LEARNING TECHNOLOGIES FOR DISABLED

By

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Abstract

The hearing impairment is a disability that causes a huge communication gap between hearing impaired handicaps and non-hearing impaired people. A number of daily life complications are faced by profound hearing impaired (PHI) individuals due to their communication inability, for example an adverse event. An adverse event is a maltreatment of a patient caused by deceptive communication by the patient or the misunderstanding by a health practitioner. Its reason is mainly attributed to the inability of health practitioners to understand and express themselves in sign language (SL). Moreover, sign language is not uniform because it mostly includes informal or natural signs that vary from region to region, which makes it difficult to be understandable globally. Cochlear implantation is another solution to facilitate profound hearing impaired to resolve their communication inability. However this solution is very expensive and is not affordable by low socio-economic society. Lip-reading from a speaker’s (i.e., speech therapist) face is another traditional method of teaching spoken language to the hearing impaired. However, the dedication required from a speaker, makes this job burdensome. Pronouncing the same word repeatedly makes the teaching problematic, if not impossible. Subsequently, a child loses engagement and interest in the learning process. Hiring a speech therapist is also a financial overhead associated with the traditional lip-reading method.

The objective of the present research is to address the identified problem and the research gap found using systematic literature review (SLR) of the domain, and hence, to facilitate hearing impaired handicaps from low socio-economic society to mitigate their communication gap through lip reading using the proposed software application (learning technology). The proposed interactive software application (LOSINA - Learning Application without Sign Language for Profound Hearing Impaired Children) was developed for
articulating English words following lip-reading method. The LOSINA presents the words in an interactive manner by selecting words containing vowels at different positions, i.e., vowels at initial, middle and final position of the words. The application demonstrates lips and mouth movements to show pronunciations of the words against a selected word. These words involve multiple tongue placements and lip movements. The proposed application implements the constructive pedagogy by enabling a student progress from single tongue placement and lip movement to multiple movements for a word pronunciation. Finally the proposed software application was evaluated for its effectiveness and usability. A pre-experimental one-shot study design was used for the effectiveness evaluation involving twenty male and female profound hearing impaired children (i.e., stone deaf). Evaluation was performed by three evaluators: sign language teacher, speech therapist and family members of the individual being experimented. The assessment parameters were designed with the help and consensus of the sign-language teacher and speech therapist to assess the articulation of words by a child and his/her behavior.

The articulation of words by the profound hearing impaired children after experimentation is usually comprehensible for an inexperienced or a common listener. Results of the Wilcoxon signed ranked test have shown significant improvement in word articulation by the profound hearing impaired children. The resulted effect size from Wilcoxon signed ranked test has shown a large effect size (0.80) on children’s word articulation through the use of Losina application. The improvement in natural voice quality, fluency and clear audibility of the tested words using LOSINA within short time span and with no formal intervention, can therefore be attributed to a contribution of the present research. Articulation of phrases, sentences, emphasis and emotions in conversation shall be considered as future work of the present research.
1

Introduction

1.1 Background

A number of daily life problems are faced by profound hearing impaired children due to their communication inability. Adverse event is a common problem faced by patients with stone deafness (Kovshoff et al., 2016; Bartlett et al., 2008; Baker et al., 2004). An adverse event is a mistreatment of a patient caused by misleading communication by the patient or the misunderstanding by a health practitioner. Studies have reported that 3 to 17 percent of them fall in adverse events. Adverse events are also visible in older patients. Adverse events are considered to be preventable using modifiable patient characteristics e.g. a deaf patient speaks the basic words such as pain or fever etc.

It is well known that language barriers and communication disabilities have a strong correlation with poor quality of care. Patients with sensory disability have been reported to face severe problems while communicating with health practitioners because practitioners cannot understand and express in sign language (SL). Moreover sign language is not uniform because it mostly includes informal or natural signs that vary from region to region. This makes it difficult to be understandable globally (Dalton et al., 2003).

Furthermore, communication disability also leads to depression and chronic diseases as reported in the existing studies (Zazove et al., 2006; Djernes, 2006). However, modifying a patients characteristics may help overcome the communication barrier and subsequently...
prevent possible adverse events.

The goal of the present work is to mitigate the communication barriers by improving spoken language of a deaf child using technology (other than the wearable-auditory equipment). Traditionally, speech therapists use lip-reading method to teach basic language to a deaf person.

Lip-reading is the ability to visually perceive the speech of a speaker without using any auditory equipment. Lip-reading from a speaker’s face is the traditional method of teaching spoken language to the students with listening impairment. It has been reported that watching a speaker’s lip movement can increase speech awareness. But on the other side, the dedication required from a speaker (speech therapist) makes this job a cumbersome one. Pronouncing the same word repeatedly will make the teaching difficult, if not impossible. Subsequently, student loses engagement and interest in the learning process. Another factor is the financial overhead associated with the traditional lip-reading method. Transportation of a deaf person or the speech therapist for lip-reading sessions requires both human and financial support. Moreover, appointments of a speech therapist add up an additional amount. Residential location of the deaf person also becomes a hurdle, as special training schools are mostly located in urban areas.

Learning from the facial expressions starts from infancy; later on this learning can help the development of the language.

Analysis of the literature reveals that mobile technology has the potential to increase learning outcome (Caudill, 2007; Sharples, 2013; Valk et al., 2010). However, less is known about effectiveness of oriented self-paced lip-reading for language improvement by deaf children. The present work justifies this claim by conducting a systematic literature review (SLR) of the domain. The results of the SLR show that huge literature sources, such as PubMed, ScieceDirect, IEEE, Springer and others have very few articles related to language learning through lip-reading technique using technology. The present work seeks to fill in the gap by implementing an interactive teaching application and reports empirical results of technology benefits over the tradition method.
The present work considers the learning ability of a child with hearing impairment to learn articulating vowels using software application (App) technology.

The present work considers language learning (more specifically, vowels) through mobile technology (Revelle et al., 2007; Sharples, 2013) as a remedy to the identified problem and the limitations of the traditional lip-reading methods. Instead of watching the speech therapist face, a child access specially designed lip-reading electronic contents on the mobile and computer screen. Interactive contents that demonstrate lip movement for speaking words are stored in the mobile devices for teaching and learning. A child may use these interactive learning contents repeatedly. This work aims at investigating an interesting question whether the App will improve the language learning of a child through technology based lip-reading method. A mobile application has been designed to measure the learning gain achieved by the stone deaf children of age 5-8 at a special education school. The learning gain in the present work refers to the improvement in speaking words containing vowels by the deaf children after using proposed application as compared to the traditional methods of physical teaching. Moreover, the comparison between technology oriented method and the traditional method will provide evidence about effectiveness of technology usage for self-paced language learning by the children with sensory disabilities. A quantitative technique, the post-experimental method, has been used to measure effectiveness of the technology in terms of spoken language. The provided empirical results of interactive mobile technology are deemed to be the novelty of the present work.

1.2 Problem Statement

The applied nature of the present research inhibits several problems. The problems that have been identified and addressed in this research are:

1. The problem of conventional teaching method and lack of individualized learning.

2. The problem with the traditional teaching method for hearing impaired children
Chapter 1 Introduction

a. Non-Uniform Curriculum

b. Cultural Influence

3. Costly, time consuming and resource intensive teaching methodology.

People from all aspects of life with sensory disability, as in case of the present work, are facing issues due to lack of communication. Especially in medical care, the deaf patients have been reported to go through drastic troubles while communicating with health physicians, as they cannot address their specific complaint in sign language (SL). Besides sign language is not an internationally uniform communication system because it mainly includes informal or natural signs that deviate from region to region. This makes it almost impossible to apply and understand globally (Dalton et al., 2003). There is no language, in this universe, which is exactly the same; consequently sign language is not standardized too. Every country has its own sign language (SL) (Djernes, 2006). More formally, the non-uniformity of the sign language is due to use of nature and grammar sign language. Formal communication, such as language determined by government is the grammar language. Whereas, habits and culture of a region provide natural sign language (Middleton, Emery, & Turner, 2010; Ladd, 2003). However British Sign Language (BSL) and American Sign Language (ASL) are there to be used but still in many countries they are not used. In Pakistan, Pakistan Sign Language (PSL) has been used and in other countries where English is not understood, they use their own native sign languages. In addition, sign language lacks the order of pronounced words which makes it much more difficult to be understood by deaf people from different institutes. Mastering sign language requires huge amount of time due to it difficult nature of reproducibility of signs by different individuals. Vocabulary of sign language is kept small to make it unified but it limits the expression and emotional power of the speaker specially when a deaf person is a patient. The polyseme nature of the sign language makes it difficult to understand without context or a given background scenario. Similar sign actions produce several meanings in different contexts.

Conventional teaching methods mainly follow the instructional pedagogical model (Lowyck et al., 2012). Learning contents are pre-authored for teaching and evaluation of concept being taught in instructional model. For PHIC, teachers skills, her knowledge and
learning material guide the learning of a student. Teacher in an instructional model acts as the only source of knowledge and assessment (Sammons et al., 2004). This instructional pedagogy limits the creative learning of a PHIC. Moreover, instructor-centered strategies makes learning difficult (Krathwohl, 2002). These strategies focus only on delivery of facts. Delivering and authoring of such learning contents not only require large amount of time but also need specialized skills, thinking and dedication from teachers and students.

Limitations of the instructional pedagogy force the teachers to use the same contents for all student, i.e., overruling interest of an individual. Authors have reported that interest and excitement of an individual accomplishes a great deal of learning without the use of formal teaching and learning methods (Perry & Dockett, 2002). On the other hand, the traditional learning hinders this learning gain due to lack of interest and excitement of the individuals. For example, some PHIC might be interested in seeing cartoon objects rather than formal representation of world entities. There is a clear and strongly visible need of an interactive learning environment where student have access to individualized learning with teaching support (Lowyck et al., 2012; Nussbaum et al., 2001; Smeets, 2005). Information and communication technologies (ICT) can contribute in creating such learning environments through the use of software technology (Goh & Quek, 2007; Nussbaum et al., 2001; Sabou et al., 2005; Smeets, 2005).

1.3 Research Questions

The word articulation of PHIC using software technology following the lip-reading method require transformation of the traditional techniques to interactive computing environment. Hence, an interactive learning software application that implements creative learning pedagogy for enabling word articulation of the profound hearing impaired children using lip-reading method is proposed in the present work. In this thesis, an attempt to provide the answers to the following questions has been made:

1. What are the methods for enabling communication of profound hearing impaired children?
2. What are technology oriented solutions for PHIC?

3. Does software technology provide cost effective solution for PHIC?

4. What are the issues that need to be addressed for designing and developing software technology solution to solve PHICs communication problem.

1.4 Objectives

To answer the research questions stated in the section 1.3, a number of objectives need to be achieved as part of this research work. They are presented below:

1. To mitigate the communication barriers of profound hearing-impaired children by enabling their word articulation ability using proposed software application (Losina).

2. To design and develop a software application (Losina) for word articulation using Lip-Reading technique.

3. To evaluate the effectiveness and usability of the proposed application.

1.5 Research Scope

The present work follows lip-reading method for word articulation through a specially designed software application. It also aims at providing a cost effective, convenient, interactive and adoptable method for teaching word articulation to profound hearing impaired children. The scope of the study is outlined as follow:

- At present, the scope of the study is limited to early age children (age between 5 to 8 years) having only signal disability, i.e., profound hearing impairment. Children with multiple disabilities, such as mental or muscular disorder with hearing loss are not included.
• The present work limits the scope of the English words to vowels (words with vowels at starting, middle and ending positions only).

