments, most of the time people with hearing impairments are pushed to learn by learning methods that focus more on effectiveness than efficiency. Consequently, these methods tend to be repetitive and time consuming [51]. Most of these methods follow a *Drill and Practice* strategy. Drill and Practice is an instructional strategy that promotes the acquisition of knowledge or skill through repetitive practice. To be meaningful to learners, the skills built through drill-and-practice should become the building blocks for more meaningful learning. “Drill and Practice activities help learners master materials at their own pace” and “There is a place for drill and practice mainly for the beginning learner or for students who are experiencing learning difficulties” [44]. For these two characteristics, a drill and practice system might be an ideal tool for helping the hearing impaired in the TLP of ESL.

Students with hearing impairements face big difficulties in regular lectures. As stated in [50] they are an alike-minority, while many are really adept at reading lips others are not, some communicate orally and others through sign languages, gestures, writing, or a combination of these methods. Usually, hearing impaired students are taught through interpretation, meaning a third person needs to be present in the classroom to communicate the content to the student, or that a visual language might be used by the instructor to communicate with the student [54]. Even when the students have an impairment in their sense of hearing, the intensive use of their sense of vision since an early age makes them more adept at learning through images and movements [6, 7, 32, 42]. Nonetheless, this enhanced peripheral vision comes at the cost of diminished central vision capacity. Therefore, the usage of visual materials in the teaching of hearing impaired people could be considered an obvious approach. Even though we follow this approach, it is very important to note that if images and visual materials are used in the classroom to aid in the learning process, the concentration and attention shifts between the interpreter and the materials; thus, the interpreter and/or materials might become barriers in the process and must be taken into account [33, 34]. These facts provide great insight as to what kind of resources should be used within the learning process that hearing impaired students undergo.

There are features of the computers that make them good assistants on the execution of drill and practice exercises [23]. Through constant feedback given by drills run on computers, the users have the possibility to improve easier and faster. Additionally, the computers provide the capacity to repeat a task or drill as many times as required by users, giving them control of their learning pace.

3 Assistive Technology for Hearing Impaired Students

Technology has been introduced in the learning process of the hearing impaired with the objectives of improving the results obtained during the process and to enhance the employed methodology. For teaching the hearing impaired, there are several technologies that are employed that can be divided in three groups. Depending to the type of media provided to the user, these systems can be divided as video-based systems [14, 15, 43, 46, 49] or sound-broadcast systems [16, 28]. Based on the digital representation [37] used to describe a sign they can be classified as notation systems, video systems or animation systems. Based on the user experience and interaction, systems can be classified as story-based systems [8, 24] or as tangible systems [25, 39, 41, 60].

This last classification offers some advantages and disadvantages i.e. story-based systems make the user participate in the storyline of a tale or game. These systems include animations in 2D and/or 3D environments prompting the user to perform several actions that may affect the storyline. As a result the immersion and motivation of users are improved. However, users have the disadvantage of requiring such interaction through keyboards and/or mouse instead of making users to practice the signs they have just learned while following the story. Another weakness of story-based systems is the limited scalability related to the recognized signs and game inventory: virtual worlds, characters, items, etc. Due to the heavy load of designing and developing process of this inventory, the rate at which new content can be integrated is very low. On the other side, tangible systems aim to provide a more natural means of interaction different from the traditional keyboard and mouse interface. By moving away from this interface, tangible systems not only capture users that do not know how to use a computer but provide interfaces with high affordance that decrease the learning time of such systems. For example, as a strategy to encourage early acquisition of sign language in young children Yarosh *et al.* [60] propose a system to augment everyday objects that can be used in an interface with a virtual world. In this system, children were able to interact with a digital environment that taught them American Sign Language. A similar, but more portable, approach is the one proposed in [25] where children were able to watch sign language videos in an modified toy bear. Other work [35, 58] have proposed the use of gloves with sensors for the recognition of sign language, but no approach to use this hardware to improve the TLP has been proposed.

4 Problem Statement & Proposed Solution

While visiting Ecuadorian centers related to the instruction of people with hearing impairments the lack of technology to support their TLP is clearly evidenced. In addition, when analyzing the current teaching strategies used in hearing impaired schools, ESL is taught using printed images as support material which means that teachers carry a considerable amount of pictures and books for the class. Similar to other sign languages ESL is composed by a wide lexicon, which increases the amount of physical material to be carried by teachers and the necessary time required to locate a certain image. For this reason, a computational system that could store all these images and provide organization among them would be very beneficial. Another factor that must be considered is that students beginning with ESL studies are not necessary adults or have experience with computers. Therefore, the proposed solution must focus on usability providing a proper feedback that can be understood by students regardless of their age or literacy/numeracy level. The decision to support a sign language instead of oralism, was made based on the following criteria: (a) Local teachers consider that when they teach a sign language, the student is able to learn a concept not only a word, as it happens when they teach how to read lips; (b) as stated in [2, 3, 4], hearing impaired people are proud of their condition, they consider themselves a minority who communicates differently rather than a group of "disabled" people.

