

**EFFECTIVENESS OF AUTOMATED SPEECH TRAINING
SYSTEM IN ENHANCING SPEECH AMONG HARD OF
HEARING LEARNERS IN SELECTED SCHOOLS IN
NAIROBI CITY COUNTY KENYA**

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DECLARATION

I declare that this thesis is my original work and has not been presented in any other University/institution for consideration of any certification. This research thesis has been complemented by referenced sources duly acknowledged. Where text, data (including spoken words), graphics, pictures or tables have been borrowed from other sources, including the internet, these are specifically accredited and references cited using current APA system and in accordance with anti-plagiarism regulations.

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DEDICATION

To my mum Phyllis Wakuthii for her continued encouragement to actualize my potential, my late dad, Muriithi who had a lot of pride in my achievement, my dear wife, Juliet and beloved children who I mentor, Maureen, Adrian, Shirleen and Elizabeth.

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ABBREVIATIONS AND ACRONYMS

ASHA	: American Speech –Hearing Association
ASTS	: Automated Speech Training System
CALL	: Computer Assisted Language Learning
dB	: Decibel
Hz	: Hertz
ICT	: Information Communication Technology
KICD	: Kenya Institute of Curriculum Development
NCSE	: National Council for Special Education
NGO	: Non-Governmental Organization
WHO	: World Health Organization

ABSTRACT

Speech training of learners who are hard of hearing in Kenya has been lacking necessary attention since 1980s. Education of learners with hearing impairment including learners who are hard-of-hearing has been skewed towards manual communication. The purpose of this study was to investigate the effectiveness of an Automated Speech Training System in enhancing speech among learners who are hard of hearing in selected schools in Nairobi City County. Objectives of the study were to: establish the level of speech perception and production of learners who are hard-of-hearing before using Automated Speech Training System, establish the effects of Automated Speech Training System on enhancing speech perception and production among learners who are hard of hearing, compare the effects of Automated Speech Training System on speech perception and production of learners who are hard of hearing with traditional methods of speech training, Find out the role played by selected demographic factors in the effectiveness of ASTS in enhancing speech among learners who are hard-of-hearing, establish the views of learners on communication modes and Speech training using traditional methods and Automated Speech Training System, and to find out the opinions of teachers on speech training of learners who are hard-of-hearing. The study adopted a mixed research design combining single-subject research design and descriptive survey design. Single-subject research design was considered for this study to allow systematic testing of the effects of the Automated Speech Training System on perception and production of speech among learners who are hard-of-hearing. The target population for the study was ninety four learners with hearing impairment and thirteen teachers in the selected schools. Using purposive sampling technique, thirty two learners who are hard of hearing and thirteen teachers were sampled. To collect data, the Automated Speech Training System was used and two semi-structured interview guides one for the learners and one for teachers. Statistical Package for Social Sciences was used to analyze quantitative data. Qualitative data was analyzed by means of descriptive statistical techniques. Major research finding of the study was that Automated Speech Training System which utilizes 3-D animation technology with both visual and audio components significantly enhanced speech among learners who are hard of hearing. Based on the research findings, the study recommended that the government should put in place policies and proper mechanisms of ensuring that speech training forms an integral part of curriculum for learners who are hard-of-hearing. This will not only help to address some of their communication challenges but also incorporate the new technology to the already existing methods of speech training to enhance speech of all learners who are hard-of-hearing.

CHAPTER ONE

INTRODUCTION AND BACKGROUND TO THE STUDY

1.1 Introduction

This chapter presents the background to the study, statement of the problem, purpose of the study, objectives of the study, research questions, research hypotheses, significance of the study, limitations and delimitation of the study, assumptions of the study, theoretical and conceptual frameworks and operational definition of terms.

1.2.1 Background to the Study

Since 16th century, education of learners with hearing impairment, who comprise hard of hearing and deaf, has been revolving around oralism and manualism which for a long time has led to a wide-ranging controversy between proponents of both approaches. The modern school of thought globally center on the philosophy of Total Communication which brings together oralists' and manualists' ideas in the education of learners with hearing impairment (Moores, 2010). It recognizes that no approach is superior to the other. Speech of learners with hearing impairment, which is a component of oralism is largely unintelligible. Improving the speech skills of these learners has been the concern of educators and clinicians for many years because the adequacy of such skills can have considerable influence on the social, educational and career opportunities available for them (Sandy, 2017).

Hearing loss puts severe limitations on social interaction with children who are deaf as well as those are hard of hearing (Gravenstede, 2009). Hard of hearing people can be defined as all people who have a hearing loss and whose usual means of

communication is by speech (International Federation of Hard of Hearing people, 2009). World Health Organization (2015) defines hard of hearing as persons with hearing loss, ranging from mild to severe, who can communicate using speech, while the deaf as those with profound hearing loss whose main mode of communication is sign language. Learners, who are hard of hearing, being linguistic minority, need to learn speech articulation to enhance their interaction with general society. Denying them speech training limits their interaction in a mainstreamed environment. Good academic results have generally been observed in mainstreamed learners with hearing impairment, but they also show higher degrees of isolation and psychological problems especially if they have limited speech (Gravenstede, 2009). According to Mayer (2008), the main reason why learners with hearing impairment experience severe problems when learning to read is that written English is essentially derived from spoken English, to which they have limited access. However, higher levels of reading achievement have been reported in studies with selective populations of orally educated learners with hearing impairment (Gravenstede, 2009).

According to Yoshinaga-Itano (2003), right ear is better than left ear at receiving sounds from speech, whereas left ear is more sensitive to sounds of music and song. Therefore, hearing loss of any degree in either ear affects speech in a different way. These were results of a study of hearing done in 3000 newborns. The study aimed at finding out the role played by each ear in the process of hearing and determine the effects in communication caused by hearing loss of each ear. Though it has long been known that the right and left halves of the brain register sounds differently because of differences in brain cells in each side, the results from that study indicated that the

ears play much more important role than previously believed. The results of that study explain why most people prefer right ear for listening. An interrupted speech test in background noise reported in a study by American Speech-Language-Hearing Association (2004) showed that right ear impaired children perform significantly poorer than the left ear impaired children and are at risk whenever reverberation conditions are poor. It further suggested that right ear impaired children are at risk of missing out a lot of valuable content in the education system.

Okombo, Akaranga, Mweri and Adera (2006) assert that the mode of communication to be used by learners with hearing impairment depends on the degree of hearing impairment and the child's communicative needs, interest and abilities. They recognized that persons with hearing impairment form a heterogeneous group whose communicative needs cannot be addressed by use of one mode. According to ASHA (2002), one of the most severe consequences of hearing impairment is that speech does not develop by itself. Without extra attention and a special approach, a little child with hearing impairment would not learn to speak. Speech has to be challenged, seized, stimulated and developed (ASHA, 2002). Speech skills gained through training should be carried over into spontaneous speech outside the training environment. Clinical experience suggests that frequent, repetitive speech drills are necessary to develop, stabilize, maintain and promote carryover of speech skills beyond the training setting (Ling, 1999). Traditionally, speech training of learners with hearing impairment was carried out through traditional approaches until late 19th century when electronic speech training aids were experimented.

Traditional speech training for children with hearing impairment is based on methods that help the children to learn speech by looking at the therapist's/ teacher's face and lips, through residual hearing or by feeling the therapist's / teacher's face, throat and expiration of air among others, to establish an orosensory motor control of their speech movements (Wankhede, 2014). Efficient speech training should offer the learners possibility to perceive invisible speech articulation as well as to imitate and compare their vocal output with that of the therapist/teacher (Oster, 2010). Ertmer (2010) recommends that the most effective use of speech training aids should be during the years of childhood, and especially during the pre-school period of language acquisition.

For many years, researchers and engineers had attempted, with little success to provide electronic aids for speech training. According to Bernstein, Goldstein and Mahshie (2002), emergence of computer and signal processing technology provided the impetus for several groups to implement new speech training aids. The first significant contribution was made by Nickerson and Stevens (1976) when they developed the first computer based speech training system. Since then, the development of the micro-computer techniques has offered more advanced computer aided speech training programmes that have enhanced the possibility for children with hearing impairment to develop intelligible speech (Osberger, 2007). In several pre-schools and schools for the deaf and hard of hearing children in Sweden, computer-based visual speech training has become a standard and valuable complement to the regular speech training activities. This was due to the results of computer based speech training with severely hard of hearing children of up to 16 years of age that not

only proved to be successful and worthwhile but also very efficient, especially in the instruction phase of training. Children appreciated it and derived benefit from the use of the system both on the segmented and suprasegmental level (Oster, 2010).

Sugano, Mizutani, Sasaki, Kitayama, Kamata and Ishida (2014) described a speech training system that used personal computer to support teachers in the schools for the deaf. The system was applied by about 80 percent of schools for the deaf in Japan and it gained high efficiency. However, they were quick to caution that the system is never a substitute of the teachers in the school because teaching must be conducted by a teacher. Sarmasik, Serbeticioglu and Knut (2009) investigated a software that combined both visual and audio technology to improve verbal communication skills of children with hearing impairment. The software was tested with pre-school children with hearing impairment, who were in the age group of 2 and 6 years with hearing aids or cochlear implant and children who were unimplantable. It is reported that the software enabled children with hearing impairment to comprehend three word sentences and correct their speaking and pronunciation problems with help of its voice analysis method.

As a form of advancement in speech training using computer technology, animated talking head technology has been developed to address some of the speech difficulties experienced by learners with hearing impairment since 2000. This has set the path for the emergence of Computer Assisted Language Learning (CALL), which applies a pedagogical agent or a virtual tutor in the form of an animated talking head. Massaro and Light (2004), developed a computer-animated talking head, ‘‘Baldi’’ that tried to teach vocabulary and grammar to children with language challenges and training

speech distinctions to children with hearing loss and to adults learning a new language. However, Baldi could not simultaneously amplify speech sounds to a level equal to, or above the learners' hearing threshold neither could it simultaneously evaluate learner's hearing ability.

In Africa, Assefa (2006) applied animated talking head technology in Mekanissa Deaf School in Ethiopia to train the learners Amharic language speech sounds. The findings showed that out of 30 learners (15 male and 15 female), 70% were able to produce sounds articulated on the lips accurately. However, the researcher reported that the system was incomplete since it could not display the vocal tract in which most sounds are articulated.

In Kenya since 1940s, education of learners with hearing impairment was based on oralism approach which gave speech training a lot of emphasis (Kenya Institute of Education, 1979). In the late 1980s, Total Communication was adopted but with time, speech training which encompasses lip/speech-reading component has been disregarded. Total communication was recognized globally as a philosophy rather than just a methodology of educating children with hearing impairment that incorporates all means of communication; signs, natural gestures, finger spelling, use of residual hearing, lip-reading, speech and body language among others. Most subjects in the school curriculum are taught using Kenyan sign language as a medium of instruction. An examination of the time tables from different schools for the deaf revealed that no aspect of speech training was slotted. This has continued to disadvantage learners who are hard of hearing, who mainly rely on speech reading, use of their residual hearing and amplification for communication.