• The present work reports the limitations of the sign language learning but does not provide comparative analysis of the proposed lip-reading technology oriented learning and traditional sign language learning. The reason, huge amount of contribution have been made to sign language learning using technology.

• The evaluation of the proposed application is mainly performed for usability testing of the application including graphical use interface, electronic contents and effectiveness in terms of learning gain by the PHIC.

![Figure 1.1: Research Activities](image-url)
1.6 Significance of the Research

The present research addresses the challenging problem of initiating word articulation ability of profound hearing impaired children using software technology. The findings of the present work contribute to both word articulation ability of PHIC and software technology for people with special needs. The present work provides a relationship between software design and development research and research on word articulation by deaf children. Word articulation by PHIC is extremely important for their well-being in today's information society. Other than the PHIC, special education teachers, speech therapist and parents of the children with disabilities can get benefits from the proposed research. On the other side, researchers from software engineering, computer and social science can extend their knowledge in these domains of research. The present work can be extended to language learning or local language learning.

1.7 Research Overview

Following research activities shown in Figure 1.1 are carried out to accomplish the above mentioned objectives:

- Phase 1: A systematic review of literature (SLR) was performed to identify problems faced by deaf people due to their communication inability. The systematic literature review comprised different technologies for deaf people, profound deaf children, pedagogical aspects for person with disabilities. The SLR is combined with review of current teaching and learning practices followed by local special education schools and institutes for word articulation.

- Phase 2: The phase 1 leads to the formulation of the proposal of developing the ability of word articulation by a stone or profound deaf child following a lip-reading method using software technology. A preliminary feasibility study of the proposal was carried out by developing and experimenting a small scale working prototype. The feasibility
study provides a directional guide for the design and development of the proposed application.

- Phase 3: Deaf children have special needs related to software usage. Careful and formal usability factors are designed to support deaf children needs. Along with proposal, the present work provides usability guidelines for software design for deaf children. Development of the application in-cooperating lip-reading and carefully design curriculum for articulation of words containing vowels is performed.

- Phase 4: In the last phase, quantitative evaluation of the proposal was performed through implemented prototype against effectiveness and usability testing parameters.

1.8 Structure of the Thesis

The present thesis spans over five chapters. Chapter 1 starts with an introduction of the research carried out in the present thesis. Background of the research domain provide brief introduction to the problem addressed by the present thesis. Problem statement, research questions and objectives are provided. The boundaries of the research are specified by research scope. Significance of study provided in chapter 1 shows the importance of this research.

A systematic literature review (SLR) is provided in Chapter 2. Different subsections that are relevant to the research domain in chapter 2 contain relevant review of existing research. These relevant domains include deaf people’s communication problems, communication methods, more specifically signed language, lip-reading and hearing aid, technology use by the deaf audience, augmented reality, voice recognition system and mobile technology. Chapter 2 concludes with the identification of research gap.

Overall methodology followed by the present thesis is provided in the chapter 3. The present research is divided into different phases. First phase analysis provides the feasibility study of the proposal, analysis of curriculum and practices. Analysis phase is followed by design phase that include curriculum design details, learning contents, contents sequencing,
usability design. Details about lip-reading implementation in the proposed application are provided in Chapter 3. The methodology includes quantitative analysis of the proposal that include experimental setup and evaluation parameters.

Chapter 4 reports the results of the evaluation. These results provide the validation of the present proposal. Evaluation was carried out against effectiveness (learning gain that is word articulation and behavioral improvement) and usability testing of the proposed application. Chapter 4 provide discussion over achieved results to annotate perspective of the researchers.

Finally, Chapter 5 concludes the research by highlighting findings achieved by the current research. Contributions made by the present work are provided along with future direction for other researchers working in this domain.
Traditionally, deaf children express and acquire knowledge using sign language, lip-reading and writing. Problems with the sign language, such as, non-unified standard, un-sequence words, time delay in understanding the sign language, ambiguity in sign gesture and excessive use of local signs were exhaustively reported by the researchers. In addition, teaching and learning the sign language is still a challenging task. Lip-reading has few benefits over sign language but it also holds several issues, such as group learning not possible and the student attention and dedication is required.

The problem faced by the deaf people while communicating with health practitioners were reported by United Kingdom Royal National Institute for Deaf People (RNID). The report shared views of eight hundred and sixty six deaf patients visiting health services distributed across UK (Middleton, Niruban, et al., 2010). A slightly below average (42%) respondents have reported difficulty in communicating with health staff. Moreover, above average (66%) of respondents who know British sign language (BSL) faced similar difficulties. A third of the respondents were prescribed wrong medicine due to communication failure between patient and the health practitioner. The present work focuses on these problems as foundation to the proposal of using software technology for mitigating the communication barrier between deaf individuals and normal persons. Researchers, practitioners and law enforcing agencies have realized this problem and has formulated a Disability Discrimination Act for hospitals to provide adjustments for enabling patients with disabilities to access services easily and accurately. Even now, patients face problems because accessing
services require facilitation for good communication rather than adjustments and resource facilitation. Traditionally, lip-speaker (a person) is used as interpreter between deaf person and the health practitioner. This is an expensive method for overcoming the communication problem. Moreover, sign language does not provide translation of the two communicators which lead to further ambiguities. In addition to communication, behavioral features are also required during patient and health staff interaction, such as eye-contact with the physician, wearing transparent mask and hand gestures.

Use of technology is a viable thing to overcome the issues with sign and lip-reading methods. A substantial amount of research work on the use of technology for sign language learning is available. However, no previous study has investigated the effectiveness of technology for language learning using lip-reading method. It is quite apparent by searching through digital libraries that a very limited research has been conducted for deaf people using technology. Searching such queries mostly results in a large number of irrelevant documents. The few contributions found are all about sign language using technology. Until recently, there is no reliable quantitative evidence is available for lip-reading using technology.

2.1 Systematic Literature Review (SLR)

A systematic literature review (SLR) has been conducted to identify the research gap. An SLR is a method to unbiasedly review a specific research area by identifying, analyzing and exploring the evidences related to a given research question. SLR is an iterative process, repeating the same strategy on different knowledge resources (digital libraries). Through SLR, the existing literature on a particular research domain is investigated, categorized and evaluated against provided inclusion and exclusion criteria.
Chapter 2  

2.1.1 Planning the Review

2.1.1.1 Research Questions for SLR

The SLR conducted in the present work addresses the following research questions:

1. What are the technologies used for language learning using lip-reading method by the deaf children?

2. Does use of technology for language learning using lip-reading method by the deaf children are empirically reported or just proposed?

![Figure 2.1: SLR Keyword/Key phrases Taxonomy](image)

2.1.1.2 Data Sources

Based on these research questions, a taxonomy of the keywords (shown in Figure 2.1) was formulated to perform queries over different digital libraries. Well known and huge sized digital libraries were selected for conductance of the SLR. The digital libraries included are:

- PubMed
Different digital libraries have different search mechanisms and filters, search queries were tailored accordingly. Search queries were formulated from combination of keywords (Figure 2.1) derived from research topic, research questions and problem domain. Only “AND” and “OR” Boolean operators were used for the concatenation of keywords in a search query. The search queries were as follow: “language development” OR (“language” AND “development”) OR “language development” OR (“language” AND “learning”) OR “language learning”, “persons with hearing impairments” OR (“persons” AND “hearing” AND “impairments”) OR “persons with hearing impairments” OR “deaf”, (“calculi” OR “calculi” OR “stone”) AND (“persons with hearing impairments” OR (“persons” AND “hearing” AND “impairments”) OR “persons with hearing impairments” OR “deaf”), “hearing loss” OR (“hearing” AND “loss”) OR “hearing loss” OR (“hearing” AND “impaired”) OR “hearing impaired”, “lipreading” OR “lip-reading”, “sign language” OR (“sign” AND “language”) OR “sign language”, (“speech” OR “speech”) AND therapist, “technology” OR “technology”, (“software” OR “software”) AND (“technology” OR “technology”, “hearing aids” OR (“hearing” AND “aids”) OR “hearing aids” OR (“hearing” AND “aid”) OR “hearing aid”. 

2.1.1.3 Query String
**Description**

**Hearing Impaired**: More often the health professionals use the term hearing impaired, rather than individuals. The World health organization (WHO) has defined impairment in its classification of functioning as “problems in body function or structure such as a significant deviation or loss”. In WHO's classification the impairment is labeled as “Disability and Health”. Community has debate on use of the term hearing impaired for deaf and hard of hearing people.

**Deaf**: A person who is profoundly deaf but able to use spoken language is referred to the term deaf. These individuals can get benefits form hearing aid, cochlear implant and lip-reading methods. Their deafness is either congenital or they lost their hearing during young or adult age.

**Deaf**: The individuals referred to Deaf (with capital letter “D”) are those who consider themselves as culturally deaf i.e. they consider their deafness as a difference from being normal rather than a disability. These people tend to use sign language as their first language. Most of their population have profound deafness due to congenital. Traditionally sign language is preferred for their communication, however, they can get benefit from lip-reading. Writing is not reported widely for this class of individuals.

**Hard of Hearing**: Hard of hearing refers to a person who have deafness of some level ranging between mild to severe. Older age individuals mainly fall in this category. Hearing aid is their preferred choice, however, lip-reading, writing and reading are other communication alternatives.

**Deafened**: A person with spoken language and has become deaf is referred to the term deafened. These individuals are mostly profound deaf (occurred accidentally or suddenly). They are unable to get benefit form hearing aid and cochlear implant. The only method for them to communicate is using lip-reading or writing (Traynor & Lucas, 2004).

| Table 2.1: Description of the Deaf for Article Selection |
2.1.1.4 Inclusion and Exclusion Criteria

The initial investigation of articles for quality assessment was performed during articles extraction. The assessment was done based on content relevance of the title and abstract of a retrieved article with the keyword taxonomy. The inclusion criteria for an article is defined as, the title of the article must contain words from the keyword taxonomy. Similarly, the abstract of the article must have addressed the sense “technology oriented lip-reading for language learning by Deaf children”. Abstract have either proposed a new technology or have reported the effectiveness of the technology. Multi-language articles with their English translation available are also included. Article with sign language technology, implantable hearing aid technology, hard of hearing, lip-reading by machines, artificial intelligence and TTY technology were excluded from the selection. Down syndrome, dyslexia etc. are some other disabilities that effect communication (Hamid et al., 2015) but are not included in the scope of present research. Moreover, further filtration on selected articles from journals, conferences, workshops and books was performed to screen out articles reporting an empirical evidence of their proposal.

Figure 2.2: SLR Approach for Article Selection
2.1.1.5 Quality Assessment

The title, abstract, study type, deaf classification (Table 2.1) and technology used are initial parameters that were examined and extracted to satisfy the research questions. Inter rated reliability analysis was used to overcome the inter-person biasness. Four randomly selected independent reviewers were selected to perform the SLR. A Cohens kappa was measured to verify agreement among all reviewers for their article selection. A reliable kappa value of 0.7 was measured for reviewers agreements.

Figure 2.2 shows the total of 19571 articles were retrieved from different digital libraries against given keywords taxonomy. After examining the title, only 32 articles were selected. Similarly, among 32 selected articles only 15 articles have some relevance to our research questions. The present work, provides a critical review of the final fifteen articles. Furthermore, only 6 articles have reported some empirical results. This small number of articles (15) from the huge literature sources shows an indication of research gap that very less has been contributed on technology oriented language learning by deaf children.