Through a prototype system and a short study, this work aims to answer: 1) what are the potential benefits that would bring the introduction of technology in the TLP of ESL? and 2) Is the proposed system easy to use?.

4.1 The Proposed Prototype System

The proposed system is mainly composed by three elements: a glove with sensors, a web camera, and a computer. As seen in Figure 1a, users wear a special glove and interact with the system through ESL signs. As a result the system projects a representation of the meaning of the sign on the screen of a computer (Figure 1b). This system was designed to recognize ESL which is composed by postures, position of the fingers in a certain moment, and gestures, trajectories done while moving the hands. ESL differs from other sign languages by not requiring facial expressions.

The design of this prototype system is focused on three features: increasing motivation, scalability, and mobility. Increasing motivation means that the introduction of this system on the TLP of ESL would boost the enthusiasm of users towards learning and/or practicing ESL. The proposed system aims to improve the scalability of the current TLP by storing large volumes of words, images and recognizable signs in computers. In addition, it must decrease the time required to locate the image related to the meaning of a certain sign. Mobility is directly affected by scalability. Due to its large storage feature, this system must provide the teacher the capability to move a large number of support material in a relatively small physical object, a portable computer. Therefore, by using a portable computer, a portable ESL classroom can be developed.

4.1.1 Posture Recognition

A seen in other research [19, 35, 58] a glove is used to obtain the position of the fingers. The advantage of using gloves over vision-based posture recognition methods is that gloves do not suffer from occlusion and are not affected by lighting variations [48]. In this implementation, a Cyberglove II wireless glove [27] was used. This glove has 23 sensors and sends data measured by the sensors to a computer via a bluetooth connection. The data measured by the glove was used with a pattern recognition algorithm for the recognition of hand postures. This algorithm consisted in a simple three-layered feed forward neural network [19, 36, 53, 57] for the modeling of the posture detection system. A three layered neural network usually consists of an input layer, a hidden layer and an output layer linked together with weights that change as the network is trained. The input units of the neural network represent measurable features and the output units represent the values used for the classification.

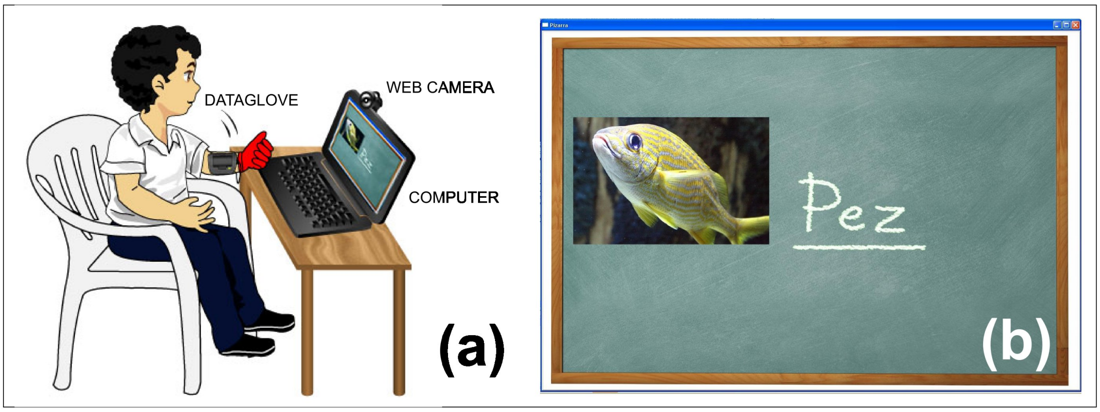

Figure 1: Interacting with the system

4.1.2 Gesture Recognition

Gestures are the trajectories or silhouettes made while moving the hands. For the recognition of the gestures, the location of the hand is required at every moment of the interaction in order to identify its trajectory. In the proposed system, hand tracking is done by color segmentation algorithms. One step prior to the segmentations is to cover the cyberglove with a red glove then , using a web camera, images of the user are continuously captured. These images are changed to the Hue-Saturation-Value (HSV) color space and the glove is detected using color segmentation algorithms filtered with erosion/dilatation operations. The main reason the HSV color space is selected was that it emphasizes the human perception in hues and that it has an easily invertible transform from RGB [11, 12] which makes it fast enough for real time processing. Once the coordinates of the hand, defined by the centroid of the red blob, are obtained. Those coordinates are sent to a Grid Algorithm based on the algorithms proposed in [55, 56] for stroke recognition.