According to the Kenya National Special Needs Education Policy Framework (2009), the government committed itself to the protection and provision of equal opportunities to learners with special needs and disabilities, inclusive of learners with hearing impairment. The government has developed a number of policy guidelines for special needs education dating back to 1964. These include: committee on care and rehabilitation of the disabled (1964) which resulted in the formulation of sessional paper No. 5 of 1968, Kenya education commission (1964) which recommended that children with mild handicaps be integrated to learn in regular schools, National education commission on education objectives and policies (1976) that recommended coordination of early intervention and assessment of children with special needs among other recommendations. Other commissions that have given policy guidelines on special needs education include: The presidential working committee on education and training for the next decade and beyond (1988) which emphasized deployment of special needs education inspectors at district level, commission of enquiry into education systems (1999) recommended the establishment of a national special education advisory board and noted that there was no comprehensive policy or legal framework on special needs education and the taskforce on special needs education (2003). However, all the policy guidelines developed by the government, are silent on education and communicative needs of learners who are hard-of-hearing who are a minority group among learners with special needs.

With the above background it is evident that different Computer Assisted Language Learning (CALL) applications have been used for speech training among learners with hearing impairment in different parts of the world. However in Kenya, studies

relating to speech training of learners with hearing impairment, especially using computer technology or even 3-D animated talking head technology are quite limited. It is against this background that the researcher developed a system for speech training using computer animated-talking head which is a component of Computer Assisted Language Learning (CALL) with audio/verbal and visual components to enhance perception and production of speech of learners who are hard of hearing.

1.2.2 Automated Speech Training System

Multimedia, particularly animation, has made significant contribution in educational setting as it makes the learning process easier and more effective (Chung & Zisserman, 2016). Series of empirical studies performed since 2000 indicate that animation can provide various instructional role, including improving speech among learners who are hard-of-hearing (Massaro, 2004). Apparently all learners with hearing impairment have difficulties in production of speech. These speech deficits in turn could lead to difficulty in finding a job because good communication skills is a principal criterion set by most if not all employers (Valk, Rashid & Elder, 2010). Animated talking head technology, which has given birth to Computer Assisted Language Learning (CALL), has mostly concentrated on alleviating pronunciation difficulties, vocabulary acquisition and reading abilities.

The development of an Automated Speech Training System to enhance speech among learners who are hard-of-hearing attempts to fully integrate computational technologies in addressing speech challenges faced by learners who are hard-of-hearing. In this system, computational technologies are widely adapted to meet the speech needs of learners who are hard-of-hearing. It has been fitted with tools to

mitigate the problems widely faced by learners who are hard-of-hearing in perceiving and producing speech. These tools include a hearing assessment tool, a sound amplification tool and a speech training tool that uses a 3-D interactive human head as a speech tutor for speech perception, production and evaluation which can be used by the learner to monitor his/her progress.

The system can be used by teachers as a teaching aid or even by learners themselves for self-teaching, or under a guardian's supervision depending on the learner's age. The system aims at simulating the whole teacher-based speech training process in order to eliminate or supplement tedious manual training. It can be used multiple times by different people. It uses 3-D talking-head technology whose main feature is the lip synchronization. To create lip synchronization, the system uses phonemes and visemes. Phonemes are sounds that are created when people speak while visemes are visual phonemes usually known as shapes that represent open/close/narrow/wide mouth (Osipa, 2010). This has been made possible by incorporating basic features of speech training i.e. audio component through amplification, video component by providing pictures, step by step supervision which is flexible and evaluation by providing learner with feedback which enables the learner to see his/her progress.

In learning speech, even hearing children rely on visual movements of the lips as well as hearing. However, some subtle distinctions among speech segments are not visible on the outside of the face. To illustrate this, the skin of the talking head in this system can be rendered transparent so that the inside of the vocal tract is visible or the system can present a cutaway view of the head along the sagittal plane. The orientation of the face can also be changed to display different viewpoints while speaking. The auditory

and visual speech can also be independently controlled and manipulated, permitting customized enhancement of the informative characteristics of speech.

These features offer novel approaches to speech training, permitting one to pedagogically illustrate appropriate articulations that are usually hidden by the human face. The system can speak slowly, illustrate speech articulation by making the skin transparent to reveal the tongue, teeth and palate, and show supplementary articulatory features such as vibration of the neck to show voicing and air expulsion to show frication.

Some of the challenges the system addresses include: saving time since there are several components in one and complacency by breaking routine. This takes care of issues like human fatigue and error among others. It also addresses skill gap since to apply it, teachers do not necessarily require intensive speech training. It contributes immensely to the digitization of education of learners with hearing impairment and addresses financial constraints imposed during manual training. The system is a progressive learning system not limited by time, scheduling e.g. lesson planning, place and age. It caters directly for learner's needs and capabilities.

1.3 Statement of the Problem

Speech and sign language are complementary in meeting diverse communicative needs of learners with hearing impairment, who comprise a heterogeneous group. While the deaf can benefit more from sign language, finger spelling and other elements of manual communication, learners who are hard of hearing benefit more through enhancing their residual hearing, speech articulation, lip-reading and other

elements of oral communication. However, in Kenya the curriculum for speech training was lastly reviewed in 1979 (Kenya Institute of Education, 1979). In comparison of Kenya with South Africa, Dixon (2015) noted that while in South Africa children with hearing impairment were encouraged to use oral methods of communication, in Kenya they are encouraged to use sign language and finger spelling which are understood by only a few members of the society.

Lawal, Karia, Buttars, Larsen, Mulwafu and Mukara (2016) asserted that speech training was a plausible method to improve learners with hearing impairment's ability to communicate verbally. Being a linguistic minority group in the society, verbal communication provides them with opportunities for improved socioeconomic status and inclusion into the larger society. Despite the much emphasis on Kenyan Sign Language (KSL) in the curriculum for learners with hearing impairment and in the Kenyan Constitution (2010), KSL cannot fully meet communicative needs of learners who are hard of hearing.

The current practice of adopting KSL as one of the National languages in Kenya has worked to the disadvantage of learners who are hard of hearing. The practice denies them an opportunity to utilize and enhance their residual hearing, speech and lip-reading skills for communication. The practice assumes that all learners with hearing impairment are homogeneous. This has led to confusion in their school placement. Sometimes they are placed in schools for hearing learners, where they are usually misunderstood, and other times they end up in schools for the deaf where the main mode of instructions is sign language. Both types of placements do not fully address their specific communicative needs. The question therefore, is: To which schools then

do they belong? They are neither deaf nor hearing. How are they expected to perform academically and socially when their specific needs are not addressed? Despite these pertinent challenges, few studies have fully addressed the plight of learners who are hard-of-hearing in Kenya. This study intended to address them by investigating the application of an Automated Speech Training System (ASTS) as an alternative strategy of enhancing speech among learners who are hard of hearing since the current curriculum seems to be skewed against speech training. The study is in line with the vision of Ministry of Education which calls for transformation of teaching and learning to incorporate new pedagogies that are appropriate for the 21st century.

1.3.1 Purpose of the Study

The purpose of this study was to investigate the effectiveness of an Automated Speech Training System (ASTS) in enhancing perception and production of speech among learners who are hard of hearing in selected schools in Starehe and Kasarani sub-counties of Nairobi County Kenya.

1.3.2 Objectives of the Study

The objectives of the study were to:

- i) Establish the level of speech perception and production of learners who are hard-of-hearing before using Automated Speech Training System
- ii) Establish the effects of Automated Speech Training System on speech perception and production among learners who are hard-of-hearing.
- iii) Compare the effects of Automated Speech Training System with traditional methods of speech training on perception and production of speech among learners who are hard-of-hearing.

- iv) Find out the role played by selected demographic factors in the effectiveness of ASTS in enhancing speech among learners who are hard-of-hearing.
- v) Establish the views of learners on communication modes and Speech training using traditional methods and ASTS.
- vi) Find out the opinions of teachers on speech training of learners who are hard-of-hearing.

1.3.3 Research Questions

- i) What was the level of speech perception and production of learners who are hard-of-hearing before training using Automated Speech Training System?
- ii) What were the effects of Automated Speech Training System on speech perception and production among learners who are hard-of-hearing?
- iii) What were the effects of Automated Speech Training System compared to traditional methods of speech training on perception and production of speech among learners who are hard-of-hearing.
- iv) What was the role played by selected demographic factors in the effectiveness of ASTS in enhancing speech among learners who are hard-of-hearing?
- v) What were the views of learners on communication modes and speech training using traditional methods and ASTS?
- vi) What were the opinions of teachers on speech training of learners who are hard-of-hearing?

1.3.4 Research hypotheses

Objectives 2 and 3 were very critical to the current study and in order to investigate them in depth, the researcher formulated two research hypotheses as follows:

Ho1 There is no significant difference in speech production among learners who are hard-of-hearing before speech training using ASTS (pre-test) and after using ASTS (post-test) in selected schools in Nairobi City County.

Ho2 There is no significant difference in speech production between learners speech trained using traditional methods and learners speech trained using Automated Speech Training System.

1.4 Significance of the Study

The findings of this study may provide an alternative way of training speech to learners who are hard of hearing by using ASTS since it is a progressive learning system not limited by age, time, place, and scheduling. Enhancement of speech of learners who are hard of hearing in this study may benefit the individual learner by easing communication with hearing members of the society thereby enhancing his/her social inclusion. It may motivate the learner who is hard-of-hearing as he/she will be completely engrossed and have full control of his/her speech training. The results may contribute to application of Computer Assisted Language Learning (CALL) for advancement of teaching and learning of children with hearing impairment in general. It may also improve learners' ability to use their residual hearing, speech, and sharpen their lip-reading skills in communication. The study has also practical significance as it will explore ways of making speech training sessions more effective and enjoyable, especially for learners who are hard of hearing. It may also open up a range of

approaches for speech training aids that are independent of or complementary to the physical presence of a human trainer. The study may guide curriculum developers at Kenya Institute of Curriculum Development to come up with a specific curriculum of speech training to benefit, among others, learners who are hard of hearing. The findings of this study may influence policy making regarding speech training of learners who are hard of hearing. It is hoped that parents who would wish to speech train their children who are hard of hearing will benefit from the study.