2.1.2 Conducting the Review

An attempt to enable communication ability of deaf children was made by using subtitles of the broadcast programs (Zárate, 2014). This work (Zárate, 2014) mainly focused on reading skills of the deaf children. A mixed method quantitative and qualitative approach was used. Empirical results from an experiment including a group of deaf children were reported to show the exploring and enhancing word recognition capability of participants. Children feedback was taken orally and reported qualitatively.

Speech recognition technology (xiao fen & jia cheng, 2010) has claimed to give benefits to the deaf community but converting voice to text using speech recognizers will only give one way communication. A deaf person can see or partially read the text but he himself cannot express. Even for reading, a deaf person must know the basic pronunciations of the alphabetic characters. The present work targets the pronunciation of vowels containing
words that will lead a deaf child to reading ability. ViaScribe (xiaofen & jia cheng, 2010) prototype application produces subtitles for content displayed during teaching. Subtitles were generated from converting teachers’ voice to text. The work (xiaofen & jia cheng, 2010) has only proposed a proposal without reporting any empirical study or experiment. A voice recognizing software application was experimented in deaf classroom for its effectiveness (xiaofen & jia cheng, 2010).

Teaching and learning by people having disability using sensory and assistive technology was proposed by the researchers (Armin et al., 2013). Kinect devices such as Microsoft Xbox and Asus Xtion are used to detect sign language movements of a deaf person. Kinect devices are efficient in detecting body movement but not feasible for lip and tongue movements. However, these motion capturing systems support sign language learning and practicing. Similar to speech recognition technology, a proposal using multi-model speech capture system (MSCS) was proposed to record and display movements of key speech articulators, i.e., lips and tongue (Sebkhi et al., 2017). Sensors are attached to the lips and tongue of the deaf person. A capturing system records the movement of the deaf speaker; this clearly visualizes the affected areas of a deaf person to a speech language pathologist (SLP). SLPs give training to a deaf person to correctly articulate word. This technology (MSCS) is useful for diagnostics of motor disabilities of a deaf person but for language learning this technique is highly expensive and difficult to adopt in real scenario. The results were reported about effectiveness of pattern matching by the proposed application for providing predefined feedback to the user. Artificial intelligence techniques such as neural networks are designed to recognize patterns. A neural network based technique for recognizing patterns from sign language movement of a person is presented in the work (Rathee, 2016). The proposed approach (Rathee, 2016) recognizes the word articulation using learning vector quantization neural network (LVQ-NN) technique. The authors have claimed a high accuracy against only ten words. All these technologies support voice recognition but do not support word articulation ability of a deaf child. Similarly, voice recognition of deaf participants using Hidden Markov Model (HMM) was reported by Zhang et. al. (Zhang et al., 2014).

Augmented reality is claiming its benefits for people with disability (Jones et al., 2014).
An augmented reality head mounted display for deaf and hard of hearing people as a reading assistance was proposed (Jones et al., 2014; Mirzaei et al., 2014). Lip reading recognition using image processing for Arabic language learning was proposed by Ghanim et. al. (Al-Ghanim et al., 2013). Videos are transformed to image frames for recognition. These different technological approaches support reading ability.

A mobile application named SMART-Sign was developed for parents of deaf children to help them learning American Sign Language (ASL) vocabulary (Xu, 2013). SMART-Sign uses vocabulary from children popular stories. Parents learn these ASL words using SMART-Sign. Later, they read the stories to their children using SMART-Sign showing story book and ASL performed by the parents. SMART-Sign has been tested for the hypothesis that parent and deaf child who use application more often have gained more benefit from the SMART-Sign application. Descriptive results of a four week experiment have been reported (Xu, 2013). SMART-Sign is an application for normal users, moreover it addresses the sign language learning rather than lip-reading.

Several researchers tried to overcome the communication gap of deaf people by providing translations into sign language (Boulares & Jemni, 2013). These works relates to subtitle generation through converting voice to text. However, the translation provides an interoperability among languages by translation or translating a picture taken by a mobile camera to object identification. All these methods are one way communication where deaf user can only get information rather he cannot express or articulate language himself. WebSign (Boulares & Jemni, 2013) was a proposed application that translates text acquired from World Wide Web via Internet and translate tokenized words into sign language gestures. An overall architecture of the WebSign application was proposed without reporting results of its usage by deaf users.

A user centered design approach was used to design mobile application for deaf youth to facilitate them in English learning (Anindhita & Lestari, 2016). The application named high fidelity prototype (HFP) was designed using conceptual models from gamification, learning levels and repetition. The application uses sign language videos for representing an English word. The experiment include deaf adults who already know sign language.
The HFP (Anindhita & Lestari, 2016) is an initial work in usability evaluation of mobile application for deaf students. A survey of the few applications for deaf users was conducted to report usability aspects. Recommendations are provided for usability features through quantitative analysis using usability experts.

Suitability of technology for deaf students specially educational software was reported by Khwaldeh & Shah (Khwaldeh & Shah, 2010). Open source learning management systems were evaluated for suitability of use by deaf users. This work has provided indication about communication and collaboration features required by deaf users in a learning management system. It provides a guideline for software developers to in cooperate few functional features to make the software more usable by a deaf user. E-learning systems provide a self-paced learning environment to its users. For the case of deaf students, e-learning support their need for individualized learning. However, e-learning systems are only provides access to learning contents but do not provide teaching support that a deaf student require. Deaf students having reading ability can be the potential users of the e-learning systems (Nasr, 2010). An enhanced e-learning system that in cooperate social networking features such as chatting, translation, sharing and posting was proposed by Mona (2010) to provide teaching support needed by a deaf student.

The importance of the emotions for attracting attentions of individuals with Dyslexia (a cognitive disability) was reported by Hamid et. al. (Hamid et al., 2015). Dyslexia and Down syndrome are some disabilities that effect communication however they have the hearing ability. The present work focuses on profound hearing impaired children, however cognitive disability is not the focus of the present work. An overall architecture of software application using machine learning was proposed without reporting empirical evidence (Hamid et al., 2015).

Selection of appropriate coursework and sequence of conductance in any learning environment is important for effective learning. Same has been reported for learning coursework design for deaf students (Chaisanit et al., 2010). A quantitative analysis of proposed coursework for deaf students attending 9th grade was reported to show effectiveness of the designed coursework. The designed coursework (Chaisanit et al., 2010) uses animations
and graphical representations of objects, same has been followed by the present research. The coursework was designed for general learning whereas there was no focus on word articulation ability of a deaf child.

### 2.1.3 Reporting the Review — Research Gap

The systematic literature review (SLR) performed in the following chapter has identified these research gaps. Systematic literature review (SLR) has provided the following resultant research papers (Shown in Table 2.2) that suits the selection criteria and quality assessment. The following research gaps formulates the research problem (Section 1.2). Addressing these research gaps will lead to completion of the present work, i.e., software technology for word articulation ability of profound hearing impaired children.

- Existing software technology for deaf people is mainly hearing aid and cochlear

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<th>Digital libraries</th>
<th>Empirical Study</th>
<th>Total Articles</th>
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<td>IEEE Xplore</td>
<td>(Chaisanit et al., 2010 (Chaisanit et al., 2010); Fen &amp; Cheng, 2010 (xiao fen &amp; jia cheng, 2010); Hamid et al., 2015 (Hamid et al., 2015); Jun &amp; Cheng, 2010 (Jun &amp; Cheng, 2010); Sebkhi et al., 2017 (Sebkhi et al., 2017))</td>
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<tr>
<td>Science Direct</td>
<td>(John, Rigo, &amp; Barbosa, 2016 (John et al., 2016); Yue &amp; Zin, 2013 (Yue &amp; Zin, 2013))</td>
<td>2</td>
</tr>
<tr>
<td>Google Scholar</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ACM Digital Library</td>
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</tr>
<tr>
<td>PubMed</td>
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</tr>
<tr>
<td>Wiley InterScience</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table 2.2:** Result of SLR Containing Empirical Study
implant that are costly solution to hearing ability. Several researches have proposed use of technology (speech recognition, e-learning, augmented reality, automated subtitling of multimedia contents etc.) for deaf people but mainly addressed reading and writing abilities. SLR shows that there is a huge gap available in research about lip-reading method for word articulation ability of a PHIC. Software technology has mainly and heavily contributed toward sign language learning.

- Designing a software application for people with special needs or more precisely people with disability has been shortly addressed in literature. Usability research has contributed toward software design for people with cognitive disabilities such as blind, down syndrome and dyslexia. But, requirements of deaf children were seldom reported in exiting work.

- Only 6 studies (shown in Table 2.2) have reported empirical results of technology usage. The sample size of these studies are shown in Table 2.3. However, rest of all have only proposed a solution for deaf people. Empirical results justifies the benefits of a proposed solution however, it is missing in the exiting literature.
## Table 2.3: Result of SLR Containing Empirical Study

<table>
<thead>
<tr>
<th>S.No</th>
<th>Article</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Audio-Visual Speech Recognition Techniques in Augmented Reality Environments</td>
<td>3 (3 adult, 8 words)</td>
</tr>
<tr>
<td>6</td>
<td>LIPPS A Virtual Teacher for SpeechReading Based on a Dialog-Controlled Talking-Head</td>
<td>15 words</td>
</tr>
</tbody>
</table>
This chapter starts with a discussion on the research methodology which encompasses the overall view of the research phases for the word articulation of profound hearing impaired children using interactive software technology following lip-reading method. The overall methodology is divided into four phases i.e. analysis, design, development and evaluation. Explanation and details of the first three phases are provided in the present chapter, while evaluation is extended in the next subsequent chapter (Chapter 4). A concluding summary is provided at the end of this chapter.

**Figure 3.1:** Overall View of the Research
3.1 Overall View of the Research

The following section outlines the research phases of the methodology and provides explanation and details on their interplay. Figure 3.1 presents the overall view of the research that shows the subsidiary methods in each phase that were carried out to accomplish the research objectives. Following subsections 3.3, 3.4, 3.5 and 3.6 highlight the individual phases of the research methodology.

3.2 Phase 1: Analysis

In this phase, problem statement was formulated from systematic literature review, analysis of the curriculum taught at special education institutes and practices followed by teachers and speech therapists through observation and interviews. Later a proposal following the lip-reading method using interactive software technology was proposed as a solution to the identified problems. Subsections of the present chapter will explain the construction of the proposed interactive software technology for word articulation of PHIC. An early feasibility study presented in the following subsections was conducted to verify the proposal.

3.2.1 Review of Curriculum and Current Teaching Practices

The analysis of curriculum and practices followed by the teachers at special education institutions was a small study to support the problems identified from the systematic literature review. Systematic literature review of the existing literature was provided in chapter 2. The analysis of the curriculum and teaching practices does not provide the precise measure of the deficiencies but only identify them along with their causes. The scope of the study is not large; rather it focuses on case studies as a means of understanding more about gap between formal and implemented pedagogical strategies and weakness of the learning material used for cognitive skills tutoring. Children of age five to eight years are referred in this study.
It was found that all surveyed institutions are following the traditional sign language instructional pedagogical approach for teaching sign language giving very negligible attention to lip-reading word articulation. Moreover this traditional method of teaching lacks engagement and personalization abilities. However teacher can make students engage with learning activities but it was observed that skilled teachers are rarely available in preschool setup and also engagement is not possible in a large group of students. Similarly instructional pedagogy does not possess the ability to provide the individual assistance.