4.1.3 Sign Recognition

Once postures and gestures are detected, they are compared against a set of rules. This set of rules describes all the signs recognizable by the system. As a measure to deal with variation or noise introduced by users while signing, these rules are represented by regular expressions (RegEx). RegEx can be defined as an expressive pattern language or strings, written in that language, that describe a search pattern [20, 22]. This feature makes RegEx appropriated to describe code sequences with low variations, becoming a useful tool for handling the human factor on encoded gestures. When a match is obtained between the identified sign and one of the signs of the set of rules, a feedback is given through the graphical user interface.

4.1.4 Feedback Interface

As presented in Figure 1b the feedback is given through a graphical user interface (GUI) on using a blackboard metaphor that presents a pictorial and textual representation of the meaning of the sign. Through pictorial representations the system provides a clear explanation of the meaning of the sign. By presenting an additional textual representation, the system extends its functionality not only helping to learn the meaning of a sign, but also helping in learning the written form of a term represented by a sign. This interface and the processing of the system were implemented using a multicore laptop. In addition, to test the potential of using technology on the TLP of ESL, the main objective of this system is to be effective and easy to understand by users (teachers and students of different ages and levels of literacy). The system included two sets of signs linked to the topics; animals and colors. Both topics included items represented by words and pictorial representations. Further details related to the implementation and accuracy of this system are presented in [40].

5 Method

To answer the research questions posed in section 4, an usability test was set-up, mainly to answer question 2 “Is the proposed system easy to use?”; however, question 1: “what are the potential benefits that would bring the introduction of technology in the TLP of ESL?” was answered through observation analysis of the users and their reactions while testing the system. The usability test included ESL teachers and/or instructors, and students.

Several variables that affect the user experience and that influence the perception of the user towards the adoption of a system were measured. The first variable was usability, which is defined by ISO (1998) as: "the effectiveness, efficiency and satisfaction with which specified users achieve specified goals in particular environments" [26], and more specifically efficacy or effectiveness and easiness of use, the latter linked to user satisfaction. Easiness of use was two-folded in easiness of use and degree of comfort while using the system. Another variable of interest was the attitude towards technology as a mean for enhancing the teaching-learning process. It was important to have a basic background about attitudes of users towards technology for teaching and learning and technology in general to understand the results we obtained with the usability survey designed for this experiment [13, 17].

This survey included 16 items, 13 used a five point likert scale (from total disagreement to total agreement) and three open questions. Attitude towards technology was evaluated using three items, producing for this variable a possible maximum score of 15 and a minimum of 3. Nine items were related to usability; thus the user could rate the usability of the system from 9 to 45 (9 times 1 or 9 times 5, respectively). Usability was compounded of three subscales: effectiveness, easiness of use and degree of comfort; each subscale was measured by 3 items. There was also one item linked to the level of agreement about the future use of the system for teaching sign-language. The open questions were about the challenges found by the user when testing the system, suggestions to enhance the final product, and perception about the comparative advantages between the system and the current teaching method used at each educational organization.

5.1 Testing Settings

The settings used for the testing were similar to the ones currently used for teaching in a one-teacher-one-student fashion (Figure 2). In regular ESL lessons, the teacher is seated next to the student, both in front of a mirror. When teaching a new sign, the teacher signs to the mirror which is constantly observed by the student. By using a mirror, the student is able to see from a reflected angle the sign made by the teacher and check if the sign he/shes is trying to do, matches the one done by his/her teacher. In addition, printed pictures or books are used to present the meaning of the sign.

5.2 Testing Procedure

Following testing lines like [38, 52] and recent work [43, 45, 49], the prototype was tested on a group of nine teachers/teaching assistants and three students from two educational organizations (six users per organization) for hearing impaired students in Ecuador. Among the teachers the average age was 44 (Min=19, Max= 60, SD=13.88). Two students were boys and one was a girl, all of them were 17.

The testing was composed of four parts: a briefing, a guided interaction test, an open interaction test, and the survey application . At the beginning of the test, five minutes were taken to give a short briefing to each user to present the system and the objectives of the test. During the guided interaction test, the user was asked to perform each of the 20 signs related to the animals and colors defined in the set of rules that described the signs; the users were requested to perform the signs according to the animals category and then to the colors category. This part of the test lasted approximately 20 minutes, one minute per sign. Later, three minutes were given to users to perform signs from the set in a random fashion. During the development of these tasks, a researcher observed the users and wrote down his impressions about the expressions and actions done by the users that could reflect their reaction to the interface. Finally, the users were asked to fill out the survey described in the previous subsection.