1.5 Limitations and Delimitations of the Study

1.5.1 Limitations of the Study

Enhancement of speech for learners who are hard of hearing was only limited to speech training system since there were other means by which learners may acquire speech such as, maturation and from the environment. The study was confined to learners who are hard of hearing in the three selected schools and therefore, the small size of the sample lead to low generalizability of the results. Speech training took 12 weeks though a longer training period could enhance higher retention of learnt sounds. Due to ethical issues, the study adopted single-subject experimental design which is one of quasi-experimental designs instead of true experimental design and that compromised generalizability of results further. The research instruments developed for the study were confined to selected speech sound segments and interview schedule for the learners and teachers, hence subject to the difficulties associated with such instruments. Additionally, the confidence that could be placed in the views and opinions of the learners and teachers and the reliability of ASTS were not above question.

1.5.2 Delimitations of the Study

There are different categories of learners with speech disorders for example learners with cerebral palsy, learners with speech impediments due to oral-facial disorders or structural anomalies and autism among others. This study focused only on learners with hearing impairment whose speech articulation can be improved by speech training and amplification of sounds. Although learners with hearing impairment are categorized into either hard-of-hearing or the deaf, the study involved only those learners who are hard-of-hearing, since using their residual hearing, amplification and speech training could enhance their speech for communication. Learners who are deaf mostly rely on sign language, finger spelling and body language for communication. The study was delimited to selected primary schools in Nairobi County. Nairobi City being a cosmopolitan area has learners with hearing impairment from different ethnic background and the main language of instruction in schools for learners with hearing impairment is English. The study selected 26 sounds of English Alphabet only since these are the first speech sounds a learner is introduced to in school. Other English sounds, learner's mother tongue and other speech sounds of languages in the environment were not considered for training. Learners with hearing impairment are not taught their mother-tongue formally. Only those learners who are hard of hearing, were willing to participate in the study voluntarily, and whose parents consented to their involvement in the study were speech trained. Parents' perceived opinions about speech training of their children who are hard-of-hearing were not determined since they did not take part in speech training during the study.

1.6 Assumptions of the Study

The study was conducted under the following assumptions

1. Some learners enrolled in the three selected schools for learners with hearing impairment were hard of hearing and had some speech deficits.
2. Learners who are hard of hearing can acquire speech with some training using an automated speech training system.
3. The audio component of the ASTS would amplify the speech sounds to an intensity equal to or above the learners hearing threshold
4. The visual component of ASTS would display visual articulation of all the selected speech sounds
5. Since perception of sound precedes its production, the study assumed that any sound, not perceived during pre-test by an individual learner and hence trained using ASTS would be produced during post-test.

1.7 Theoretical and Conceptual Framework

1.7.1 Theoretical Framework

The study was guided by Mayer's Cognition Theory of Multimedia learning (2001) and Bruner's Constructivist Learning Theory (1991). According to Mayer's cognitive theory of multimedia learning, human beings process information through dual channels; the visual channel that processes visually represented materials and the audio channel that processes audio and text materials (Mayer 2001). Mayer believes that human understanding occurs when learners are able to mentally integrate visual and audio representations of a subject matter as both channels are being activated simultaneously.

In this study, the Automated Speech Training System performed two functions. First, it amplified the speech sounds to the level above each learner's hearing threshold such that the learner could hear the sounds. The learner wore headphones connected to the system through which he/she received the amplified audio content in form of individual sounds (phonemes) and words. Secondly, the system's computer screen displayed the animated talking head showing articulation of individual speech sound and visual presentation of sounds in form of text/word for the learner to see and imitate the articulation. The pictorial representation of how each sound was articulated was done using a 3-D talking-head, which simulated a human head. The talking head was manipulated to display place of articulation for speech sound e.g. the lips, tongue, alveolar ridge and palate. Therefore, as the learner heard amplified sound through the headphones, he/she could view pictorial articulation and visual representation on the computer screen both occurring simultaneously. The two channels reinforced each other to enable a learner who is hard of hearing to enhance his/her speech using the two channels. According to Mayer, learning is dual channel activities, which are visual pictorial channel and auditory-verbal channel. In this study, Automated Speech Training System applied both channels. Visual pictorial articulation on computer screen was processed in the visual-pictorial channel and the amplified speech sound was processed in the auditory-verbal channel. After hearing the amplified sound and observing its articulation on the computer screen, the learner could perceive and imitate production of the sound.

Mayer (2001) also believes that each channel in the human cognitive system has limited capacity in processing information. Therefore in the current study, the

limitations of visual channel were complimented by the audio/verbal channel while limitations of audio channel were complimented by visual channel.

Lastly, Mayer's Cognitive theory of multimedia learning talks of active processing, where learners are involved in active processing in the channels, which includes media selection (sounds and pictures), organizing the media into verbal and pictorial mental model and finally integrating them with pre-existing knowledge which results in meaningful schema acquisition. This happens when corresponding verbal/audio and pictorial representations are in working memory at the same time (Mayer, 2002). The issue of integrating visual and audio information in order to retain it in the long term memory is important in 3-D talking-head learning condition applied in this study. The application had the capability of assisting learners who are hard of hearing to integrate the visual form of the 3-D talking-head with facial expression and lip movement displayed by 3-D talking-head with the audio (amplified speech sounds). Likewise, they were able to store the knowledge acquired from the sensory memory (listening and watching the 3-D talking-head) and working memory (integrating 3-D talking-head and the pronounced sound/word) in the long-term memory and apply it precisely.

The constructivist learning theory approach by Bruner on the other hand claims that learning is an active, creative and socially interactive process in which learners constructs new ideas based upon their current and past knowledge (Bruner, 1991). This theory applies to language learning in which successful language learning is achieved through learner's exposure level towards the language and also their genuine interaction with the language (Pemberton, Fallahkhair & Masthoff, 2005). In a

constructivist-inspired programme, learners are required to perform tasks and solve problems involving listening, reading and speaking to ensure a high level of communication (Pemberton, et al, 2005). Listening, reading/watching and speaking are some of the skills this study was utilizing in enhancing speech among learners who are hard of hearing. The constructivist view point is often strongly associated with communicative teaching approaches, and this has been the basis for many initiatives in interactive computer assisted language learning (Pemberton, Fallahkhair & Masthoff, 2004).

In applying Computer Assisted Language Learning (CALL), the learner who is hard of hearing enhanced his/her speech by constructing new pronunciation based upon his/her current and past knowledge. This was made possible through continuous and successive exposure to speech sounds using ASTS. The system provided communicative teaching approach to the learner utilizing both his/her visual and audio ability. Even though constructivist learning theory is one of the traditional learning theories, it still has an impact on new innovative teaching and learning method such as computer assisted language learning (Craig & Van Lom, 2009). It enables the computer technology to focus on learner's ability to be self-directed and to draw conclusions on the knowledge acquired on their own (Karagiorgi & Symeou, 2005). In the context of this study, the automated speech training system gave learners the luxury to learn at their own pace and to construct a new way of learning articulation of speech sounds by watching, listening and pronouncing the sounds using computer assisted language learning technology.

This theory also directed the study by allowing the targeted learners to focus on their ability to learn without the guidance of an actual teacher at their own learning pace anytime and anywhere. In the current study the 3-D talking-head in the automated speech training system simulates an actual human head. This can be associated with the constructivist theory since according to Hoek (2009), constructivist approach allows the learners to relate the knowledge acquired from the simulation with a similar situation in the real world. For example, the perception and production of speech training experience that the learners acquired from the automated speech training system application could be applied in the real world in pronouncing the same sounds when needed.

1.7.2 Conceptual Framework

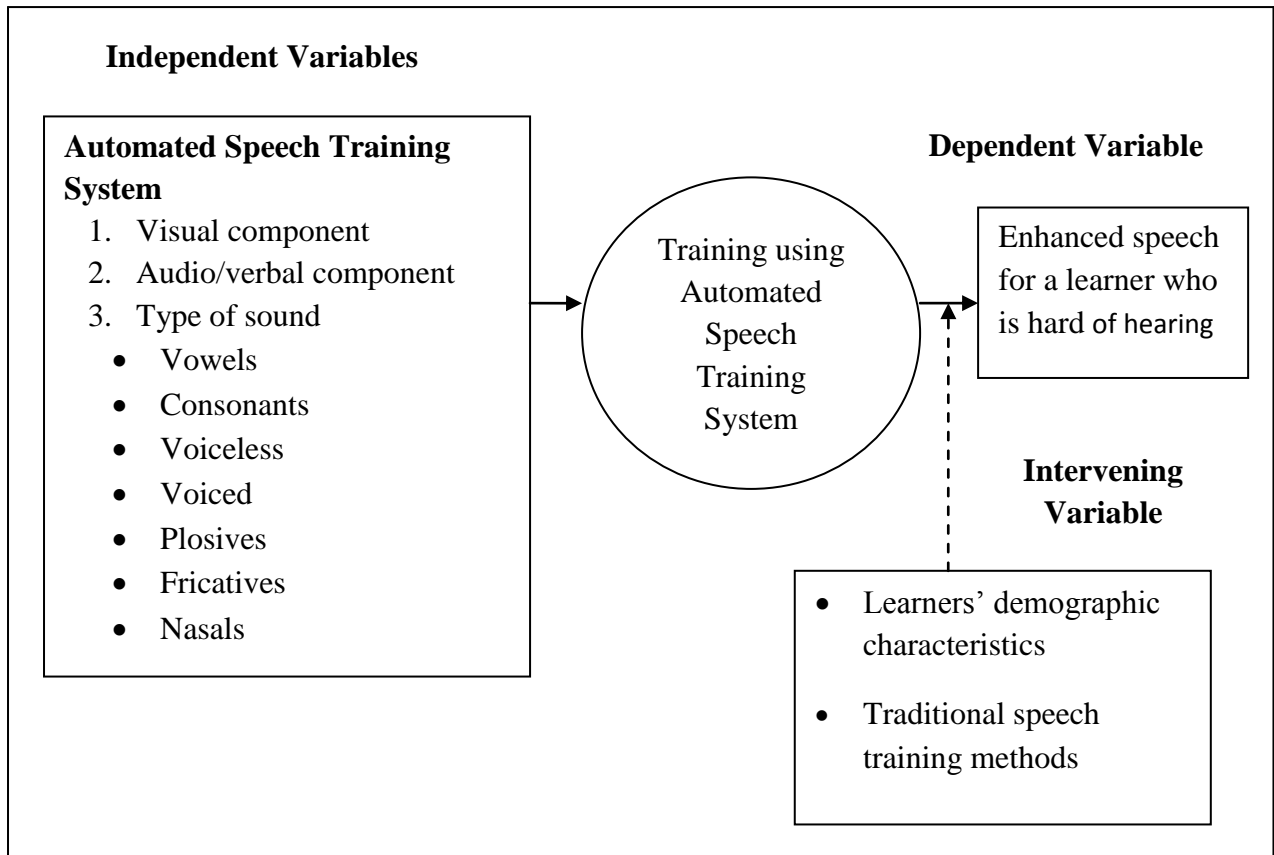


Figure 1.1: A conceptual framework adapted from cognition theory of multimedia learning by Mayer (2001)

The conceptual framework shows how different variables in this study interact. These variables include; independent variable which comprise an automated speech training system. This system has an audio component to amplify the intensity of sound to the level above individual learner's hearing threshold and modulate frequencies for perception and production of each individual sound. The system also has visual component which uses a 3-D talking-head simulating actual human lip formation, and movement, tongue movement and other speech apparatus. The 3-D talking-head displayed lip synchronizing and facial expressions in the articulation of each

individual sound. The learner interacted with the system using visual and audio/verbal channels. Dependent variable was the speech of the learner who is hard of hearing. Enhancement of the speech depended on corresponding manipulation of the automated speech training system. Intervening variables which the researcher could not be able to control included demographic characteristics of the learner and traditional speech training methods.