Analysis phase reviews the current practices followed by teachers to teach hearing impaired children. The widely used method is the sign language (SL). It has been analyzed that different categories of deaf children (as identified in Chapter 2), require different needs for learning. The present work only focus the worst effected category of profound hearing impaired children. Other categories of the deaf children may use hearing aid for some support, but for PHIC it is not useful. There are speech therapists who; manually try to help partially HICs who wear aids and whose audiometry is to the extent that can be helped to improved their speech manual through Lip-Reading which involves a lot of human effort. Main issue is the financial management by the family of HICs. That is like paying per session fee of speech therapists, and that includes of the transportation too. There is another category hearing loss children Profound Hearing Impaired (PHIC) that is who cannot be helped through hearing aids they can only use cochlear implantation. Cochlear implantation is so expensive that is not affordable.

3.3 Phase 2: Design

This section presents the design details of the proposed interactive software application (Losina). The design contributions of the present work comprise content design, curriculum sequencing and usability design. Content design addresses the design issues and perspectives of the learning content, i.e., what specific learning contents are required for initiation of word articulation. Curriculum sequence consider the order of learning contents being taught that adopt the child need and support motivation and interest. Usability design concerns about considerations followed for graphical interface design. All three major aspects of
design are addressed to support special needs of the PHIC.

### 3.3.1 Content Design

A software application was developed for teaching English words. The words selected for training contain vowels at different positions, i.e., vowel at the start, at the middle and at the end of the word. The training set (Appendix C was designed by experts of the domain (the speech therapist). The application demonstrates lips and mouth movements to show pronunciations of the words. The lip-reading training set includes 75 common vocabulary words, mainly nouns and color names. Each vowel has 15 words. The length of the words ranges from 3 to 7 characters (average 4.2). A student starts from single tongue placement and lip movement and gradually progress to multiple movements for a word pronunciation.

### 3.3.2 Curriculum Sequencing

Curriculum sequencing is a part of pedagogical model, which is responsible to present leaning contents in a sequence that adapt the students needs and understanding. Adaptive learning systems (Brusilovsky & Peylo, 2003) use curriculum sequencing techniques as their intelligent part. Previously researchers (Stankov et al., 2008) used personalization techniques (student modeling) for tutoring of weak or unknown topics. Nowadays, curriculum sequencing is considered as more effective than individualized learning in several aspects, such as emotional learning (Mao & Li, 2010; Lehmann et al., 2012), learning style (Popescu 2010) and personality (Leontidis et al., 2011). Currently the experimented school is not following any specific curriculum however, the present work has formulated a words list from an expert speech therapist. She has arranged the sequence of words in an order of easiness to difficult one. Similarly considering the single and multiple tongue movements. Vowels position is the most important feature for a word selection. For the present work, all three placement of vowels are considered i.e. vowel come at initial, middle and last position in a word.
3.3.3 Usability Design

There is an important role of information and communication technologies (ICT) in bringing together people and technology, more specifically people with special needs and specially designed technology. Society is changing with the advent of ICT usage in everyday life in the form of mobile and smartphone technologies. The nature of software design for people with disabilities is challenging because it depends on the nature of disability. Usability experts or the user interface designer need to put special consideration on the abilities a software tool can enable to its users rather than focusing their disabilities. This makes the software design for people with disabilities more difficult for designers as compared to normal use software.

Authors have reported the benefits of having communication access to different target groups for their economic, cultural and social development. However, there is very few contributions made toward benefiting from ICT by the hearing impaired people. More or less, the people with disability are seems to be excluded from the information society (Boulares & Jemni, 2013). Recently, researchers are collaborating on this topic through international conferences such as “Conference on Computers Helping People with Special Needs”. However, the research groups, industry and academia is far less contributing to disabilities, more precisely mental disabilities as compared to other domains.

3.3.4 Accessibility Guidelines

The design considerations for products, software, devices, services or environment for people with disabilities is known as accessibility guidelines. The accessibility guidelines for software and mobile applications were initiated by the Web Accessibility Initiative (WAI) under World Wide Consortium (W3C). WAI has published Web Content Accessibility Guidelines (WCAG 2.0) for designing the software and mobile content using web technologies. WCAG addresses software and mobile content, mobile applications, native applications and hybrid application using web and software together. These guidelines provided footings for the present work in term of software design specially for hearing
impaired children. It is worth mentioning here, software design for different age group among disable people require different considerations to be addressed. On the other hand, involving disable person during design process in not possible in many cases. It is apparent that there is no clear and valid method for developing software application for people with hearing impairment. The present work has addressed this challenging task to some extent as described in subsequent sections. The present work satisfies specific requirements and recommendations for designing software for children with hearing impairment.

3.3.4.1 Graphics, multimedia and Navigation Design

**Consistency and Simplicity**: The implemented navigation between learning contents and screens in Losina application is developed through menus and buttons. The navigation is consistent and simple to understand. A same sized buttons with iconic representations are used for consistency. Menus are kept at a single location for all learning contents and screens within Losina.

**Symbolic Representation**: Losina application was designed using symbolic representation for all of its controls. Buttons with iconic representation, entities are represented with graphics and images. Directional symbols are used for navigational controls.

**Notifications**: Appropriate notifications, warning and feedback messages are shown within Losina application for clear understanding of ongoing or forthcoming situations. Notifications size can be adjusted according to a user choice. Notifications also have symbolic representation for a common meaning. The same category notifications are given the same color to make a user recognizes them easily. Notification display remains on the screen until the user himself respond to them.

**Sound Notification**: A common software do have requirement for sound notifications, but Losina is designed for profound hearing impaired children. Losina handles this requirement by animated notifications. A congratulation sound for example in Losina is shown with an animated smiley icon raising its hands and smiling aloud. A wrong answer is represented by animated vibrating notification window with a smiley shaking head side to side.
Minimized Input: Losina application is designed in such a way that it minimized the input from a user. This is a specific requirement for software used by people with disabilities. Losina application provides selections among choices at every step to minimize user input. Video navigation has clear controls for positioning the video content at the beginning of the video from any point during play. A User can configure a number of repetitions for all videos to playback, this minimizes the input. After a number of repetitions, a user may configure the software to go to further training of in test mode.

Simple Gestures: Losina application has given consideration to positive and negative gestures. A positive gesture motivates a user to continue further, whereas negative gesture identifies a user about something wrong has been done. Star rating are adopted to motivate PHIC for keeping their interest in learning. Later in evaluation, these gestures were evaluated for a reason to behavioral change in PHIC.

Labeled User Input: Since user input is kept at minimum possible but still mouse movement and clicking are few inputs required from the user. All possible input locations within Losina application are appropriately labeled with text and accompanied with a common input symbolic representation. A user can easily identify all input places on a given screen of the Losina application.

Status Indicators: Encouraging interest and engagement of a user, Losina application provide progress status, remaining tasks count, number of already attempted tasks and subsequent action details on screen the whole time user interaction. Status is saved along with user profile for personalization aspect.

Clickable Area: Discrimination between clickable and non-clickable area on a given screen is designed within Losina application using color differentiation. Identification of clickable area makes input minimized and less cognitive load on the user. It makes actions of a user while interactions directed and precise.

Adjustable Contrast: Losina application supports different screen contrast level for ease of use by its user. Contrast ranges between high, normal and low settings. Images and
video quality kept at high resolution for clear visibility of lips and jaws movements.

From usability perspective, text labels with iconic representation are mandatory to communicate the meaning and reduce ambiguity.

**Text as Image:** Losina application provide large sized animated text for user engagement. This text having different colors is implemented using text as images. Children software has mostly text represented as an image for colorful display, Losina follows the same.

**Brief Language:** Since objective of the Losina is to initiate the ability of word articulation of PHIC using software technology. The words or language used within Losina application was carefully selected that should remain brief and well explanatory. Words combinations are used to specify tasks and actions. This brief language has provided indication to PHIC to continue further other than training and test words. Words like Start and End are not part of the training and test wordset but still few students picked these words as action representation. Looking at teachers face saying Start, few PHIC knows to start training session. Same for the word “nd”.

**Text alternatives for Non-textual Contents:** During loading screens, Losina provide textual and animation for representing the current action being processed. Similarly, text alternative is provided for non-textural elements such as graphics and videos on few places where required.

**Short and Simple Titles:** Every screen, notification window, pop-up window of Losina has a clearly mentioned title to show user the relevance of the screen being shown. Titles are kept simple and short for better understating and it also adds vocabulary to PHIC visual memory.
3.3.4.2 Text Representation

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3.3.4.3 Personalization Aspects

**Provision of Configuration Details:** Several studies have reported that a user remain engaged with a software application that provides customization (in terms of task or user interface) to its users. The reason, they feel an ownership over the software. Losina provides customization and configuration to its users to support their needs. The present study has
considered only participants with a single disability, i.e., profound hearing impairment, but few participants have low vision are using spectacles. These users need different font sizes, background color, images sizes, video zoom and navigational control sizes. Losina supports discontinuation of an ongoing task at any time. The same task can be resumed at any other time. Losina maintains a user profile for action logging and curriculum sequencing.

**Theme Settings:** Losina provides different themes settings for users to support their interest. Floral, cartoon characters and plain colors are few themes that are implemented in Losina application. Each user can set his/her own avatar or his/her photograph to get a feel of ownership.

**Cascading and Consecutive Functionality:** Losina application provides each actions in an order to synchronize the whole word articulation process. Each activity is followed by a relevant and connected activity which puts very less cognitive load on the PHIC.

![Development Phase of Losina](image)

**Figure 3.2:** Development Phase of Losina
3.4 Phase 3: Development

Development and implementation of components (modules) of Losina application for the validation of the proposal is an objective of the present work. The following section provides the designing and development details, i.e., architecture, software design, development environment and screenshots of the Losina application.

In development phase, the modules of the Losina application was developed. More specifically, Losina was developed to implement interactive lip-reading method through software technology for enabling word articulation ability of the deaf children. Unified modelling language (UML) models, such as use case, sequence diagrams, class diagrams and storyboard for visualizing the prototyping system are the input for development of Losina application. Development phase is shown in Figure 3.3. Moreover, other inputs include development tools, coding and system compilation for development phase. The output of the development phase is a working prototype named Losina.

The software application Losina was developed for large screens display, such as laptops and desktop computers. Large screen is a requirement of the deaf children. The Losina application has replaced the traditional printed card method for teaching sign language and lip-reading to digital learning contents with the use of software technologies. Positive effects of software technologies in educational setups was reported by several studies (Anderson et al., 2004; Bonastre et al., 2006; Hulls, 2005; Mock, 2004; Osmon, 2011). All stakeholders get equal benefit from the software technologies, i.e., students and teachers in learning and teaching activities (Prey et al., 2006; imek & brahim Alper Doru, 2014). Losina is a

Figure 3.3: Top Level Interface Pattern
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Application</th>
<th>Tool/Equipment/Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Programming Languages</td>
<td>Open XML, HTML5, JavaScript.</td>
</tr>
<tr>
<td>2</td>
<td>Development Operating System</td>
<td>Apple iOS</td>
</tr>
<tr>
<td>3</td>
<td>Frameworks and APIs</td>
<td>VLC Video Codec, Xpath</td>
</tr>
<tr>
<td>4</td>
<td>Photos/Graphics Editor</td>
<td>Adobe Photoshop CS5</td>
</tr>
<tr>
<td>5</td>
<td>Version Control System</td>
<td>Git, GitHub</td>
</tr>
<tr>
<td>6</td>
<td>Application Production System</td>
<td>Adobe PhoneGap</td>
</tr>
<tr>
<td>7</td>
<td>Equipment</td>
<td>Apple PC</td>
</tr>
</tbody>
</table>

**Table 3.1: Development Details**

A platform independent application that can be installed on any hardware with any operating system. The Losina application was tested on apple OS, however it can easily ported to other platforms due to its development technology (Open XML). Development details are provided in the Table 3.1.