6 Results

While observing users during the usability test, the researchers detected the following impressions from users: a)they were really surprised about the cyberglove and the number of gloves needed (3) to interact with the system and discomfort caused by the glove; b) users were very cooperative and talked about alternative ways to improve and use the system once they got used to it and understood how it works; for instance, they suggested the system might be used to support self-learning, and peer-tutoring; c) signs like pink, hippo, rabbit were more complicated for the users to be done and took longer periods to be executed, five users performed these signs while staring at the hand with the glove or with the help of the other hand; these signs needed crossed fingers or more flexibility to be executed; d) one teacher performed different signs for red, black and rooster than the ones in the system, he stated that these signs are different in other regions in the same country; e) a student interacting with the system got support and clues from others, not using the system, when executing different signs; f) users were really happy at the end of the usability test and asked when the system was going to be installed in their premises.

Figure 2: Test in currently teaching settings

From data gathered from the survey, the participants indicated a positive attitude towards technology. The first quartile was 13.25, second quartile 15.00 and the third quartile 15.00 with *SD*=1.07. The users were also very positive towards the usability of the system. Table 1 presents the results for each of the subscales in the survey that evaluated usability.

Table 1: Descriptive statistics for Efficacy and Easiness of use (N=12)

	Efficacy	Easiness of Use	
		Easiness of Use	Degree of Comfort
Mean	10.63	12.42	10.88
Std. Deviation	3.28	2.74	3.26
Minimum	6.00	7.00	6.00
Maximum	15.00	15.00	15.00
Percentil 1	7.00	11.00	13.6
Percentil 2	10.50	13.50	14.75
Percentil 3	7.75	10.50	14.50

As can be seen from Table 1, efficacy was the subscale with the lowest mean, followed by degree of comfort, while the mean of easiness of use was the highest. Friedman test to find differences in the subscale usability scores was used and no significant differences were found ($X^2(2) = 188, p < .552$). The total scores of usability calculated from summing up the individual scores of each subscale resulted in a mean value of 33.92 (*Min*=21.50, *Max*=45, *Q1*=30.00, *Q2*=34.75 *Q3*=37.00, *SD*= 6.98). Even though the overall scores were according to the expectations of the authors, teachers were less positive than students when evaluating the system as shown in Figure 3. However, this difference was not found significant when tested using Mann-Whitney U test (U=10, p<.515). Regarding the perception of the users about the future adoption of the system for the TLP in ESL, most of the users fully or partially agreed (91%) on the adoption of the system, only 9% of them indicated a partial disagreement. As for the advantages foreseen by the users, they indicated that the system is efficient (33.3%), easy to learn, supportive for the TLP, very good and no comments (16.6.% each). The challenges faced by users during the testing period were the following: difficulty when using glove (inflexible, heavy), too many devices to be worn, the combination of the first and second challenge, inaccuracy in sign detection, no comments (16.7% each); difficult usage and none (8.3%). Some suggestions pointed by users were: "only one glove should be used" (25%); "customized gloves according to actual user sizes should be used", the system need to be used several times to get better accuracy, keep working "its is a great system" 16.7% (each); and, provide more feedback when making wrong signs and no suggestions (8.3% each).

7 Analysis and Discussion

This section will present first the weakness of the study and later the strengths of it. One of the weaknesses found is that there were few users in the usability test as opposed to what is suggested in [18]. On the

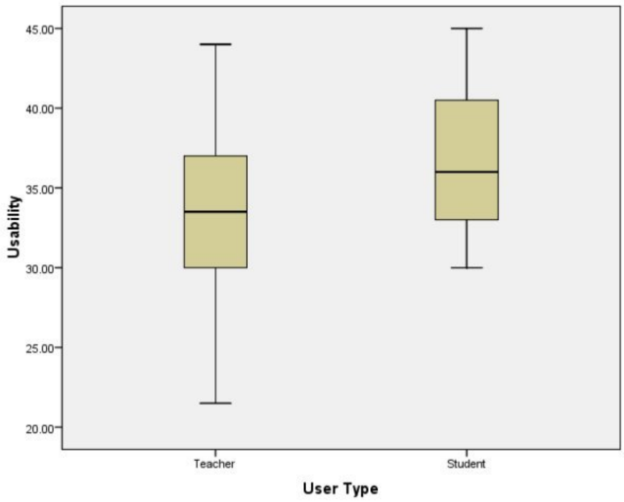

Figure 3: Difference in usability perceptions among participants.