Based on the theories and the literature reviewed, the study adapted conceptual framework shown above for enhancing speech among learners who are hard of hearing. When the learners utilized 3-D talking-head as their speech training assistant, they perceived the practice in working memory structure via two channels namely visual channel and audio/verbal channel. Facial expressions with automated lip-synchronizing strategy of 3-D talking-head animation were processed in the visual channel, while the pronounced sounds and words were processed in the verbal channel concurrently. By utilizing both channels, the issue of limited capacity was minimized. Besides addressing limited capacity issue, dual-channel activation had potential in promoting active processing in the working memory. When visual and audio speech sounds were processed simultaneously in the working memory, referential or activation of audio system by visual system or vice versa occurred. The learner at this point developed a more accurate mental model of the pronounced sound or word. This helped the learner to process the knowledge acquired from the sensory memory through listening and watching the 3-D talking-head in the working memory through integrating facial expression with lip synchronizing (visemes), pronounced sound or words (phonemes) and prior knowledge for adequate schema acquisition.

Adequate schema acquisition was important for accurate schema formation to be stored on more-or-less permanent basis in the long-term memory. As a result, in the future, when learners come across the same sound or word, they may have improved articulation level of the respective sound or word.

1.8 Operational Definition of Terms

The following terms were used within this thesis and the definitions adopted are outlined below:

Automated speech training system- Use of a computer application in place of a human trainer to speech-train learners with hearing impairment (Massaro & Light, 2004). In the current study, it refers to a system that uses audio and visual components embedded in a computer, simultaneously to speech-train learners who are hard-of-hearing.

Manualism- Education of learners with hearing impairment using sign language, finger spelling and body language (Khairuddin, Miles & McCracken, 2018). In this study, it is a mode of communicating with learners who are hard-of-hearing using finger-spelling, sign language, body language, pantomime and facial expressions.

Oralism- Education of learners with hearing impairment through oral language using lip reading, speech, and mimicking the mouth shapes and breathing patterns of speech (Khairuddin, Miles & McCracken, 2018). For this study, it is a mode of communicating with learners who are hard-of-hearing using speech, lip/speech reading and residual hearing.

Phonemes- Sounds that are created when learners with hearing impairment speak (Allegria & Leechat, 2005). In the current study, it refers to speech sounds that learners who are hard-of-hearing were trained to articulate.

Speech perception- How learners with hearing loss recognize speech sounds and use this information to understand spoken language (Oster, 2010). In the current study, it refers to understanding and discrimination of speech sounds that learners who are hard-of-hearing were trained to articulate.

Speech production- Process by which learners with hearing impairment translate their thoughts into speech and articulation of the resulting sounds using vocal apparatus (Osbrger, Moeller & Kroese, 2007). In this study, it refers to articulation of speech sounds that learners who are hard-of-hearing were trained to articulate.

Speech training- Treatment/intervention to improve the speech of learners who have difficulty in learning to speak due to hearing impairment (ASHA, 2002). For this study, it refers to teaching learners who are hard-of-hearing how to articulate speech sounds.

Suprasegmental- features of speech of learners with hearing impairment, as stress, pitch and length that accompany individual consonants and vowels (Osberger, 2007). In the current study, it refers to different features that accompany actual articulation of speech sounds.

Total communication- a philosophy of educating learners with hearing impairment that incorporates all means of communication (Khairuddin, Miles & McCracken, 2018). In the current study, it refers to use of all available modes of communication to communicate with learners who are hard-of-hearing.

Visemes- Visual phonemes or shapes that represent open/close/narrow or wide mouth when speaking displayed by 3-D animated talking head (Mayer, 2001). For this study, it refers to different shapes displayed by the visual component of the Automated Speech Training System during speech training.

3-D – Talking head - A simulation of a human head manipulated to display movement of sound articulators (Massaro, 1998). In the current study, it refers to virtual teacher in the automated speech training system used for displaying visual articulation of speech sounds.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.0 Introduction

In this chapter, literature was reviewed under the following topics: speech perception and production before training using ASTS, effects of automated systems on speech of learners with hearing impairment, comparison of traditional and automated speech training methods, factors influencing speech production among learners who are hard-of-hearing , views of learners on communication modes and speech training and opinions of teachers on speech training of learners with hearing impairment..

2.1 Speech Perception and Production Before Training Using ASTS

In reviewing literature about Speech perception and production of learners with hearing impairment and particularly who are hard-of-hearing, characteristics of speech among learners with hearing impairment and traditional speech training approaches were reviewed.

2.1.1 Characteristics of Speech among Learners who are Hard-of-hearing

Lack of auditory feedback for learners with hearing impairment leads to a speaking disability in them. Hence, they are unable to speak, in spite of having proper speech production mechanism. Even if a learner with hearing impairment tries to speak by visualizing lip movements, his articulation, accuracy, stress and intonation patterns are affected, since vowels and consonants with tongue movement hidden in the mouth are not distinguishable to him and neither speech intensity nor pitch variations are understood. Depending on the severity of the hearing impairment, either auditory, or

tactile or visual feedback could be provided to the learners with hearing impairment (Wankhede, 2014)

In general, because perception precedes production (Fletcher, Dagenais & Critz-Crosby, 1991), it follows that speech sounds that are most difficult to access auditorily are also more difficult to produce. The oral communication skills of children with hearing impairment have long been of concern to their educators, speech-language pathologists and audiologists because the adequacy of such skills can influence the social, educational and career opportunities available to these individuals (Fordham, 2003; Assefa, 2006). Initially, the area that received the greatest attention among researchers involved articulation of consonants, vowels and diphthongs, but later on investigations involving acoustic characteristics of learners with hearing impairment were carried out.

Until 1980s, little attention was being paid to the speech of children who are hard of hearing. This is largely due to the fact that researchers traditionally had viewed the communication and education problems of the learners with profound hearing impairments as more serious than those of the children who are hard of hearing and, thus, the majority of research effort has been devoted to the children who appeared to have greatest need (Wirz, 2001). It is now known that the presence of even a mild hearing loss can affect speech and language development and interfere with academic performance. Often, children who are hard of hearing are neglected in the public school system (ASHA, 2004). They frequently fail to receive the support services from appropriately trained professionals that they require in order to perform successfully in a regular classroom (Ertmer, 2010). The purpose of the pronunciation

activities for learners who are hard-of-hearing is relative. According to Trezek and Malmgren (2005), learners who are hard-of-hearing must learn to consistently pronounce sounds and words that are reasonable versions of “normal” phonetic production. For example, they learn that, although the movement of the lips is visually similar, the difference between the pronunciation of sounds /d/ and /t/ involves voicing the /d/ and not voicing the /t/.

Of relevance to today’s learners with hearing impairment are the findings of a research study by Ertmer (2010) which showed that, despite amplification and speech training, the speech of individuals with hearing impairment was on average only 20% intelligible. This is because the typical audiological configuration of sensorineural deafness impacts significantly on the perception, hence, the production of spoken language.

A study by Geffner and Rothman (1980) identified common features of the speech of persons with hearing impairment such as consonants being affected more than vowels. Errors included omissions of word-final consonants, fronting/back errors (Martin, Herman, Hirson, Thoma & Pring, 2007); fricatives realized as plosives (Bernhardt, Gick, Bacsfalvi & Ashdown, 2003) and voicing errors (Fletcher et al., 1991). Reduction of consonant clusters and deletion of unstressed syllables have also been reported (Bernhardt, Gick, Bacsfalvi & Ashdown, 2003). Whereas some of these errors are similar to those found in typically developing young hearing children, others are not, examples are where consonants that are less visible on the lips are replaced by other sounds, such as glottal stops (Panteleimidou, Herman & Thomas, 2003). Suprasegmental aspects of speech may also be affected among persons with

hearing impairment: voice quality may be compromised by excess laryngeal tension (Wirz, 2001); resonance may be hypernasal, mixed or cul-de-sac (Boone & McFarlane, 2000); deaf speakers may adopt a higher fundamental frequency compared to hearing speakers. They may exhibit difficulties with use of intonation; rate and rhythm of speech may be affected by the use of lengthened syllables, longer pauses between words and shortened voiced segments (Bernhardt et al., 2003).

Svirsky, Robbins, Kirk, Pisoni and Miyamoto (2000) examined changes in speech intelligibility and speech perception as a result of cochlear implantation. Indeed, the advent of cochlear implantation mostly in young children has had a major impact on the potential for intelligible speech (Moeller, Hoover, Putman, Arbataitis, Bohnenkamp, Peterson & Stelmachowicz, 2007). However, not all children with hearing impairment are equally successful following cochlear implantation and others are simply not eligible for the implants; hence, speech intelligibility continues to be a target for intervention. Earlier interventions emphasized the use of residual hearing with amplification to develop auditory skills and consequently speech production skills (Hogan, Stokes, White, Tyszkiewicz & Woolgar, 2008). In addition, there is some evidence that working on speech production can lead to changes in speech perception (Massaro & Light, 2004). Other than utilizing residual hearing with amplification, the current study added the visual component to improve perception and production of speech sounds.

From various studies it can be concluded that, consonant errors include: voicing errors involving confusion of the voiced-voiceless distinction, substitution errors especially of phonemes with similar place of articulation, substitution errors according to the

manner of articulation, omission of consonants in the initial and/or final position of words and consonant-cluster errors. Acoustic characteristics of consonant production among learners with hearing impairment involve contrasts such as voiced versus voiceless or aspirated versus unaspirated and formant patterns of transition. Learners with hearing impairment have been described as having difficulty in moving their articulators correctly from one phoneme to the next. Errors involving production of vowels and diphthongs in the speech of learners with hearing impairment have been classified as: substitution of one vowel for another, neutralization of vowels, diphthongization of vowels, nasalization of vowels and errors involving diphthongs whereby either the diphthong is split into two distinctive components or the final member of the diphthong is dropped (Geffner & Rothman, 1980). Though these studies have tried to identify common speech problems among learners with hearing impairment, it is important to recognize that each learner with hearing impairment has unique speech impediment which should form the basis of his/her speech training.