![Image of Activity Title and Navigational Components]

**Figure 3.4: Workspace Interface Design Pattern**

Consistency between design models, i.e., UML, interface, links and functions are kept carefully during coding process. Finally, all modules compiled to form the final Losina application. User Interface design patterns were used in developing the graphical user interface of the Losina application as shown in Figure 3.3 and 3.4. To solve the common design problems, software designers and usability experts frequently use user interface design patterns. User interface design patterns provide a standard reference point for
software developers, designers, usability experts and stakeholders.

Figure 3.3 shows the top level interface design pattern. All activities carried out within Losina application starts with a home screen and ends with a closing screen. These home and end screens provide an indication to the deaf child about preparing himself for an initiating activity and the successfully finishing an ongoing activity. Home screen is followed by a workspace window, i.e., the main working area of the Losina application. All modules of the Losina application interact together within the workspace area. Figure 3.4 further elaborates the workspace area. Title of an ongoing activity is clearly shown to the user as per requirements from the usability experts. Learning contents with textual representation accompanying the lip-reading video is shown to the user during any word articulation activity. Video playback controls are provided within the video streaming area. Navigational components that support both activities navigation and curriculum sequencing is provided at the footer area of the Losina application. Selection among different activities can be performed as the selection list shown in Figure 3.4 interface design pattern. Appendix B provides screenshots of the Losina application.

**Figure 3.5:** Losina Architecture

Software architecture of the Losina application is shown in the Figure 3.5. Learning activity in Losina application is a recursive activity that starts from the selection of vowels.
A user can select any vowel of his choice. Similarly, Losina can sequence learning activity of a child by providing information about completed tasks and remaining tasks. A user can re-select any vowel to improve his/her word articulation ability for the selected vowel. Placement of vowels at starting of the word, middle of the word and ending of the word creates different difficulties or experience for a user. Selection of vowel placement within a word is an important feature of learning contents designed within Losina. Similar to vowel selection, Losina can sequence the vowel placement activity by utilizing a user profile and selects a best choice for the user. Losina sequence learning activity in a way that it leads user from easier to difficult exercises. The selection of the learning activity is followed by its representation and actions carried out by a user.

The proposed application was installed on the laptop. The researcher to make every participant familiarized with the application and its targeted outcome performed a demonstration of application using lip-reading. Each participant was allowed to use the application individually. Keyboard keys were used to navigate between training words. An eye-tracker device can be used to record eye movement of a student, but at that moment, the experimenter was sitting next to the student to ensure that the student was involved in the experiment.

A list of vowels appears by clicking on any vowel to open its specific vowels window will open. To illustrate it further, list of vowel Aa is been clicked and then it will show the vowel Aa along with its lip movement and tongue placement and exact pronunciation (Figure 3.4). There are three big rectangular tabs buttons of Initial, Middle and Final at the end of the screen written on them. This means by clicking on them will go the category of words starting, in middle or ending with that vowel. Selection of vowel placement will shows list of selected words starting with vowel Aa. For example for selected word “apple”, where vowel Aa at the initial position. Similarly for the selected word “red” where vowel Ee is at the middle position and showing the tongue placement and lip movement to articulate that word. The selected word “chili” is showing where Ii is at the finial position, along with the tongue placement and lip movement to articulate that word. There is a play button on the video to play there is scroll bar to move forward and backward during play motion according to desire and can pause too. From this can move back to list of vowels by clicking Vowel tab, can move on to list of words having this vowel at initial position or move to next word.
3.5 Phase 4: Evaluation

The evaluation phase concerns about evaluation of Losina application to validate the proposal of using software technology for word articulation by the PHIC. The evaluation include effectiveness and usability testing. The learning achievement and behavioural modifications made by the proposed application are evaluated through effectiveness testing. Usability testing provide measures about Losina supportiveness in term of its usage by the PHIC. Figure 3.6 illustrates the procedures of the evaluation and the output.

3.5.1 Effectiveness Testing

Effectiveness of the proposed application is an objective of the present work. Effectiveness of the proposed application (Losina) is measured for learning gain achieved by the PHIC. Learning gain refers to word articulation ability of a PHIC after using Losina for one hundred and twenty five sessions (Cole et al., 2011). Effectiveness evaluation of Losina is different from usability effectiveness evaluation, the later refers to the accuracy and completeness of a given task (Frøkjaer et al., 2000) whereas the effectiveness here refers to word articulation ability and behavioral improvement after using Losina.
3.5.1.1 Sampling

Effectiveness of the proposed application is an objective of the present work. Effectiveness of the proposed application (Losina) is measured for learning gain achieved by the PHIC. Learning gain refers to word articulation ability of a PHIC after using Losina for one hundred and twenty five sessions Cole et al. (2011). Effectiveness evaluation of Losina is different from usability effectiveness evaluation, the later refers to the accuracy and completeness of a given task Frøkjær et al. (2000) whereas the effectiveness here refers to word articulation ability and behavioral improvement after using Losina. An empirical evaluation using Wilcoxon signed ranked test and mean comparison has been used for effectiveness testing.

Interventional study was conducted on a group. The total sample size was 20 profound hearing-impaired children, having hearing loss between 100dB and 120dB. Their audiometry test is again taken by audiologist to verify their hearing loss level. They were of both genders (i.e., 10 males and 10 females). The research participants were profound hearing impaired (i.e., single disability) students of Kindergarten at National Special Education Center for Hearing Impaired Children (NSEC-HIC), located in sector H-9/4 Islamabad Pakistan. The school comes under Federal Government of Pakistan and imparting free education. As it is a school for hearing impaired children, therefore all the children communicate in the school through sign language. The selected participants were in age ranged from 5 to 8 years and they were from a low rank in society. The students never participated in speech therapy sessions. It was a focus experimental group study. The children participated both in group sessions and individual sessions without using formal sign language (SL); with only visual input for speech perception and production which enable the PHIC to articulate on the proposed application especially developed for this study.

The participants were profound hearing impaired (i.e. single disability) students of Kindergarten. The students never participated in speech therapy sessions. The sample of profound hearing-impaired children, having hearing loss between 100dB and 120dB. They belong to both genders. The children participated both in group sessions and individual sessions on the proposed application especially developed for this study. Students enrolled
in the school mostly belong to humble, lower and unpretentious class. Some students have also siblings with hearing impairments studying in the same school in different classes. Students are having hearing impairments due to several different reasons such as, by-birth impairments, hearing impairments as a result of some disease like meningitis, etc. Parents of this lower middle class do not have enough knowledge about how to control hearing impairments and prevent it from further deterioration. They have no education on formal sign language. They mostly used informal home-based naturally evolved signs to communicate with their PHIC. One of the major limitations in slow progress of PHIC students is the lack of knowledge of their parents, such that they cannot practice the formal sign language at their homes. In addition, for many reasons, parents of this lower class are not able to maintain proper hygienic environment for their children, which results in frequent illness of PHICs. This also affects their learning progress.

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The participants were selected on the criteria that they had never gone through any speech therapy before the present intervention. Moreover, the participants are from Kindergarten level of education, those who have no exposure to language learning using lip-reading method. The only way these participants communicate with their family was using self-made signs e.g. making a circle of fingers and bringing them close to lips for Water etc.
3.5.1.2 Data Collection

The research (i.e., research questions) was measured in two ways, i.e., (i) articulation (speaking) of words, and (ii) the effect of behavior during learning sessions.

The articulation of word was measured with scale 0—2. The 0 stands for unintelligible, 1 stands for intelligible and 2 stands for good. The data set of the words used for training of the PHIC was developed with the help of sign-language teacher and speech therapist. The words in the data set are based on vowel as recommended in (Kritzinger et al., 2014; Pereira & Fortes, 2010). These words contain the vowel at the initial, middle and final positions of the words. Secondly, the behavior of PHIC were measure on the basis of the four parameters, i.e., eye contact, imitation, attention span, level of cooperation. These parameters are explained as below. The scale of the measuring the parameters is 0—3, i.e. 0 stands for unacceptable, 1 stands for weak, 2 stands for average, and 3 stands for good. A child gives no response is graded as unacceptable and who gives slight response comes under weak. Similarly better and best response of a child is graded as average and good respectively. These parameters play an important role in PHIC speech learning ability.

The importance of eye contact in PHIC is significant because they have only visual memory and do not have their auditory memory. A child's eye contact behavior depicts the child's motivation, whether the child is interested in the lesson or not. This can affect the speech learning process.

Imitation means here how a PHIC copies the lip movement from a video clip of the proposed application. Imitation depends on eye contact of a child. If a child did not have good eye contact, he/she would not be able to capture the exact or very close to exact lip movement to imitate.

Since PHIC do not have auditory memory, they cannot speak and convey their feelings. Therefore they usually convey by being hyperactive or aggressive to express themselves. They mostly have very short attention span that can badly affect their learning ability. The attention span can be increased by creating interest in the teaching lessons.
Level of Cooperation is as stated earlier in the previous point, PHIC are usually very hyperactive and aggressive, therefore they can show a lack in cooperation. The level of their cooperation with the teacher and speech therapist can affect their speech learning ability.

![Pre-Experimental Design](image)

**Figure 3.7:** Pre-Experimental Design

### 3.5.1.3 Experiment

The Pre-experimental design is most widely used research design for significantly measuring the performance of a given task. As the “pre” shows they are introductory to true experimental designs. There are three types of Pre-experimental designs shown in Figure 3.7.

![One-Shot Case Study Design](image)

**Figure 3.8:** One-Shot Case Study Design

The research design used in this research is One-Shot Case Study (Figure 3.8). In this type of pre-experimental design a single group is studied and is exposed to an experimental treatment that is presumed to have caused change. The carefully studied single instance is
compared to general expectations of what the case would have looked like had the treatment
not occurred and to other events casually observed. In this only post-test was conducted to
obtain results and does not use a control group. A treatment was done on the selected group
that was to test. Other was on SL so was unable to be compared.

![Diagram](Figure 3.9: One-Shot Case Study Design)

The study design used in this research was pre-experimental design One-Shot Study
Design (Figure 3.9), where a teacher was assigned to the selected group. Before the actual
experiment started for articulation of words, two significant activities were performed. First
the children were given some warm up exercises, i.e., (i) blowing candles and pieces of
papers, (ii) chewing bubble gums and (iii) blowing balloons both in groups and individual
sessions to activate their mouth muscles and palate so that they start working. Secondly,
since the children do not have auditory memory, they were used to place their thumbs
on their mentum (slightly under the chin) and nostril to sense the vibration of their word
articulation.

The treatment was performed both in group and individual sessions. Initially group
sessions were performed to make the children familiar with the laptop and the proposed
application. Then individual sessions were conducted with each individual child.

Before performing the actual experiments, preliminary training sessions of four weeks
were conducted. In these sessions, first of all sample screening was performed and PHIC
students with only a single disability were selected. After the sample screening, the selected
PHIC students performed some warm up exercises. These exercises helped the PHIC
students to mobilize their mouth and palate muscles. Moreover, PHIC students were
familiarized with the application in this preliminary training session.