contrary, usability studies as the ones carried out by Nielsen and Virzi included only a maximum of five users because most of the usability problems in a system are detected by this number of users [38, 52]. Another weakness is that this usability test was focused more on the easiness of use and degree of comfort when using the system, than other metrics included in usability studies like: number of errors, time to complete a task or ratios of success and failure to complete a task [30]. The current analysis is based on descriptive statistics, mainly due to the limitation in the number of participants of the study. It was proved that the main usability weakness of the system is concerned with the discomfort using the cyberglove, which affected the development of tasks (interruptions) during long periods of time. For instance, it was observed that some users looked at their hand when trying to do signs where crossing fingers were required (when signing color pink); for some users, putting the fingers in the correct position was difficult because the glove was to rigid or too big, resulting in wrong signs. In addition, the cost of the cyberglove (approximately US.$5000) represents a barrier towards the massive adoption of the system. For these reasons, future work should focus on approaches that do not rely on specific hardware, for instance appearance-based algorithms as the ones researched in [10].

The general attitude of the participants towards technology was very positive, resulting in also a positive perception of the users about the adoption of the system in the future. This result might be different with a group of people with a more heterogeneous attitude towards technology. Another weakness of this part of the study is the lack of a formal attitude survey used by other researchers previously. The fact of only reporting descriptive statistics can be seen as a weakness. However, other inference tests were used to identify significant differences between the opinion of teachers and students. These tests resulted in no significant differences between the conditions.

Two promising potential benefits were detected: technology assisted self-learning and technology assisted group learning. The group of teachers said that as the system provides a feedback when a properly done sign is recognized, it can be used as a tool for self-learning among the students. By doing this, the time and attention of the few ESL experienced teachers can be given to beginner students while students with previous ESL knowledge can interact and gain new knowledge from the system. Observations on the students showed how their motivation drove them to sign together when just one student was interacting with system. This fact shows a promising use of the proposed system to drive a methodology of technology assisted group learning or peer tutoring on ESL. This might represent a significant contribution on the learning process of ESL, which has been taught in a personalized one-teacher-one-student mode during the last years.

Observations also reflected that, locally depending on the area or region, few words were signed differently, which influenced the recognition accuracy of the system perceived by the teachers. This factor of sign variations on the location, must be considered for future mass adoption of the system.

Finally, in contrast to previous work aiming to improve the TLP of hearing impaired students, there are two factors in which the solution proposed on this paper differs. Compared to [25, 60], which targets children, the solution proposed on this paper aims to reach students and teachers independently of their age. Another difference with [25, 60] and [14, 15], is that the interaction means of the present proposed solution pushes the student to practice the sign language. For example, users interact with the system through signs while in the other systems, the interaction was driven by a mouse, keyboard or another external tool. Previous work similar to the one proposed on this paper can be found in [24], but even when they have the similarity to push the user to interact through signs, they differ in scalability. While the proposed system uses a minimalistic GUI, [24] proposes the use of an enriched GUI composed by elements that might delay the rate at which new content is added to the system.

The results achieved in this study are similar to ones obtained by Parton [41], where it was also observed that users picked the process very quickly and that technology was a facilitator rather than a distracting factor. On the other hand, the perception of the teachers towards using that system for group learning was not so positive since they expressed that it was too focused on only one student at a time. Similar to what was seen in [25], the presented prototype offers an engaging experience and has a promising application for group learning, but the prototype presented in this papers has the advantage of being targeted to not only children, but adults as well. Related to use of gloves with sensors, this study yielded the same results as the ones in [24], where users expressed the discomfort produced on their wrist by the gloves. On the other hand, the presented prototype has the advantage of not being user dependent.

8 Findings

"What are the potential benefits that would bring the introduction of technology in the TLP of ESL?" it was found that the present system has a promising future, as perceived by teachers. One potential benefit foreseen before the implementation of the system is that the system offers portability and mobility for the teacher, making her-him possible to provide a portable ESL classroom. This portable classroom system would provide access to learning to students from rural areas. Another benefit brought by the system was its potential use as a self-learning tool for students. By doing this, the time of the teacher can be focused on new students; producing a better use of resources. Powered by the motivation of the students, the use of this kind of technology for teaching/learning proved the possibility to perform group learning, peer tutoring, resulting in a better use of resources as well as providing a one-to-many teaching by extending the system with a projector.

"Is the proposed system easy to use?" the usability tests demonstrated that it was easy, however some issues about the degree of comfort when using the cyberglove is an issue to be solved. As stated by several users, the cyberglove was too rigid and make it difficult for them to do the signs. This represents a difficulty that prohibits the use of the proposed system for long periods of time. The cost is another factor that may also limit mass adoption. Even though the results obtained in this study are very positive and the future of the system seems promising, more research is needed for attempting its mass adoption and generalizing its suggested use.