According to Oster (2010), diagnosis of individual speech deviations should form the basis of speech training. The first stage involves an assessment of the deviations that should be corrected in order to increase the intelligibility of a child's speech. One of the strategies of addressing speech deficits commonly found among learners who are hard-of-hearing was using traditional speech training approaches which were in place even before the emergence of Computer Assisted Language Learning (CALL) devices.

2.1.2 Traditional Speech Training Approaches

Although there has been a lot of focus on oral language development of learners with hearing impairment, and development of numerous approaches to support it, oral language remains an area of great concern (National Council for Special Education, 2009). Approaches referred to as “oral” or “auditory oral” focus on promoting production and understanding of spoken language and minimizing to various degrees, visual support for language. According to Beattie (2006), sub types of oral education include auditory verbal methods, which aim to build attention to and understanding of language solely via hearing or audition (Hogan, Stokes, White, Tyszkiewicz & Woolgar 2008), as well as traditional oral methods that include an emphasis on using visual information provided by context and lip-/speech-reading along with auditory information.

Natural auralism stresses that learning should make use of audition in naturally-occurring interactions instead of through a more structured approach for building spoken language skill (NCSE, 2009). The maternal reflective method combines the use of written text with use of oral methods and stresses a naturally-occurring conversational approach. Cued speech (Leybaert & Alegria, 2003) is also considered an essentially “oral” method although it uses visual signals presented through specific hand shapes produced in specific locations to represent auditory phonemes to supplement and disambiguate information available from lip-reading and residual hearing. Traditional speech training approaches include; auditory-oral approach, auditory-verbal approach and cued speech.

1. Auditory Oral Approaches

Proponents of the various ‘oral’ methods in education of learners with hearing impairment stress the social, linguistic, and academic access provided by ability to comprehend and produce the surrounding culture’s language (NCSE, 2009). Auditory oral approach focuses on lip-reading/speech-reading to understand the speaker’s message. The primary goal of an oral education approach is to build speech perception, production and general spoken language skills. In addition, spoken language is thought by many (e.g. Mayer & Wells, 1996, Perfetti & Sandak, 2000) to provide an optimal basis for acquisition of literacy skills in that children are expected to make the transition to reading and writing more easily if they can move directly from spoken to printed forms of the same language. Since most young hearing children apply phonological knowledge as a major way to decode print, it is also thought that a thorough grounding in the phonology of the spoken language will enhance deaf and hard of hearing children’s acquisition of literacy skills (NCSE, 2009).

A review by National Council for Special Education (2009) shows that participation in traditional oral programming does not result in deaf and hard of hearing children attaining literacy achievements equivalent to those of hearing peers. The same review indicates that when hearing loss is in mild to severe range, some children make age-appropriate progress using oral approaches. The review further reports that children with profound hearing loss, using hearing and participating in oral programmes, develop spoken language at only 50 per cent of the rate of hearing children. Deaf and hard of hearing children have been noted to have deficits in oral language but the

deficits are less in children fitted early with cochlear implants and also in children identified early with moderate to severe hearing loss (Moeller, Toblin, Yoshinaga-Itano, Connor & Jerger, 2007).

Nicholas and Geers (2007) found that at around three years, whereas the hearing children were using spoken language consistently, deaf children in oral programming continued to use frequent pre-linguistic vocalizations and gestures. Their hearing loss had been diagnosed on average at 12 months, and were said to use speech in only a minority of their expressive communication (about a third of the time). Most speech productions were imitations and not spontaneous communications (Nicholas & Geers, 2007). This clearly shows that without some extra efforts, deaf children will continue to lag behind in terms of speech development. Nicholas and Geers (2008) noted that the tendency to use speech communicatively seemed to be associated with speech perception abilities, so it might be expected that children with earlier diagnosis and use of advanced amplification or cochlear implants would show more rapid development. On the basis of findings of the studies cited in this section, oral approaches to speech and language development can support adequate language development for some but not all children with hearing loss.

In an effort to address the above highlighted speech challenges, the current study investigated the use of ASTS as an alternative advanced amplification to enhance speech perception and production abilities among learners who are hard of hearing. Nicholas and Geers (2007, 2008) presented evidence that children who had received cochlear implants before 24 months and who participated in either traditional oral or auditory-verbal programmes in which reliance on visual input was de-emphasized

developed language abilities by age 4½ at levels within the typical range documented for hearing children. However, all children studied by Nicholas and Geers had non-verbal cognitive functioning in at least the average range. Secondly, they came from families in which English was the only spoken language. The hypothesis in the current study was that when a child who is hard of hearing uses visual and audio ability to acquire speech, his/her perception and production can improve significantly.

2. Auditory-Verbal Approach

Auditory-verbal approach differs from auditory-oral approach due to its decreased attention to visual accompaniments of auditory input. It emphasizes mainly the child's listening abilities to learn spoken language. Its proponents are of the view that it is a therapeutic approach typically conducted by highly-trained specialists with children during pre-school years (Ericks-Brophy, 2004). It aims at having the children acquire spoken language skills appropriate for their chronological age by the time traditional schooling begins at age five or six (Ericks-Brophy, 2004; Rhoades, 2006). Ericks-Brophy (2004) and Rhoades (2006) undertook reviews of available evaluative information and concluded that although case study and descriptive-level evidence supported the approach, no existing studies had employed designs rigorous enough to produce evidence-based judgments of its effectiveness.

National Council for Special Education (2009) reports that responses to surveys distributed to various graduates of auditory verbal therapy from America, Canada and Swiss parents provided qualitative evidence of positive developmental outcomes. Most participants were said to have average to high literacy levels and to interact primarily in mainstream or hearing environment. Although these studies show an

estimate of satisfaction of participants in auditory-verbal therapy, and the reports of high evidence of mainstreaming and age-appropriate reading skills are consistent with its aims, samples in all cases were self-selected and survey data obtained were retrospective and inherently subjective. Also in these studies, the council was of the view that participants tended to achieve high-level literacy skills than typically reported for the deaf or hard of hearing learners. The studies either provided no normative information with which to compare the auditory-verbal instruments for data collection.

In investigating the effectiveness of an automated speech training system, the current study used experimental design to enhance speech among learners who are hard of hearing. The learners who are hard of hearing were sampled purposively in the selected schools. Though the auditory-verbal approach does not advocate the use of visual accompaniments, the current study combined both visual and auditory inputs in enhancing speech.

In their study, Easterbrooks and O'Rourke (2001) found that using auditory verbal approach; language and literacy levels of the boys fell, on average, 3.8 years below what would be predicted from a non-verbal measure of cognition. Girl's language/literacy scores fell 2.7 years below predictions based on the non-verbal measure. Easterbrooks and O'Rourke who were primarily interested in gender related differences noted that language and literacy performance were associated with aspects of child attention behaviours and aided (amplified) hearing levels. Other variables suggested to relate to progress but not controlled in their study included age of identification, entry into and duration of time in the programme. The current study

also sought to establish whether there was gender difference in enhancement of speech using ASTS among boys and girls.

From various studies documented by national Council for Special Education (2009), auditory-verbal approach is available approach for some deaf and hard of hearing children whose families choose to focus on spoken language development instead of sign language. However, auditory verbal therapy seemed to be most successful with children from fairly highly educated families who remained intensely involved with training approach and who have high expectations for spoken language development. The council pointed out that despite reports of children who acquire spoken language at near-typical rates, many in auditory-verbal therapy programme do not. Further, the council noted that though the approach is among the viable choices, certainly it is not the only one available to families based on their goals for their children.

The ASTS in the current study aimed to supplement other speech training approaches which seemed to be more manual requiring more time and concentration. The ASTS can be used in different platforms like desk-top computers, lap-top computers, tablets and even some modern smart mobile phones.

3. Cued Speech

According to National Council for special education (2009), Cued speech was developed by Orin Cornett (1967) to provide deaf and hard of hearing children access to the phonology of spoken language and thus to promote acquisition of literacy skills. Recognizing that a mere 20-30 percent of the sounds of English can be reliably determined from watching the lips (Speech reading) Cornett developed a set of

manual signals differing in hand/shape and in the location of production that would effectively supplement and disambiguate information available from observing lip shape and movement. Cued speech signals represent auditory-based phonemes (sounds) and not semantic characteristics or meanings. It is meant to be produced concomitantly with spoken language and results in an integration of information pointing to a single, unambiguous, phonological effect that cannot be obtained from either source alone (Hage & Leybaert, 2006). According to Marschark (2001), Cued speech is more popular or at least more peer-reviewed in countries in which French or Spanish is the dominant language. In USA, its use has decreased and there is little research or evidence-based evaluation information available for cued English.

Hernandez, Montreal and Orza (2003) compared deaf children using Cued Spanish, those in other traditional oral programmes, and those using Spanish sign language with a group of hearing children. They concluded that the combination of visual cues and speech-reading made small but important Spanish grammatical morphemes perceptually salient for deaf children and thus allowed them to develop higher levels of competencies. Some of these skills were utilized in the current study like combining both visual and audio skills in acquiring speech sounds. Cued speech requires relatively fine motor movements and production of hand shapes in location that may not be visible to the Cued. In the current study the ASTS displayed the invisible speech organs through the use of a 3-D talking head.

Hage and Laybart (2006) reported improvement by children who used cued speech and had cochlear implants. The children had more auditory access to spoken language than was typically the case without implants. Despite improved auditory access, a

number of researchers have pointed out that the signals received from cochlear implants were not as clear as those received by hearing children (Holt & Svirsky, 2008; Pisoni, 2000; Spencer & Marschark, 2003). In the current study the ASTS amplified the sound to the hearing level of each individual learner who is hard of hearing.

Finally Mashark (2007) noted that despite the success associated with cued speech in supporting literacy skills in children who learn French, Cued speech has never been shown to provide similar support for literacy skills in English. This is likely because of the lesser transparency of sound-to-spelling correspondence in English compared to French and Spanish (Alegria & Lechat, 2005).

From the literature reviewed, it is evident that learners who are hard-of-hearing have speech impediments as a result of the hearing impairment. Despite numerous efforts to address the impediments using traditional speech training approaches reviewed, none of the approaches has exhaustively addressed them. Therefore, other avenues need to be explored to mitigate them hence the intention of this study to investigate the effectiveness of an automated speech training system in addressing those impediments.

2.2 Effects of Automated Systems on Speech of Hearing Impaired Learners

Assistive technology is one means by which learners experiencing speech deficits due to hearing loss can be assisted. Along with the evolving technology already in use (e.g. hearing aids and cochlear implants), technological advancement can potentially provide individuals who are hard of hearing with some of the help they need to

perceive and speak more intelligibly. Since speech training is a labor-intensive task, requiring endless hours of one-on-one training between the learner and the teacher, interactive technology may offer a promising and cost-effective means to improve the perception and production of speech of learners who are hard of hearing. Tailoring training lessons based on the specific needs of the learner allows for learner centered instruction, increased time on task, speech training outside of the classroom and treatment setting, and ideally increased competence and confidence in perceiving and producing speech sounds (Martin et al., 2007). Advances in the Information and Communication Technology (ICT) have changed the roles of language teachers and learners. Massaro (2006b) asserts that using computer technology as a tool can increase the language learner's self-esteem, vocational readiness, language proficiency and overall academic skills.