The sign-language teacher was present in all the initial group sessions for support and
motivation of the children. The children were made to speak words in the given time. The
training and the test (evaluation) sessions were performed separately and were administered on different days. Then the actual experimentation was started and continued for a period of 6 months. In this time period, each student was taught how to articulate without any hearing aids, in 125 sessions. By session, we mean a period of 40 minutes where training for word articulation of one PHIC student is conducted. The syllabus/contents for sessions were articulating vowels, and words containing vowels at initial, middle and final position of the words. The list of words, articulated in the sessions, is given in the Appendix C. Training words are carefully selected by an expert speech therapist. She has arranged the sequence of words in an order of easiness to difficult one. Similarly considering the single and multiple tongue movements. Vowels position is the most important feature for a word selection. For the present work, all three placement of vowels are considered i.e. vowel come at initial, middle and last position in a word. One session of one PHIC student took placed in a day and total of six sessions were conducted for six different PHIC students in the day. In other words, four hours of a day were spent in conducting sessions in this experiment. Moreover it was observed that PHIC students were often not willing to attend a session due to multiple reasons, such as, illness, unwillingness or any unfavorable circumstances. In this way each students turn of taking a session came after 3-4 days.

In addition to the teaching sessions, separate evaluations sessions with each individual PHIC students were carried out. Evaluation sessions of each PHIC student were conducted after every 25th session. PHIC students are learning things through their visual aids and visual memory not through their auditory memory. In order to avoid that they might use their photographic memory (i.e., short term memory) for assessment, the evaluation sessions were not conducted immediately after each session because such assessments would not be reliable enough. In other word the aim, behind carrying out separate evaluation sessions after every 25 sessions, was to assess the long-term memory of the PHIC students. Evaluation session was carried out by three evaluators, i.e., teacher, parent/guardian and speech therapist. The students were assessed for word articulation starting from vowels to different words randomly in each evaluation session.

The assessment forms were designed with the help and consensus of the sign-language teacher and speech therapist to assess the articulation of words by a child and his/her
behavior. The assessments were conducted on designed forms. Finally, all sessions were recorded and then analyzed using the Statistical Package for the Social Science (SPSS) version 23 software.

### 3.5.2 Usability Testing

Assessment of the interaction between users and Losina application is conducted using a usability test. Losina application need special design in terms of usability as its users are special children, i.e., PHIC. In the present work, user testing a type of usability test was performed.

User Interface, pedagogy and learning contents of the Losina application was assessed through user testing (Lazar et al., 2010). There are two types of user in Losina application i.e. i) active user and ii) passive user. PHIC are the active users who use the application directly. Teachers and parents use application indirectly, which makes them passive user of the proposed application. A questionnaire on usability assessment of educational software was used as instrument for conducting user testing. PHIC are unable to participate themselves in the user testing, therefore the questionnaire is designed in such a way that it allows teachers to record their observations while they are aware of the children during the test. The level of usability support is measured with this user testing.

#### 3.5.2.1 Questionnaire Design and Selection of Respondents

The educational games domain of research has heavily contributed toward evaluation of educational games. The questionnaire used for usability evaluation of Losina application was adapted from a research work (de Freitas & Oliver, 2006; Omar & Jaafar, 2010). This adopted educational games evaluation questionnaire is comprised of several usability heuristics (Pinelle et al., 2008; Song & Lee, 2007). The reason for adoption is that original questionnaire contains several sections such as Multimedia, Content, Pedagogy, Playability and Interface. These sections are highly related to evaluation of the proposed application. The section Playability is not used in usability evaluation of Losina as it is not a pure
game, i.e., first person shooter, board game etc. Appendix A provides a sample of the adopted questionnaire. The evaluation of the proposed application was carried out through educational games evaluation questionnaire by three experts of the usability domain. These usability experts are professors and assistant professors from two different universities having specialization in software engineering more specifically in software usability. Consent of agreement about the validity of the questionnaire in relation to the proposed application was also taken from all experts. All of the domain experts agrees with the questionnaire adopted and have agreed on its relevancy with the evaluation of the proposed application. All evaluators have rated the usability questions against a five scale Likert scale (1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree).

3.5.2.2 Test Execution and Data Collection

The usability testing was conducted individually by all domain experts. A demonstration of the proposed application was presented to the usability evaluators. Later an individual copy of the Losina was installed on the laptops of the evaluators. Evaluators have responded in the questionnaire while experiencing themselves the functionality of the proposed application. Evaluators are allowed to ask about any queries related to proposed application from the researcher of the present work. All evaluators are given sufficient time for evaluation as per their need. The data obtained from the evaluation was analyzed using Statistical Package for the Social Sciences (SPSS) version 23.

The evaluation from the obtained data was carried out by analyzing the mean and mode values of the usability evaluation. These analyses will provide an indication about usability soundness of the proposed application for its interface, learning contents, pedagogy and multimedia details. The analysis will conclude the percentage of acceptance by the usability experts about Losina usability. The mean value will provide a central tendency among distribution while the mode value will be used if the mean value falls between some real numbers (Coakes & Steed, 2009). For example, if the mean value is 3.28 from scale 3(neutral) and 4(agree) then mode analysis can provide a representation that respondent had chosen which scale the most. Following are the usability factors that are subject of the
present evaluation:

**Interesting & Engaging:** User interest is dependent on engagement factors of the usability. Engagement is defined as “emotional, cognitive and behavioural connection that exists, at any point in time and possibly over time, between a user and a resource” (Attfield et al., 2011). The following definition provides an evaluation parameter to measure engagement by Losina application to attract user attention. This become an indicator for Losina effectiveness in term of its usability.

**User Goal:** How much a software product provides ease to its user to accomplish the specified tasks is termed as user goals in the usability design. The goals comprise efficiency of performing a given task, effectiveness and satisfaction in a specified context during software usage. A user goal refers to easily and efficiently accomplishing a task that a user wants himself as a user. Losina application allowed users to perform their needed tasks to be accomplished.

**Visibility:** Human mind is good at perceiving and interpreting visual clues of the real world. The same can be modeled in a software application under visibility factor. Losina visibility provide an internal cognitive processing for deaf children to perceive and interpret the given task of word articulation. On the other hand, it has been reported that excessive visibility of the operations underlying a task may impose negative effects on the user. Evaluation of Losina application usability factors will give an indication about its usefulness and adoptability.

**Consistency:** For similar situation or objectives the usage behavior of the user remain same is termed as consistency in usability design. Consistency is the primary and most widely addressed issue in usability literature.

**Learnability:** The understanding and familiarizing with a software application is termed as learnability in usability design practices. Training time required for a software application depends on learnability. High learnability will reduce training time and even a novice user can perform actions provided by the underlying software application. Learnabil-
ity factor evaluation of the Losina will provide an indication of its usage by the deaf student who requires a software application with high learnability factor. The learnability of Losina will measure the correlation between knowledge of a deaf child and the required knowledge for the effective interaction.

### 3.6 Summary of the Chapter

This chapter discussed on the detailed methodology for word articulation of profound hearing impaired children using interactive software application following the lip-reading method. The research flow includes the analysis phase consisting analysis of available technologies for hearing aid and teaching practices used in special schools, state-of-art and preliminary testing of the proposal. Design phase include the details of interactive software application architecture, content design, usability considerations and development details. Finally all the methods used for the evaluation of the proposed application are provided. The evaluation parameters are effectiveness, behavior and usability. Discussion about evaluation method for each evaluation parameter is provided.
The evaluation of the proposed software application (Losina) is focused on word articulation and behavioral improvement of the PHIC. Table 4.1 provide an overview of the experimental study conducted within the present work. Experimental parameters are effectiveness (improvement in word articulation and behavior of PHIC) and usability (ease of use). Both quantitative and qualitative methods are used for evaluation but they are interrelated to each other. Each item of the evaluation is discussed in detail in the following chapter.

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Experimental Parameters</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Effectiveness</td>
<td>How much lip-reading based interactive software application (Losina) is effective in terms of word articulation and behavior improvement?</td>
</tr>
<tr>
<td></td>
<td>User Testing</td>
<td>How much Losina is usable by a PHIC?</td>
</tr>
</tbody>
</table>

**Table 4.1:** Experimental Study Overview
Chapter 4 Results And Discussion

4.1 Effectiveness — Learning Gain

The evaluation of the Losina application was conducted to determine its effectiveness in terms of word articulation and improvement in behavior of the PHIC. Losina is composed of learning modules containing learning material and curriculum sequencing mechanism for vowel containing word articulation. These integrated modules should enhance children word articulation as compared to performing the traditional sign language teaching and speech therapy involving human support and pre-authored cards contents. In the present work, Losina is an assistive tool to enhance the exiting word articulation process instead of replacing it. Therefore, the evaluation of the proposed application for effectiveness was conducted using Wilcoxon signed ranked test. Moreover, Wilcoxon signed rank test was used to analyze significant improvement in word articulation by comparing the median score of the experimented children.

As discussed in Methodology (Chapter 3), each individual was assessed in five steps after every 25 individual sessions (Figure 4.1) by three evaluators, which are shown through table 4.2, 4.3, and 4.4 and box plots in Figures 4.2, 4.3 & 4.4 respectively. The tables present the descriptive analysis of increase in ability of word articulation by profound
Chapter 4 Results And Discussion

Table 4.2: Session-wise Teacher’s Evaluation for Articulation of Words

<table>
<thead>
<tr>
<th>Description</th>
<th>N</th>
<th>25th Session</th>
<th>50th Session</th>
<th>75th Session</th>
<th>100th Session</th>
<th>125th Session</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
<td>µ</td>
<td>σ</td>
<td>µ</td>
<td>σ</td>
<td>µ</td>
</tr>
<tr>
<td>Average_A</td>
<td>20</td>
<td>0.8767</td>
<td>0.38466</td>
<td>1.2900</td>
<td>0.32965</td>
<td>1.3733</td>
</tr>
<tr>
<td>Average_E</td>
<td>20</td>
<td>0.8133</td>
<td>0.30328</td>
<td>1.2500</td>
<td>0.40516</td>
<td>1.4000</td>
</tr>
<tr>
<td>Average_I</td>
<td>20</td>
<td>0.9846</td>
<td>0.43126</td>
<td>1.2615</td>
<td>0.42822</td>
<td>1.3923</td>
</tr>
<tr>
<td>Average_O</td>
<td>20</td>
<td>0.9531</td>
<td>0.44697</td>
<td>1.2594</td>
<td>0.42596</td>
<td>1.4219</td>
</tr>
<tr>
<td>Average_U</td>
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<td>0.9154</td>
<td>0.44288</td>
<td>1.2346</td>
<td>0.43477</td>
<td>1.4077</td>
</tr>
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<td>0.40181</td>
<td>1.2591</td>
<td>0.40475</td>
<td>1.39904</td>
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</tbody>
</table>

Table 4.2: Session-wise Teacher’s Evaluation for Articulation of Words

hearing-impaired children. The box plots show that improvement is getting significant as the number of sessions increases. There is gradual increase in median and decrease in the sizes of box plots. The short height of the boxes at 100th and 125th sessions shows a uniform learning gain by the participants. However, the long height box reflects that there is a difference between learning scores of the children but still the median is toward increasing trend. The results show a positive effect of the intervention.

Table 4.2 presents the descriptive analysis of increase in the mean of the vowel as it is assessed in 5 different steps after every 25 sessions. There is gradual increase in mean and decrease in standard deviation. The results show a pattern of improvement with increasing number of training sessions. Table 4.2 present participants learning improvement using proposed application, which was administered between different training sessions. It can be seen that all participants have shown an increased performance with increasing number of training sessions. The initial mean value of all participants after 25th sessions is 0.90862 and elevated to a score of mean value 1.85108 after 125th sessions. This reflects an increased spoken ability of the participants. Across the participants, the mean differences between initial sessions and final sessions are (1.85108 - 0.90862 = 0.94246) i.e. 94.246% increment.