References

[1] Stephen M Alessi, Stanley R Trollip. Multimedia for Learning Methods and Development. 2000. Allyn & Bacon. ISBN:0205276911.

[2] AllDeaf. "Minority or Disability." Bulletin Message. Available on line from: http://www.alldeaf.com/general-chat/5911-minority-disability.html. Retrieved on August 2009.

[3] AllDeaf. "Is is offensive to sign in Public?." Available on line from: http://www.alldeaf.com/sign-language-oralism/67941-offensive-sign-public.html. Retrieved on August 2009.

[4] AllDeaf. "Is it Offensive to Talk while among a Deaf crowd?." Available on line from: http://www.alldeaf.com/sign-language-oralism/68231-offensive-talk-while-among-deaf-crowd.html. Retrieved on August 2009.

[5] Andrews, C., The benefits of introducing young children to ICT. 2008. Early Years Update. Available on line from: http://www.teachingexpertise.com/articles/the-benefits-of-introducing-young-children-to-ict-3072. Retrieved on August 2009.

[6] Bavelier, D., Dye, M. and Hauser P. Do deaf individuals see better?. 2006. Trends Cognitive Science. Vol. 10 (pp. 512â518).

[7] Bottari D., Turatto M., Bonfioli F., Abbadessa C., Selmi S., Beltrame M.A., Pavani F. Change blindness in profoundly deaf individuals and cochlear implant recipients. 2008. Brain Research, 1242 (C) (pp. 209-218).

[8] Brashear, H., Henderson, V., Park, K., Hamilton, H., Lee, S., and Starner, T. American sign language recognition in game development for deaf children. 2006. Proc. of the 8th international ACM SIGACCESS Conference on Computers and Accessibility. (pp. 79-86).

[9] William I Bullers. and Stephen Burd and Alessandro F. Seazzu, Virtual machines — an idea whose time has returned: application to network, security, and database courses. 2006. Proc. 37th SIGCSE technical symposium on Computer science education. ISBN:1-59593-259-3.

[10] Chen, Q., Georganas, N. and Petriu, E.: Real-time Vision-based Hand Gesture Recognition Using Haar-like Features. 2007. In *Proc. Instrumentation and Measurement Technology Conference*, pp 1-6.

[11] Tse-Wei Chen, Yi-Ling Chen, Shao-Yi Chien, Fast image segmentation based on K-Means clustering with histograms in HSV color space. 2008. *IEEE 10th Workshop on Multimedia Signal Processing*, pp 322-325.

[12] Chen, W., Shi, Y. Q. and Xuan, G., Identifying computer grahics using HSV color model and statistical moments of characteristic functions. 2007. *Proc. of IEEE International Conference on Multimedia and Expo*, pp. 1123â1126.

[13] Culpan, O. Attitudes of end-users towards information technology in manufacturing and service industries, 1995. Journal of Information Management. Vol. 28 (pp. 167-176). ISBN: 0378-7206. Elsevier Science Publishers B. V.

[14] Drigas, A. S. and Vrettaros, J. and Kouremenos, D., An e-learning management system for the deaf people. 2005. Proc. of the 4th WSEAS International Conference on Artificial Intelligence, Knowledge Engineering Data Bases. (pp. 1-5). ISBN:960-8457-09-2.

[15] Drigas, A.S. Kouremenos, D. Kouremenos, S.; Vrettaros, J. An e-learning system for the deaf people. 2005. Proc. of the Information Technology Based Higher Education and Training 6th International Conference. (pp. T2C/17- T2C/21). ISBN:0-7803-9141-1.

[16] Dubsok, P., Israsena, P., Pan-ngum, S. Designing an Embedded Digital Wireless System for Hearing Impaired Students. 2008. The 3rd International Symposium on Biomedical Engineering. (pp. 260-265).

[17] Ess, C. Cultural attitudes towards technology and communication: New directions of research in computer-mediated communication. 1999. Journal AI & Society. Vol. 13 (pp. 329-340). ISSN 0951-5666.

[18] Faulkner, L. Beyond the five-user assumption: benefits of increased sample sizes in usability testing. 2003. Behavior research methods, instruments, & computers : a journal of the Psychonomic Society, Inc 35 (3), 379-383.

[19] Fels, S.S. Hinton, G.E. Glove-talk II - a neural-network interface which maps gestures toparallel formant speech synthesizer controls. 1997. IEEE Transactions on Neural Networks. Vol. 8 (pp. 977-984). ISSN: 1045-9227.