Speech and language science evolved under the assumption that speech perception was solely an auditory event (Massaro, 2006b). However, a burgeoning record of research findings reveal that our perception and understanding are influenced by a speaker's face and the accompanying visual information about gestures, as well as the actual sound of the speech (Massaro, 2006a; Trezek & Wang, 2006). Perceivers expertly use these multiple sources of information to identify and interpret the language input. Information from the face is particularly effective when the auditory speech is degraded because of noise, limited bandwidth, or hearing loss. The combination of auditory and visual speech has been called super additive because their combination can lead to accuracy that is much greater than the sum of the accuracies on the two modalities presented separately (Massaro, 1998). Furthermore,

the strong influence of visible speech is not limited to situations with degraded auditory input. A perceiver's recognition of an auditory-visual syllable reflects the contribution of both sound and sight.

In addition to the information value of visible speech, another reason why the use of auditory and visual information together is so successful is complementarity of auditory and visual speech, which means that one of the sources is most informative in those cases in which the other is weakest. Due to this, most speech distinctions are differentially supported by the two sources of information. That is, two segments that are robustly conveyed in one modality are relatively ambiguous in the other modality (Massaro, 2003). For example, the difference between /ba/ and /da/ is easy to see but relatively difficult to hear. On the other hand, the difference between /ba/ and /pa/ is relatively easy to hear but very difficult to discriminate visually. The fact that two sources of information are complementary makes their combined use much more informative than would be the case if the two sources were non-complementary or redundant (Massaro & Light, 2003).

Massaro and Cohen (1999) concluded that research from several different places has shown that both children and adults with hearing loss benefit greatly from having visible speech presented jointly with the necessary degraded audible speech. Although individuals with hearing loss have less auditory information, they integrate information in the same optimal manner as those with typical hearing. There is also some evidence that individuals with hearing loss become experts in speech reading (Bernstein, Demorest & Tucker, 2000).

These positive findings encourage the use of multi-modal environments for persons who are hard of hearing. Ling (1999), however, reports that clinical experience seems to show that children taught exclusively through a multisensory approach generally make less use of residual audition. For these reasons, speech trainers might use bimodal training less often than would be beneficial. The working hypothesis of this study is that visible speech as well as auditory speech can be productively included in the training of speech perception and production hence the purpose for amplification as per individual learner's hearing needs and visual articulation of speech using 3D-animation technology.

Massaro (2003) made a great contribution by experimenting use of visible speech to train perception and production of speech for individuals with hearing loss. The findings of the study showed that speech perception and production improved for each of the 7 learners. In his study, Massaro did not establish the speech deficits of each learner before training. Instead, the researcher enquired from the teachers speech deficits each learner had. Therefore, there was a possibility that some learners may have been trained speech sounds they had already acquired. The current study intended to establish speech deficits of each learner through a pre-test before training as recommended by Oster (2008). The system amplified the sounds and directly illustrated the vocal tract and articulators during speech production and used this information to facilitate the learning of speech perception and production of learners who are hard of hearing.

Learners who participated in Massaro's study were sampled from mainstream regular schools, where oral language was the main method of communication in the

classrooms. In addition, the learners used to receive the services of regular teachers and speech-language pathologists. There is a possibility that learners' acquisition of speech sounds could have been influenced by those two factors. The current study sampled learners from classes of learners with hearing impairment in order to minimize the possibility of environmental influence on speech acquisition. During the training in Massaro's study, all the sampled learners were trained on the same set of speech sounds regardless of individual speech deficits. In the current study, the Automated Speech Training System established speech deficits of individual learner before training. In Massaro's study, the speech sounds to be trained in were provided by their instructors though most of them had been identified as general problematic for all learners with hearing impairment. During the training, learners wore their hearing aids but in the current study the system amplified the sounds and also did the training.

Assefa (2006) developed a speech training system for training articulation of Amharic speech sounds. In Assefa's study, 70% of the learners sampled were able to produce sounds articulated on the lips accurately. Automated Speech Training System in the current study trained selected English speech sounds. Assefa's study proposed a device that could be used to analyze the articulation of the vocal tract, the eye gaze and part of the face around the mouth. Further, the model was only able to display visible articulators like lips, teeth and tongue and therefore proposed a system that could display other articulators to make speech for learners with hearing impairment more visible. These proposals by Assefa were addressed in the current study. Like in Massaro's study, the learners sampled in Assefa's study were integrated in regular

school thereby giving the learners advantage of learning speech from the environment. From the literature reviewed, a good attempt has been made to address speech deficits among learners with hearing impairment using automated systems but it is evident that more needs to be done. The present study intends to address the already identified gaps in the already developed automated systems.

2.3 Comparison of Traditional and Automated Speech Training Methods

Traditional speech training also known as teacher/therapist assisted mostly is based on methods that aim at assisting the learner to learn speech by simply looking at the teacher/therapist face and lips. The learner is expected to make maximum use of his/her residual hearing and also feel the teacher's/therapist's face, throat and expiration of air among other techniques in order to establish an orosensory motor control of his/her speech movements (Oster, 2010).

Traditional approaches of remediating speech sound disorder often rely on tactile (e.g. physical stimulation) and auditory feedback. However, some individuals are resistant to traditional therapy and may benefit from treatment that involves additional types of feedback (Fletcher et al., 1991). These alternative approaches to therapy may include the use of visual feedback to help a learner correct his/her speech. In typical speech development, movements become habituated during the first few years of life (Ertmer, 2010). This pattern of development allows even relatively young speakers to converse rapidly and focus on expressing ideas, rather than the specific mechanical movements needed for each speech sound or word. Typically, children use auditory feedback to self-monitor and fine-tune their speech productions to match the speech sounds they hear in their environment (Pickett, 2013). Teachers and speech therapists

use this auditory feedback loop in assisting children adapt their own productions to match the teacher's/therapist's correct productions. Speech therapists may also give verbal cues on how the child can manipulate the articulators to where placement occurs during correct sound production.

Speech therapist also commonly uses tactile cueing to assist children with speech sound disorders. Once incorrect speech sound production is acquired at an early age, it creates habitual motor patterns that can be very difficult to the individual to change at a later age of development (Pickett, 2013). Tactile cueing aids in breaking habitual speech by providing information to the speaker about where movements begin and how they should be produced, which ultimately improves motor planning and execution for later habituation of correct sound production (Marschark, 2007). In traditional articulatory therapy, children are given verbal instruction for lingual positioning in the oral cavity for sounds. However, some children may not conceptually understand commands given by verbal instructions alone. Using only auditory feedback in the treatment of speech sound disorders may be unsuccessful because clients have an incorrect perceptual model of the sound, thus additional cueing modalities, such as visual presentation of sound, may be needed to increase both oral and lingual awareness prior to achieving correct speech sound production (Pickett, 2013). Traditionally, tactile cueing has been provided through methods as simple as touching a child's articulators with a gloved finger or a drinking straw to indicate the correct placement of the tongue or lips for a particular sound. However, tactile cueing during therapy has also involved custom-made devices such as

removable acrylic plates or specialized cueing tools such as speech buddies (Ertmer, 2010).

Using multiple feedback modalities within treatment e.g., combining tactile, auditory and visual feedback may increase the initial learning and retention of correct speech sound production (Pickett, 2013). In a three-study review, Ruscello (1995) found that when more than one mode of feedback was used to treat speech sound disorders, the efficacy of therapy increased. In addition to auditory and tactile feedback, commonly used in traditional approaches to therapy, visual feedback can also facilitate correct speech production (Bernhardt et al., 2003). Visual feedback can be provided to a client through a number of different therapy techniques, ranging from using a mirror to show lip movement to Electropalatography (EPG). A great deal of progress has been made in EPG technology ranging from non-electric to electric palatography to obtain a visual display of a client's articulation. According to Dagenais (1995), EPG can assist in the remediation of specific types of speech sound disorders.

In particular, EPG therapy may be valuable in treating speech sound disorders secondary to hearing impairment. Individuals with hearing impairment often have difficulty perceiving the auditory characteristics of speech sounds, which is the primary means of cueing during traditional therapy. Reviewing whether EPG therapy was more effective than traditional means of therapy in treating speech sound disorders for individuals with hearing impairment, Dagenais (1995) took two groups of nine children with hearing loss and gave them either EPG therapy or traditional aural-oral therapy. Results indicated equal improvement in articulation intelligibility for both groups a 3-4 week period. However, individuals who participated in EPG

therapy produced better consonant linguapalatal contact patterns and higher scores on listener identification ratings than those in the traditional group, whose contact patterns were also measured using EPG. A study by Bernhardt and others (2003) indicated that using EPG-enhanced therapy, adolescents with hearing impairment significantly improved their productions of the consonants /t/, /d/, /k/, /g/, /s/, and /z/ in a 3-4 week period of time. Pickett (2013) reported that severity of the speech disorder was not a predictor of EPG therapy success.

In comparison of speech training methods with deaf adolescents, the effects of speech training using computerized display speech training were examined and compared to the effects of non-computerized display speech training ASHA (2001). Comparisons between the two approaches were accomplished by determining how frequently each method resulted in improvement and maintenance of improvement. Each of the four subjects selected for the study demonstrated improvement under both forms of speech training in a relatively short time.

Coleman, MacLauchlan, Cihak, Martin and Wolbers (2015) compared teacher-provided and computer-assisted simultaneous teaching of vocabulary development among three students who are deaf or hard of hearing. In their findings, for two students, computer-assisted instruction was equally effective as teacher-provided instruction. For the other student, computer-assisted instruction was not effective at all in improving vocabulary. They attributed this to the student's learning style. Computer-assisted instruction has been demonstrated to be effective for teaching many types of skills to learners who are deaf or hard of hearing (Barker, 2003; Massaro & Light, 2004). While weighing amount of time spent on using technology

for vocabulary instructions, Barker (2003) criticized the technology for being more than an expensive, high-tech memorization tool and expressed the belief of many teachers and speech pathologists that their potential cannot be ignored.

Oster (2010) experimented a computer-aided speech training device known as speech viewer in schools for the deaf as well as in the pre-school training of severely hearing-impaired children in Sweden. The results of the experiment showed that the speech viewer, when used as a supplement to traditional speech training methods offered by the therapist, was an objective and effective tool in helping to increase the intelligibility of the speech of deaf children. Further, the experiment with speech viewer showed that computer-aided speech training may as well be used as a valuable expansion of traditional speech training of severely hard-of-hearing children. However, Oster (2010) pointed out that even the best computer programme could never replace a therapist, but only assist in his/her work. Computer-based speech training should be a compliment to traditional methods and a powerful tool for those therapists who in addition to mastering the technique are competent in articulatory and acoustic phonetics (Oster, 2010). Oster concluded that computer-aided speech training is a complement to traditional methods and has a pedagogical value for the therapist who has a good knowledge of articulatory and acoustic phonetics as well as of the computer technique.