The same fact has been shown in the box plot in Figure 4.2. This shows that improvement is getting significant as the number of sessions increases. The short height of the boxes at 100th and 125th sessions shows a uniform learning gain by the participants. However, the
long height box at 50th session reflect that there is a difference between learning scores of the children but still the median is toward increasing trend. After the first 25th sessions, the median is skewed toward bottom, reflecting that many students have achieved a low score while few of them have better scores as compared to their peers. But later after 50th and 100th sessions, the median value moves toward higher scores, showing a positive effect of the intervention.
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Results And Discussion

Figure 4.4: Session-wise Speech Therapist’s Evaluation for Articulation of Words

<table>
<thead>
<tr>
<th>Description</th>
<th>N</th>
<th>25th Session</th>
<th>50th Session</th>
<th>75th Session</th>
<th>100th Session</th>
<th>125th Session</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>μ</td>
<td>σ</td>
<td>μ</td>
<td>σ</td>
<td>μ</td>
</tr>
<tr>
<td>Average_A</td>
<td>20</td>
<td>.6900</td>
<td>.31140</td>
<td>.9400</td>
<td>.28193</td>
<td>1.1267</td>
</tr>
<tr>
<td>Average_E</td>
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<td>.6267</td>
<td>.31671</td>
<td>.9533</td>
<td>.32235</td>
<td>1.1267</td>
</tr>
<tr>
<td>Average_I</td>
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<td>.31753</td>
<td>.9920</td>
<td>.32250</td>
<td>1.1269</td>
</tr>
<tr>
<td>Average_O</td>
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<td>.6594</td>
<td>.32601</td>
<td>1.0188</td>
<td>.33937</td>
<td>1.2406</td>
</tr>
<tr>
<td>Average_U</td>
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<td>.6577</td>
<td>.35071</td>
<td>1.0161</td>
<td>.35185</td>
<td>1.2292</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>0.66138</td>
<td>0.32447</td>
<td>0.98404</td>
<td>0.3236</td>
<td>1.17002</td>
</tr>
</tbody>
</table>

Table 4.3: Session-wise Family’s Evaluation for Articulation of Words

The same group of PHIC was assessed in the same way in different sessions by their family members. The result the session evaluation is shown in Table 4.3 In the beginning sessions (i.e., 25) the children could not perform well because they were not expecting evaluation from their family members or they were shy and not cooperating in evaluation. The same trend is shown in box plot in Figure 4.3.

Speech therapist also assessed the PHIC group after the same sessions professionally. They provided comfortable atmosphere to PHIC and carefully evaluated them. Their evaluation results are shown in Table 4.4 The trend is also shown by box plot in Figure 4.4.
Table 4.4: Session-wise Speech Therapist’s Evaluation for Articulation of Words

<table>
<thead>
<tr>
<th>Description</th>
<th>N</th>
<th>25th Session</th>
<th>50th Session</th>
<th>75th Session</th>
<th>100th Session</th>
<th>125th Session</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>μ</td>
<td>σ</td>
<td>μ</td>
<td>σ</td>
<td>μ</td>
</tr>
<tr>
<td>Average_A</td>
<td>20</td>
<td>.8000</td>
<td>.44433</td>
<td>1.1667</td>
<td>.54440</td>
<td>1.3867</td>
</tr>
<tr>
<td>Average_E</td>
<td>20</td>
<td>.7633</td>
<td>.40952</td>
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<td>.59678</td>
<td>1.3300</td>
</tr>
<tr>
<td>Average_I</td>
<td>20</td>
<td>.8308</td>
<td>.42471</td>
<td>1.2500</td>
<td>.56575</td>
<td>1.4308</td>
</tr>
<tr>
<td>Average_O</td>
<td>20</td>
<td>.8531</td>
<td>.45355</td>
<td>1.2719</td>
<td>.56242</td>
<td>1.4187</td>
</tr>
<tr>
<td>Average_U</td>
<td>20</td>
<td>.8346</td>
<td>.47107</td>
<td>1.2154</td>
<td>.52977</td>
<td>1.4269</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>0.81636</td>
<td>0.44064</td>
<td>1.23214</td>
<td>0.559824</td>
<td>1.39862</td>
</tr>
</tbody>
</table>

The evaluation made by the speech therapist, it has been shown by the evaluation performed by different evaluators that children are making progress in articulation of words. The trend of mean of means has been shown in Figure 4.5. Figure 4.5 also provides evidence about understanding by a common person (in case of present work, the parents). Their evaluation shows that they understand words even after 25th sessions but not good as a teacher and the speech therapist. But after 125th sessions, the understanding of the parents and speech therapist become same.

Figure 4.5 shows the comparison of the assessments performed by all three evaluators. In the beginning sessions (i.e., 25, 50, 75) the children could not perform well particularly in assessment performed by their family members as compared to other evaluators. The reason
is, they were not expecting evaluation from their family members or they were shy and/or not cooperating in evaluation. Even though with every passing session, the result shows a steady increase in the word articulation. The end results after 125 sessions shows twice the performance metric as compared to its value after starting 25 sessions. This trend reflects a tremendous gain in articulating words. Moreover, Wilcoxon signed rank test was used to analyze significant improvement in word articulation by comparing the median score at 25\textsuperscript{th} session with 125\textsuperscript{th} session. The test shows a statistically significant increase in word articulation by PHIC who participated in the intervention, i.e., $Z = -3.921$, $p < 0.050$. The median score on the performance of children increased from 25\textsuperscript{th} session (Md=0.908) to 125\textsuperscript{th} session (Md=1.851). Correlation coefficient or the effect size can be measured using $Z$ value from Wilcoxon test as $r = Z / N$ (where $N$ is sample size). The $r$ value also reflects the effect size. Thus, the effect size is $0.876$ ($r = -3.921/4.472$), which is a large effect as per Cohens rule ($r_{0.5}$).

### 4.2 Measuring the effect of PHIC Behavior Change

The learning of articulation depends on the behavior of PHIC, which were measure on the basis of the four parameters, i.e., eye contact, imitation, attention span, and level of cooperation. These were the most important parameters. Learning is directly dependent on behavioral parameters.

Attention span is very important behavioral parameter in case of PHIC. As they cannot express themselves therefore they become very hyper and have very short attention span over object. The scale of the measuring the parameters is 0-3, i.e. 0 stands for unacceptable, 1 stands for weak, 2 stands for average, and 3 stands for good. A child has least attention span during a session is graded as unacceptable and who shows slightly better attention span comes under weak. Similarly a PHIC whose attention span is increasing from better towards best is graded as average and good respectively. This parameter play important role in PHIC speech learning ability. As the graph is showing on horizontal axes scale the attention span measuring the parameters is 0—3 and on vertical axes is the net performance. It is showing that it has an clear indication that when there is an increase in the attention
span the net performance of PHIC will increase. As this graph shows by the evaluation of all the evaluators.

Eye Contact is very significant behavioral parameter in case of PHIC. As they do not have auditory memory therefore whatever they learn they use their visual memory. The scale of the measuring the parameters is 0-3, i.e. 0 stands for unacceptable, 1 stands for weak, 2 stands for average, and 3 stands for good. A child has least eye contact during a session is graded as unacceptable and who shows slightly better eye contact comes under weak. Similarly a PHIC whose eye contact is increasing from better towards best is graded as average and good respectively. This parameter play important role in PHIC speech learning ability. As the graph is showing on horizontal axes scale the eye contact measuring the parameters is 0-3 and on vertical axes is the net performance. It is showing that it has a clear indication that when there is an increase in the eye contact the net performance of PHIC will be better. As this graph shows by the evaluation of all the evaluators is different. Familys assessment had nice starts then gets a downfall at level 2 and as moves ahead it raise but it varies throughout the assessment, the reason is PHIC are not used to of family assessment, they get shy of their of parents. Whereas the teacher gets the eye contact straight at 2 the
reason PHIC are familiar to their teacher and PHIC know that teachers are always there for assessing them. Speech therapist is doing assessment through listening the voice and observing the PHICs eye contact while articulating.

Imitation is the very essential behavioral parameter in case of PHIC and plays a vital role in PHIC speech learning ability learning. As they do not have auditory memory therefore whatever they learn they use their visual memory. The scale of the measuring the parameters is 0-3, i.e. 0 stands for unacceptable, 1 stands for weak, 2 stands for average, and 3 stands for good. A child has least Imitation during a session is graded as unacceptable and who shows slightly better Imitation comes under weak. Similarly a PHIC whose Imitation is increasing from better towards best is graded as average and good respectively. As the graph is showing on horizontal axes scale the imitation measuring the parameters is 0-3 and on vertical axes is the net performance. It is showing that it has a clear indication that when there is an increase in the imitation the net performance of PHIC will be better. As this graph shows by the evaluation of all the evaluators is almost going into similar direction. Familys assessment has a slight deviation that has the same reason, as the PHICs do not consider their families as their evaluators so they act shy and do not give their full performance. Whereas the teacher and speech therapist gets the imitation at the same level. The graph
very clearly depicts that if the PHIC will not do good imitation will not have good learning at all. Where as on the other hand when the PHICs imitation scale will increase the learning measures will increase.

Level of cooperation is the very imperative behavioral parameter in case of PHIC and plays a dynamic role in PHIC speech learning ability learning. As they cannot express themselves and their emotions therefore sometimes they become very hyper and short temper and this is the reason their level of cooperation varies. The scale of the measuring the parameters is 0-3, i.e. 0 stands for unacceptable, 1 stands for weak, 2 stands for average, and 3 stands for good. A child has least Level of cooperation during a session is graded as unacceptable and who shows slightly better Level of cooperation comes under weak. Similarly a PHIC whose Level of cooperation during the sessions is increasing from better towards best is graded as average and good respectively their learning is effected in positive manner. As the graph is showing on horizontal axes scale the Level of cooperation measuring the parameters is 0-3 and on vertical axes is the net performance. It is showing that it has a clear indication that when there is an increase in the Level of cooperation the
net performance of PHIC will be better. As this graph shows by the evaluation of all the evaluators is almost going into similar direction eventually. Teacher and Familys assessment are in same direction covering same range on the graph whereas the speech therapist is varying with slight changes in results has a slight deviation but ends at same point. The graph very clearly depicts that if the PHIC will not do good Level of cooperation will not have good learning at all. Whereas, on the other hand when the PHICs Level of cooperation scale will increase the learning measures will increase.

4.3 Usability Testing

It has been reflected in literature review (Chapter 2) there are very few existing software application for PHIC. Moreover, all of the available software applications focused on technical aspects of the software but had neglected the user perspective. User perspective that is ease of use and focusing the need of the PHIC (usability) is an utmost important feature of consideration (Chen et al., 2012). Usability evaluation of Losina was carried out through formal usability evaluation questionnaire proposed by (Omar & Jaafar, 2010). The questionnaire was reported for its high reliability for evaluation of educational games.
using usability heuristics. The interface section of the heuristics questionnaire comprised of evaluation issues such as consistency, navigation, interactivity, screen design and pleasure to use. The pedagogical issues evaluated within questionnaire are learning goals, motivation, learners control, feedback and individualized learning. Multimedia aspects of the questionnaire evaluates issues such as usage of text, usage of animation, usage of graphics, usage of audio video, combination of multimedia items and suitability of the multimedia items used. Finally the evaluation of learning contents used within Losina were evaluated against reliability of content, clear understanding and integration of learning contents. The usability questionnaire is provided as Appendix A.