[20] Friedl, Jeffrey, Mastering Regular Expressions, O'Reilly Media, Inc., (2006).

[21] Gaible, E. Survey of ICT and Education in the Caribbean: A summary report, Based on 16 Country Surveys. 2009. Available on line from: `http://www.infodev.org/en/Publication.441.html`. Retrieved on August 2009.

[22] Goyvaerts, J., Levithan, S., Regular Expressions Cookbook Detailed Solutions in Eight Programming Languages, O'Reilly Media, Inc, (2009).

[23] Haddad, W.D., Jurich, S., ICT for education: potential and potency, Technologies for Education: Potential, Parameters, and Prospects. , 2002. International Leadership for Educational Technology. ISBN 0-89492-112-6. Available on line from: `http://ict.aed.org/infocenter/pdfs/TechEdBook.pdf` . Retrieved on August 2009.

[24] Henderson, V., Lee, S., Brashear, H., Hamilton, H., Starner, T., and Hamilton, S. 2005. Development of an American Sign Language game for deaf children. In Proceedings of the 2005 Conference on interaction Design and Children. (pp. 70-79).

[25] Huang, Kevin and Smith, Jesse and Spreen, Kimberly and Jones, Mary Frances. Breaking the sound barrier: designing an interactive tool for language acquisition in preschool deaf children. 2008. Proc. of the 7th international conference on Interaction design and children. (pp. 210–216). ISBN:978-1-59593-994-4.

[26] International Organization for Standardization, 1998. ISO 9241-11, Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs), Part 11: Guidance on Usability, Geneva.

[27] Immersion Cyberglove II specifications Available on line from: `http://www.cyberglovesystems.com/products/hardware/cyberglove_specs.php`. Retrieved on August 2009.

[28] Israsena, P. and Pan-ngum, S. A study of low-cost, robust assistive listening system based on UHF wireless technology. 2007. Proc. of the 1st international Convention on Rehabilitation Engineering & Assistive Technology: in Conjunction with 1st Tan Tock Seng Hospital Neurorehabilitation Meeting. (pp. 139-141).

[29] Kinuthia, W.. Educational Development in Kenya and the Role of Information and Communication Technology. International Journal of Education and Development using ICT [Online], 5(2). April 2009, Available: http://ijedict.dec.uwi.edu/viewarticle.php?id=740.

[30] Kuniavsky, M. Observing the User Experience: A Practitionerś Guide to User Research. 2003. ISBN:1558609237, Morgan Kaufmann Publishers Inc.

[31] Olivia A. T. Frimpong Kwapong. , Comparing Knowledge and Usage of ICT among Male and Female Distance Learners of an Endowed and Deprived Area in a Developing Country in Africa. 2009. Journal of Information Technology Education (JITE), vol. 8. (pp. 1-17).

[32] Lee, W., Deaf & Hearing-Impaired, Universal, Usability in Practice. 2001 Available on line from: http://otal.umd.edu/uupractice/hearing/ . Retrieved on August 2009.

[33] Marschark, M. . Literacy in deaf children: About more than literacy?. 2005. International Congress on Education of the Deaf.

[34] Marschark, M., Pelz, J., Convertino, C., Sapere, P., Arndt, M. E., and Seewagen, R.. Classroom interpreting and visual information processing in mainstream education for deaf students: Live or Memorex?. 2005 American Educational Research Journal, Vol.42 (pp.727â762)

[35] Mehdi, S.A., Khan, Y.N. Sign language recognition using sensor gloves. 2002. Proc. 9th International Conference on Neural Information Processing. Vol.5 (pp. 2204- 2206).ISBN: 981-04-7524-1.

[36] Murakami, Kouichi and Taguchi, Hitomi. Gesture recognition using recurrent neural networks. 1991. CHI '91: Proceedings of the SIGCHI conference on Human factors in computing systems. pp.237-242. ISBN: 0-89791-383-3.

[37] Naqvi Saduf. Artificial Representations of Sign Language to Access Information: How affective are they?. 2008. International Tech Symposium Instructional Technology and Education of the Deaf.

[38] Nielsen J. and Landauer T. A mathematical model of the finding of usability problems. 1993. Proc. of the INTERACT '93 and CHI '93 conference on Human factors in computing systems. pp. 206-213. ISBN: 0-89791-575-5.

[39] Novis, C., Allerhand, E. and Shemer, S., Virtual Reality: A Brave New World in Service of Man. 2008. Open University of Israel. Open Letter No. 20 Autumm (pp. 24-25). Available on line from: http://www-e.openu.ac.il/geninfor/openletter/ol20/24-25.pdf. Retrieved on August 2009.