While examining different speech training aids for learners with hearing impairment, Bernstein, Goldstein and Mahshie (2002) cautioned that engineering efforts alone are unlikely to result in intelligible speech by the deaf. They anticipated that if the speech training aids are to be effective, they must be used with a therapist working within a

curriculum. Development of such a curriculum requires carefully planned and executed clinical investigations. Thus, favorable technological climate must be regarded as only necessary, but not sufficient, context for development of speech training aids for the deaf.

Similarly, Sugano and others (2014) while describing a speech trainer that used personal computer to support teachers in schools for the deaf and gained high efficiency cautioned that a speech training system cannot substitute the teachers in school because teaching must be conducted by a teacher. From the comparisons reviewed, both traditional methods and automated systems have contributed to enhancement of speech among learners with hearing impairment. In the current study, speech perception and production of learners who had formal prior speech training using traditional methods was compared to speech perception and production of learners who had not experienced formal speech training, hence were trained using ASTS only.

2.4 Factors Influencing Speech Production Among Hard-of-Hearing Children

Several neuropsychological and neuro-imaging studies on gender differences in speech processing suggest that females use the neuro network of predictive and integrative analysis of speech to a larger extent than male (Stelnikov, Rouger, Lagleyre, Fraysse, Deguine & Barone, 2008). In their study, they observed that female speech-read words better than male. However, they did not observe any gender differences during speech-reading of isolated phonemes and concluded that the better speech-reading ability of female for words but not for phonemes was in line with their greater use of predictive and integrative strategies for speech processing.

In their study, Tobey, Geers, Brenner, Altuna and Gabbert (2003) female subjects with hearing impairment produced more accurate consonant production (71.0%) than male subjects (65%). However, it is important to note that in their study no difference was noted between male and female subjects in vowel production, 61.1% and 62.1%, respectively. In conclusion, Tobey and others (2003) asserted that speech production performance in children is influenced by nonverbal intelligence, gender, intervention characteristics including the length of time using the newest speech processing strategies and educational programs emphasizing oral-aural communication. Factors previously thought to be major contributors to speech production performance, such as age of onset of deafness and age of intervention did not appear to play significant roles in predicting levels of speech production performance in their study.

According to Yoshinaga-Itano (2003), in the journal of Deaf studies and Deaf Education, early identification/intervention predicts better language development. Better language development predicts better speech intelligibility. In a study of 147 children between ages 14 and 60 months, Yoshinaga-Itano and Sedey (2000) found that the primary predictors of speech development of deaf and hard of hearing children in order of influence were chronological age, expressive language development, degree of hearing loss, and mode of communication (i.e. oral or manual). They reported that mode of communication accounted for a very small amount of variance in speech production after the variance accounted for age, expressive language development, and degree of hearing loss. Degree of hearing loss was a significant predictor of the variance in number of vowels types, number of consonant types and overall speech intelligibility. Age of the child and expressive

language accounted for a greater proportion of the variance in speech production than degree of hearing loss. However, Calderon (2000) reported that degree of hearing loss was a significant predictor of speech production. Yoshinaga-Itano (2003) reported that vowel production and consonant production were better for children with more hearing.

According to Oster (2010), it is a general opinion that there exists a very close relationship between degree of hearing loss and speech intelligibility of deaf learners. Poor speech accompanies higher hearing loss. In her study of 11 deaf children, Oster (2010) has shown that the articulation of a deaf child's speech was significantly correlated with his or her degree of hearing loss and that speech articulation decreased with increasing hearing loss until a loss of about 90dB.

Globally, the philosophy of total communication guides the communication for persons with hearing impairment. It incorporates all means of communication which include speech, speech reading and sign language among others. In a study by Yoshinaga-Itano and Sedey (2000), mode of communication used in the family accounted for a very small amount variance in speech production of children with hearing loss. The participants in that study included children with mild to profound hearing loss. For children with severe and profound hearing loss who developed intelligible speech, 50% of the severe hearing loss group had families who had chosen sign language, and 50% were in families who had chosen oral speech only. Only 2 children of 34 children with profound loss developed intelligible speech by age 5 and had families who had chosen an oral-aural approach.

Various predictors of speech development among learners with hearing impairment have been discussed in the reviewed literature. In the current study, the researcher aimed to find out whether some selected demographics had any effect in speech training using ASTS.

2.5 Views of Learners on Communication Modes and Speech Training

In a study on deaf learners' experiences in Malaysian schools, Khairuddin, Miles and McCracken (2018) report a case of one learner with profound hearing impairment introduced to speech therapy and amplification using hearing aid early in life. This intervention enabled him to attend a local school for the hearing learners with his siblings following the speech therapist's recommendation. According to the learner's experiences in school, the teachers spoke too quickly which made it difficult for him to hear hence he had to always focus on teacher's lips. The learner admitted that it is because of the dedicated support he received from parents and teachers' extra tuition that helped him to maintain his hearing aids, learn to speak and achieve academically in the examination-focused education system.

Another learner with hearing impairment in the same study was fitted with hearing aid at the age of three. She had regular speech therapy but stopped wearing hearing aid at the age of ten because she did not find them useful. She attended a regular school for hearing learners but learnt sign language. She could use sign language to communicate with deaf people but could also use speech to communicate with her mother. Being able to hear spoken language at an early age probably helped her to establish proficient sign language skills and fully participated in the education system (Leigh & Johnston, 2004). However, the girl relied on written communication with

people who do not know sign language. The girl's experience highlights the importance of gaining literacy skills as they have profound and lasting repercussions for the lives of persons with hearing impairment (Leigh & Johnston, 2004). Another experience reported by Khairuddin, Miles and McCracken (2018) is of a twelve year old boy who has worn hearing aids since he was two years old when he became deaf as a result of severe jaundice. His mother wanted him to speak, so she sent him to a mainstream school where he had no support from a qualified teacher of the deaf. After four years the mainstream teachers advised the mother to take him to a special school for the deaf since he could not keep with the fast pace of the lessons. In special school he received support from two qualified teachers of the deaf, the curriculum was less challenging, and the class had only three learners. The boy was taught sign language and could communicate with his two deaf classmates and participate in the lessons. He became proficient in sign language and speech, although sign language was dominant. According to Mayer (2008), regular exposure to an accessible language, and meaningful interactions with others who are capable users, is essential for deaf children to become literate enough to benefit from formal education.

In a study by Hsing and Lowenbraun (1997), sixteen learners were interviewed on their preferences on teaching modes used by their teachers. Most of the learners preferred that teachers use some combination of speech and sign language. 44% preferred teachers to use speech plus natural sign language and 38% preferred teachers to use speech plus grammatical sign language. The literature reviewed showed that both manual and oral methods of communication play an important role in the life of a person with hearing impairment and especially learners who are hard-

of-hearing. This study intended to contribute to speech training which is lacking in the current curriculum for learners with hearing impairment in Kenya.

2.6 Opinions of Teachers on Speech Training of Hearing Impaired Learners

According to Gravenstede (2009), the method of communication used in teaching learners with hearing impairment has an effect on the learner's academic performance. After a long controversy between proponents of manual and oral communication modes for the learners with hearing impairment, the modern school of thought settled on the philosophy of total communication.

The philosophy allows use of any available means to communicate information, experiences and ideas to learners with hearing impairment. In Kenya, the philosophy has become the communication policy for teaching learners with hearing impairment. However, teachers have divergent views regarding what to emphasize in total communication. For instance, Hsing and Lowenbraun (1997) suggested that schools for the deaf should emphasize speech training and speechreading training for the deaf students. The students would then learn natural sign language and consequently, parents and teachers would become more accepting of natural sign language, thus develop a bilingual curriculum incorporating use of speech and sign language. In their study on teachers' perceptions and actions in carrying out communication policies in a public school for the deaf, Hsing and Lowenbraun (1997) found that total communication was advocated for but not well used in the school.

Total communication was viewed as an umbrella term covering a variety of methods, teachers felt able to use any method according to their personal interpretation of the

total communication philosophy. In Hsing and Lowenbraun (1997) study, interview results indicated that the communication modes teachers at the elementary school level thought they were using were the mandarin oral manual system and total communication. Speech plus grammatical sign language and speech plus grammatical sign language plus natural sign language were used by junior and senior high school teachers. In comparison of deaf and hearing teachers concerning their perception of their own communication competency, deaf teachers felt more competent than hearing teachers in expressive and receptive communication and in natural sign language. Deaf teachers also felt more competent than hearing teachers in grammatical sign language. Conversely, hearing teachers felt more competent in speech and sign communication. Teachers believed that the most appropriate communication mode for the first and second grades was the mandarin oral-system, and that total communication was most appropriate for third grade and above (Leigh & Johnston, 2004).

The most commonly used modes of communication by the teachers were speech plus grammatical sign language, grammatical sign language only, and speech plus natural sign language. Additionally, the teachers indicated that speech training should be strengthened at the elementary school level and, if possible, used through high school.

In a study in Malaysia by Tee (1990), teachers were asked to give their professional opinions regarding the most effective method of teaching the hearing-impaired learners according to the degree of hearing loss (mild, moderate or severe). There was an overwhelming choice for total communication. Two-thirds or more of the teachers cited total communication as the most effective way of teaching deaf children

irrespective of the degree of hearing impairment. 13.5% were of the opinion that oral method was more suitable for the mildly hearing impaired learners than for moderately or severely hearing-impaired learners. More teachers felt that sign language and finger spelling was more appropriate for the severely hearing-impaired learners than for the mildly or moderately impaired learners. More teachers felt that oralism combined with cued speech was effective in teaching mildly hearing-impaired learners compared to severely hearing-impaired learners.

From the literature reviewed, teachers' opinions are in favour of total communication philosophy in teaching learners with hearing impairment. Speech, being a component of total communication was preferred than sign language in instances like elementary grades of learning and for learners with mild hearing loss. However, documentation of opinions of teachers who teach learners with hearing impairment in Kenya regarding communication modes is quite limited. The focus of the current study was to seek opinions of teachers in relation to learners who are hard-of-hearing whose hearing loss is mild and moderate.

2.7 Summary of Literature Review

In this chapter, literature was reviewed on speech training according to the objectives formulated to guide the study. Different references were critically examined and analyzed, majority of which were derived from primary sources. The review clearly showed that research on speech training of learners who are hard-of-hearing specifically using automated systems has been conducted globally but very limited in Africa and in particular Kenya.