![Usability Evaluation of Losina](image)

**Figure 4.10:** Usability Evaluation of Losina

The mean value of the evaluated usability is shown in Figure 4.10. The learning content (LC) among usability constructs is highly rated with a mean value 4.21, pedagogy (PD) follows by a mean value of 4.20. Similarly, the interface (IN) is rated above average i.e. 4.06. The multimedia (MU) constructs remains the least with a mean value 3.81. The high mean value of the learning content, pedagogy and interface supports the validity of the proposed application in term of usage by the PHIC. Since Losina is a research prototype, that has less consideration on multimedia items as compared to a off the shelf software application. Multimedia items used within Losina were carefully adopted from the World Wide Web keeping in view their inter-synchronization and relatedness with the proposed
application theme and interface. But still they lack the special designed capability of high value multimedia items. Moreover, multimedia mean value still falls above average score. The mean scores can be reflected as percentage of agreement and disagreement by the usability experts about Losina.

<table>
<thead>
<tr>
<th>Usability Factor</th>
<th>Strongly Disagree (%)</th>
<th>Disagree (%)</th>
<th>Neutral (%)</th>
<th>Agree (%)</th>
<th>Strongly Agree (%)</th>
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</thead>
<tbody>
<tr>
<td>Interesting &amp; Engaging</td>
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<td>0</td>
<td>20.02</td>
<td>34.83</td>
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<td>Consistency</td>
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<td>27.14</td>
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<td>Learnability</td>
<td>0</td>
<td>2.86</td>
<td>17.14</td>
<td>36.43</td>
<td>43.57</td>
</tr>
</tbody>
</table>

*Table 4.5: Frequency Distribution of Losina Usability Evaluation*

The percentage distribution (5=Strongly Agree, 4=Agree, 3=Neutral, 2=Disagree and 1=Strongly Disagree) of the usability evaluation against five usability factors is shown in Table 4.10. A decision can be made about Losina usability through high percentages against any usability factor. The results shown in Table 4.5 presents that a low percentage (2.86) is visible against learnability (usability factor). Analyzing the data shows that this low percentage is mainly about individualized learning statements as self-directed or individualized learning (refers to PD7 Appendix A) is possible with Losina but not fully implementable as inquired by the questionnaire. Similarly, the percentage against user goal (a usability factor) is related to adequacy of multimedia elements used in Losina (refers to MU2 Appendix A). It is clear from the results, that evaluators have recognized the usability quality of the Losina application.

### 4.4 Discussion

A prompting effect (refers to the large effect size 0.876 Wilcoxon signed ranked test) has been observed in the articulation ability of the participants of the present study.
Even though, the experimental period was short span (i.e., six months), positive changes in speaking words were recorded for all participants. The articulation of words by a participant after experimentation was easier for an inexperienced or a common listener to understand, that shows the significance of the proposed software application.

An unexpected benefit of the present work is reported by the teachers about the improved change in the behavior of the participants after the intervention. That is, an increased confidence in several participants was also observed, which provides evidence that proposed application has conveyed the target goal to its users. Moreover, participant shows increased attention towards lessons being taught. On inquiring, the participants with increased confidence were willing to take part in the experiment again. On several occasions, these participants speak a word immediately after seeing the lip-reading demonstration for already experimented objects. But when a new object is shown, they first try to grasp the lip and mouth movement for the shown object. This shows that participants have well understood the process of learning and speaking using lip-reading through the application. Similarly, several participants spoke words loudly to show their confidence.

Results show that the problem of reworking with a student was solved by the usage of the proposed application. Traditionally, after several sessions conducted on a day, the students need to redo previous exercises because of the lack of practice work and any learning activity at home. With the use of the proposed application, students can learn on their own pace even at their home. The improvement in natural voice quality, fluency and clear audibility of the tested words within short time span and with no formal intervention, can therefore be attributed to a contribution of the proposed software application used in this research.

The evaluation made by the speech therapist, teacher and family have reported that the intervention has made participants able to recognize the lip-reading method for language learning. This ability has shown a positive effect on the participants in terms of their confidence and cooperation. Moreover, knowing about lip-reading will provide a continuous learning opportunity to the participants in future. During our study, the limited numbers of words were experimented but participants having ability to recognize lip-reading can
learn different new words from different sources. It is apparent from the results that with the increase in the number of training sessions using the application improves language learning. During final conversation with the teacher of the deaf students, she had shown positive attitude towards using the proposed application for improving language learning skills.

One of the limitations of the present work is that no formal assessments for new unseen words were experimented. However, a very few tests were executed with few participants without formally recording the outcomes. Moreover, nasality was not a parameter of a consideration in the present work. Although, the present study involves profound hearing impaired participants that are not directly associated with a hospital settings, but the problem raised by the present study can be supported by the reported results.
5.1 Chapter Overview

This chapter concludes the results and findings and provides a summary of the entire research work. The research findings are mapped with the research objectives to conclude the present research. The present research contributes to the domains of software technology with a view to helping people with disability and child learning through technology. Modeling the lip-reading to a software and experimenting it with profound hearing impaired children has brought novelty to this work. Behavioral improvements in experimented children show a clear evidence of benefits of the present proposal. This chapter provides a summary of the findings that meet all the research objectives and answers the identified research questions. Limitations of the present research and its contributions to the body of knowledge are also provided here. Finally, the chapter ends with future directions and recommendation for future researchers to carry this work forward.

5.2 Summary of Research Findings

The following section discusses about research findings made by the present work. Research objectives are mapped to the provided discussion for identification of contributions achieved by present research. Following discussion provides the research findings.
1. **Objective 1**: To mitigate the communication barriers of profound hearing-impaired children by enhancing their word articulation ability using proposed software application (Losina).

   **Findings**: The daily life communication problems faced by the profound hearing impaired children were identified to formulate the problem statement for the present work. Current practices were evaluated to know how much these practices address the said problem. However, current practices, such as sign language teaching and lip-reading by a speech therapist have their own limitations. These traditional practices have contributed toward communication improvement of a hearing impaired person but their natural limitations have raised several additional problems. Access to sign language and lip-reading formal learning is not accessible to children from low socio-economic status. Individualized learning that is the most important need of the PHIC is not supported by the traditional practices. In addition to this, high cost is associated with traditional practices. The present work has proposed the use of software technology for initiation of word articulation by the PHIC. This proposal has shown positive contribution toward mitigating the communication barriers previously faced by the PHIC.

2. **Objective 2**: To design and develop a software application (Losina) for word articulation using Lip-Reading technique.

   **Findings**: A specially designed software application named Losina was designed and developed to experiment the word articulation proposal of the present work. Requirements of people with disability specially hearing impaired children for the case of present work, are different and complex as compared to traditional software requirements. Special considerations for interface, pedagogy and multimedia were implemented in Losina to support PHIC needs. Losina application can be used individually by PHIC after some training sessions. Losina application is portable, which makes it useable widely on different platforms. All experiment sessions were conducted with Losina only. There was no other learning method or practice used other than Losina application. The empirical results of using Losina application usage show its contribution in initiating word articulation ability of the PHIC. From the usability perspective, Losina has implemented several usability factors such as educational
3. **Objective 3**: To evaluate the effectiveness and usability of the proposed application.

**Findings**: Evaluation of the proposal consists of effectiveness and usability of the proposed application. The usability testing of the proposed application Losina was performed using educational games heuristics evaluation (HEG) method. Interface, pedagogy, engagement and interest, educational goals and learning contents were several usability factors that were evaluated. All of the usability factors resulted in above average score. Results from usability evaluation has shown strong agreement of usability experts with usability factors on the Losina. The mean value comparison provides a statistical proof that Losina has passed the usability requirements for users with disability i.e. PHIC. These findings address the research questions highlighted in Section 1.3.

A pre-experimental one-shot case study test was conducted with twenty profound hearing impaired children between age 5 to 8 years. The test was conducted to initiate the word articulation ability of the experimented children. The purpose of the experiment was to assess the effectiveness (word articulation ability and behavioral improvement) of Losina application as compared to the traditional practices. For the evaluation of the PHIC word articulation performance, one hundred and twenty five sessions have been conducted for each individual for a six month period of time. Carefully selected words containing vowels at different positions were used during experiment.

Selection of the participants has been made on the defined criteria. No individual has ever experienced any technology oriented learning or the traditional lip-reading sessions before. The experiment continued for six months. The empirical results have proved the null hypothesis that there is a difference between mean scores of the children before and after using Losina application. Results of the Wilcoxon signed ranked test has shown significant improvement in word articulation by the PHIC. The resulted effect size from Wilcoxon signed ranked test has shown a large effect size (0.80) on children’s word articulation through the use of Losina application. This has statistically proven (refers to Table 4.2, 4.3 and 4.4) that usage of specially designed software technology for word articulation has a positive effect on mitigating
communication barriers of the PHIC.

5.3 Research Contribution

The present work has contributed the body of knowledge as follow:

1. This research provides an evidence about benefits from information and communication technologies (ICT), more specifically software technology, for people with disabilities. The present proposal enables the disable person (hearing impairment for the present case) to act normally in their daily life activity.

2. Limitation of the traditional teaching and learning methods for hearing impaired children were addressed and the proposal provides a remedy to those limitations. The present research provides a cost-effective, self-paced learning, usable and teaching assistive software solution enabling the word articulation ability of the PHIC. Moreover, the present work justifies the claim through systematic literature review that no other predecessor is available in literature or as an industrial solution for word articulation using technology. This brings novelty to the present work.

3. A contribution is made toward quantitative and empirical reporting of the findings for word articulation ability of the profound hearing disability children using the proposed application. The evaluation of word articulation ability of the experimented children by sign language teacher, speech therapist and parents of the children shows a clear impact of the present work.

4. People with disabilities have known behavioral problems, such as rigidness to learning activities, loose attention and unwillingness to participate. The present work contributed toward behavioral improvement of the experimented PHIC. The qualitative results reported in the present work show the participants of the experiment have gained confidence, Losina application has attracted their attention during learning sessions, participants were interested in the whole activity and they become less rigid to learn. However, a deeper study is needed to further research about behavioral
effects of Losina application.

## 5.4 Limitations

While conducting the present research, it has faced several limitations which have been mentioned below:

1. The evaluation study has a small sample size that in a sense does not reflect the whole population. However, all of the studies related to people with disabilities have similar number of the participants. Collecting a large sample size for studies like the present work is difficult or near to impossible. It has been observed that better results can be achieved with increased experiment time. Present work has not reported the effectiveness in terms of homeschooling of the participants using the proposed application. Experimentation has not considered the cultural differences among PHIC.

2. During our study, a limited number of words were experimented but participants having ability to recognize lip-reading can learn different new words from different sources. One of the limitations of the present work is that no formal assessments for new unseen words were experimented. However, a very few tests were executed with a few participants without formally recording the outcomes. Moreover, nasality was not a parameter of consideration in the present work.

## 5.5 Future Research

Several other possible domains can be extended from the present research as mentioned below:

1. This research can be extended to noun phrases and sentence formation. The future work trend of this research is work on the rest of the phase left such as Phrase Articulation, Sentence Articulation, Paragraph Articulation and Conversation Articulation.
In all these visual datasets of lip movement is also created to help severe hearing impaired children to PHIC (profound hearing impaired children) attempt to utter specific words which make a phrase, then utter a small sentence by combining words together; and by combining few sentences together, a specific small paragraph is formed. By combining few sentences together attempting to utter a specific small paragraph and finally uttering specific small conversation by combining small paragraph together.

2. Then another main objective on which future work focuses is the Speech Therapy of PHIC (profound hearing impaired children) in Urdu or English by training the speech recognizer system on the voices of both normal hearing person and hearing impaired person and then evaluate the performance of speech using Automatic Speech Recognition. To measure the performance of speech of the hearing impaired children we will use Word error rate WER or Phoneme error rate PER.