[40] Oramas, J., Moreno, A. and Chiluiza, K. Technology for Hearing Impaired People: A novel use of Xstroke pointer gesture recognition algorithm for Teaching/Learning Ecuadorian Sign Language. 2009. Proc. ACM SICHI.BE New Communities Conference.

[41] Parton, B. and Hancock R. Vision 3D: Digital Discovery for the Deaf. 2008. Proc. Instructional Technology and Education of the Deaf: Supporting Learners, K- College: An International Symposium.

[42] Proksch, J., and Bavelier, D.. Changes in the spatial distribution of visual attention after early deafness. 2002. Journal of Cognitive Neuroscience, Vol.14 (pp. 687â701).

[43] Richards J., Hibbard E., Hardman J., Woodcock K., Fels I. Signlinking 2.0. 2008. International Tech Symposium Instructional Technology and Education of the Deaf.

[44] Saskatoon Public Schools. Instructional Strategies. 2008. Available on line from: http://olc.spsd.sk.ca/DE/PD/Instr/strats/drill/index.html. Retrieved on August 2009.

[45] Saksiri B. Learning Computer with Virtual Sign Animated Pedagogical Agents. 2008. International Tech Symposium Instructional Technology and Education of the Deaf.

[46] Saksiri B. and Suphajanya P. Web Based Instruction on Solar Eclipse and Lunar Eclipse for Deaf and Hard of Hearing People. 2008. International Tech Symposium Instructional Technology and Education of the Deaf.

[47] Strahovnik V, MeÄava B. Storytelling and Web 2.0 Services: A synthesis of old and new ways of learning eLearning Paper. 2009. elearningeuropa.info, P.A.U. Education, S.L. ISSN 1887-1542, Available on line from: http://www.elearningpapers.eu/index.php?page=doc&doc_id=14398&doclng=6&vol=15. Retrieved on August 2009.

[48] Sturman D. and Zeltzer D. A survey of glove-based input. 1994. IEEE Computer Graphics and Applications. Vol. 14 (pp. 30-39). ISSN: 0272-1716.

[49] Trager B. and Stanislow J. Instructional Software Tool: A visual learning approach to conceptual barriers. 2008. Proc. Instructional Technology and Education of the Deaf: Supporting Learners, K- College: An International Symposium.

[50] University of Berkeley. Teaching Students with Disabilities. Disabled Student's Program. Available on line from: http://dsp.berkeley.edu/TeachStudentsWithDisab.html. Retrieved on August 2009.

[51] University of Illinois. Disability Resources and Educational Services Teaching Students with Disabilities - A Practical Guide. 2008. Available on line from: http://www.disability.uiuc.edu/page.php?id=61 . Retrieved on August 2009.

[52] Virzi R. Refining the test phase of usability evaluation: how many subjects is enough?. 1992. Human Factors Journal. Vol 34 (pp.457-468). ISSN: 0018-7208. Human Factors & Ergonomics Society, Inc.

[53] Waldron, M.B. Soowon Kim. Isolated ASL sign recognition system for deaf persons. 1995. IEEE Transactions on Rehabilitation Engineering. Vol 3 (pp. 261-271) ISSN: 1063-6528.

[54] West Virginia University - Department of Education. Strategies for teaching students with hearing impairments. Available on line from: http://www.as.wvu.edu/~scidis/hearing.html#sect2. Retrieved on August 2009.

[55] Willey, M.: Design and Implementation of a Stroke Interface Library. 1997. IEEE Region 4 Student Paper Contest.

[56] Worth, C.: Xstroke: Full-screen Gesture Recognition for X. 2003. Proc. of the USENIX 2003 Annual Technical Conference.(pp. 187-196)

[57] Wray Vamplew P. Recognition of Sign Language Using Neural. 1996. Networks. Ph.D. thesis University of Tasmania. Available on line from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.88.8019&rep=rep1&type=pdf. Retrieved on August 2009.

[58] Wu jiangqin, Gao wen, Song yibo, Liu wei, Pang bo. A simple sign language recognition system based on data glove. 1998. Fourth International Conference on Signal Processing Proceedings. Vol. 2 (pp. 1257-1260). ISBN: 0-7803-4325-5.

[59] Yahya, S., Arshad, N., and Wahab, N. e-Education Systems Implementation Success Model. 2009. International Journal of Education and Development using ICT. Available on line from: http://ijedict.dec.uwi.edu/viewarticle.php?id=601. . Retrieved on August 2009.

[60] Yarosh, Svetlana and Huang, Kevin and Mosher, Ian and Topping, Marisa, Playware: augmenting natural play to teach sign language. 2008. CHI '08 extended abstracts on Human factors in computing systems. (pp. 3249-3254).