Some of the research and knowledge gaps identified in the related literature reviewed deserve urgent attention since speech enhancement is crucial in the academic and social life of the learners who are hard-of-hearing. For instance, existence of hearing impairment of any degree affects different aspects of speech production among learners who are hard-of-hearing. However, despite numerous speech impediments associated with learners who are hard-of-hearing, they are yet to be addressed in Kenya since the current curriculum does not cater for their speech training even using traditional approaches which have been used in other countries with some degree of success. Clearly, the literature reviewed demonstrated significant success in speech training of learners with hearing impairment using automated systems in other countries. However, speech training of learners who are hard-of-hearing using automated systems to supplement traditional speech training methods in special education institutions in Kenya is yet to be documented. Therefore, this was a study gap that deserved systematic investigation, analysis and documentation in Kenya.

Closely related to these knowledge gaps was the need to compare the effects of the already documented traditional speech training methods with the effects of automated speech training method. From the literature, both methods have shown positive results in enhancing speech among learners with hearing impairment. Despite the positive results, none of the comparisons has been undertaken in Kenya. Some demographic factors like gender and age have been found to influence speech production of learners with hearing impairment. The current study aimed to find out whether demographic factors had any influence in speech enhancement of learners who are hard-of-hearing during training using ASTS. Other gaps identified in this chapter of

literature review that needed to be filled through research in Kenya included: views of learners who are hard-of-hearing towards speech training using traditional and automated system, and also teachers opinions on speech training learners who are hard-of-hearing since the current curriculum in Kenya emphasizes the use of total communication but in practice its skewed towards manual communication. Studies seeking opinions of learners with hearing impairment and particularly learners who are hard-of-hearing and their teachers' opinions are limited. Such studies would contribute in informing the policy regarding curriculum development for learners with hearing impairment and precisely learners who are hard-of-hearing.

The present study addressed these issues to a large extent. Since limited research in this field has been accomplished in the African context, especially in Kenya, the present study sought to fill that void in the existing literature by investigating the effectiveness of an automated speech training system in Nairobi City, Kenya. As described in the next chapter, the system was developed for the study designed to answer six research questions.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

The discussion on this chapter focused on research design, variables, location of the study, target population, sampling techniques and sample size, research instruments, piloting, validity and reliability, data collection techniques, data analysis techniques and logistical and ethical considerations.

3.2 Research Design

The study adopted a mixed research design combining a single-subject experimental design and descriptive survey design. According to Ary, Jacobs, Sorensen and Walker (2014), mixed methods research combines quantitative and qualitative research methods in different ways, with each approach adding something to the understanding of the phenomenon under study. Mixed method was employed for the purpose of complementarity in which single-subject design (quantitative) was complemented by participants' interview (qualitative). Using the mixed design, the researcher was able to train and test speech sounds the learners had acquired using ASTS and at the same time seek their opinions about the whole process.

Mixed design provided the researcher with answers to the research questions raised in testing the effectiveness of ASTS. The goal of mixed method research is not to replace quantitative or qualitative approaches, but rather to combine both approaches in creative ways that utilize the strengths of each within a single study (Tashakkori & Teddlie, 2008). Complimentarity involves seeking elaboration, illustration,

enhancement, or clarification of findings from one method using results from another (Ary, Jacobs, Sorensen & Walker (2014). Thus, different approaches were used to measure different facets of a single phenomenon. The quantitative data gathered using ASTS on speech enhancement of learners in this study was mixed with qualitative data gathered through interviews. Learners were interviewed on their preferred communication mode and their perceptions on ASTS. The teachers were interviewed on their opinions regarding speech training learners who are hard-of-hearing. The learners, being the first consumers of the automated speech training system, were evaluating the system by giving their views on its effectiveness.

Single-subject experimental design combined with descriptive survey design enabled the researcher to measure the participant's behavior when the treatment was not present (pre-test) and again when the treatment was present (post-test) as suggested by Ary, Jacobs, Sorensen and Walker (2014). The design was considered for this study because according to Kourea and Lo (2016), single subject research design is particularly beneficial and suitable in education since it is appropriate for systematically testing an intervention and its associated variables using a small number of participants before it is tested in a large scale in a group comparison format. In practice, researchers often have difficulties finding a large group of participants, particularly those with special characteristics especially with certain types of disabilities, and with similar profiles (Kourea & Lo, 2016) hence its choice for this study. The design allowed the researcher to compare the performance of learners who are hard of hearing prior to intervention and after intervention. Single-subject research design has been recommended by Odom and Strain (2002) for

providing useful information and evidence based-based practices particularly in the field of special education. Ary, Jacobs, Sorensen and Walker (2014) recommended single-subject research design in educational research and added that it is particularly useful in clinical applications in which the focus is on the therapeutic value of an intervention for a client. In this study, the focus was on the effectiveness of the automated speech training system as a form of therapy for enhancing speech of learners who are hard of hearing in the selected schools.

Descriptive survey was found appropriate for combining with single-subject in this study because it helped the researcher to collect data based on views of learners who are hard-of-hearing after undergoing speech training using ASTS. For example, during the interview, the learners were able to pinpoint what they liked about the system and also suggested areas of improvement. Descriptive survey is concerned with determining the nature of prevailing conditions, practices or attitudes, perceptions or opinions that are held, processes that are going on or trends that are developed (Ary et. al., 2014).

3.3 Variables

According to Cherry (2009), a variable is a characteristic of interest that a researcher would like to handle, observe or manipulate in the research. There are two types of variables; independent and dependent variables. An independent variable is a variable that influences or causes change in another variable, whereas a dependent variable is one that is influenced or changed by one or more variables (Mugenda & Mugenda, 2009). In the current study both independent and dependent variables were discussed.

3.3.1 Independent Variables

The independent variable in single-subject research typically is the practice, intervention, or behavioural mechanism under investigation (Horner, Corr, Halle, McGree, Odom, & Wolery, 2005). Odom and Strain (2002) state that the independent variable in single subject research should be actively, rather than passively, manipulated. The independent variables considered for this study was the Automated Speech Training System which was used to asses and train speech sounds each learner had deficits in. Other independent variables included the type of speech sounds which were vowels and different types of consonants which included; voiceless, voiced, plosives, fricatives and nasal sounds.

3.3.2 Dependent Variable

Single-subject research employs one or more dependent variables that are defined and measured. In the current study the dependent variable was enhancement of speech among learners who were hard of hearing in the selected schools. Horner et al (2005), opined that the dependent variable in single-subject educational research is a form of observable behaviour which is selected for its social significance, an opinion supported by, Odom and Strain, (2002) who suggested that a dependent variable is chosen not only because it may allow assessment of a conceptual theory, but also because it is perceived as important for individual participant, those who come into contact with the individual, or for society. Speech enhancement among learners who are hard-of-hearing in this study has a lot of social significance not only to the individual learner but also to the entire society.

3.4 Location of the Study

The study was conducted in three special units for learners with hearing impairment in selected schools in Nairobi City County (Appendix VI). Nairobi City County being a cosmopolitan city, learners with hearing impairment were taught in English. The people of Nairobi come from diverse ethnic background and the same applies to learners. Since there were no maps available for the selected schools, the researcher obtained and provided the following brief direction to the specific schools.

1. Special Unit A

The unit is within a public regular primary school located in Kasarani sub-county. It is in the middle of the busy industrial area about 10 kilometres north of Nairobi City centre. The learners had been undergoing speech training using traditional speech training methods under a programme sponsored by Starkey Ear Foundation. Teachers there preferred to instruct learners using speech and sign language. In class, learners communicate in speech among themselves though not very intelligibly. Academically, they are at different levels of primary school curriculum and each level was handled by one teacher. Their hearing losses ranged from mild to profound.

2. Special Unit B

The unit is integrated in a public regular primary school about 12 kilometres north of Nairobi City centre in Kasarani sub-county. The school is easily accessed from Kiambu road or Thika super-highway. Learners had not been speech trained formally. During instructions, teachers used simultaneous communication, that is, they talked and signed at the same time. The hearing loss of the learners ranged from mild to

profound. Teaching there is based on primary school curriculum. Although children were in one class, they were at different levels academically.

3. Special Unit C

The unit is within public primary school about two kilometers on the eastern side of the city centre. Administratively, the school is in Starehe sub-county. Although the school was not among schools under Starkey Ear Foundation, teachers emphasized on the use of speech during instructions. Learners too especially those who were hard-of-hearing enjoyed communicating using speech. The unit was academically structured like a regular school from pre-school to class eight. Each class was handled by one teacher. Like the other sampled units, hearing loss of learners ranged from mild to profound. A few learners, especially the refugees, were about seventeen and eighteen years old. They followed the regular primary school curriculum.

3.5 Target Population

In this study, the target population comprised all learners with hearing impairment in the selected schools. Thus the study targeted a total of 94 learners with hearing impairment from the three special units and 13 teachers. Therefore, the study targeted a total of 107 participants. Population in research refers to the large group of people, events, or objects with similar characteristics which the researcher is interested in so as to obtain information to make generalization about the research. Target population is the units from which the information is required and actually studied. Ary, Jacobs, Sorensen and Walker (2014) noted that a target population is the large group to which the researcher wishes to generalize the results of the study. The learners in this study

came from diverse social backgrounds, were in different classes and of different ages. Their hearing levels ranged from mild to profound hearing loss.

3.6 Sampling Techniques and Sample Size

3.6.1 Sampling Techniques

In view of the nature of this study, purposive sampling technique was adopted. Sampling special or unique cases technique was employed to sample learners who were hard of hearing and their teachers in the selected schools, which Tashakkori and Teddlie (2008) recommended when a specific group of cases is a major focus of the investigation. WHO (2015) defined hard-of-hearing as persons whose hearing losses range from mild to severe and can communicate in speech. According to Tashakkori and Teddlie (2008), purposive sampling techniques involve selecting certain units or cases based on specific purpose rather than randomly. Thirty two learners sampled for this study had hearing losses ranging from mild to severe. This was ascertained through their audiograms and confirmed through Pure Tone Audiometric (PTA) assessment conducted by the researcher. In this study, learners who are hard of hearing were the major focus. The study had 13 teachers purposively sampled from the three schools involved in the study. Only those teachers who were teaching in the special units for learners with hearing impairment were sampled.

3.6.2 Sample Size

Ary, Jacobs, Sorensen and Walker (2014) recommended sampling of the whole group with similar characteristics when the group size is very small. In this study, all the 32 learners who were hard of hearing and 13 teachers in the three selected schools were sampled as shown in the table 3.1.

Table 3.1: Sample size

School	Target population	Sample size	Percentage %
A	30	11	36.7
B	24	11	45.8
C	40	10	25.0
Teachers	13	13	100
Total	107	45	

3.7 Research Instruments

In this study data was collected using the Automated Speech Training System. To supplement the data gathered by the system, interviews were conducted from the sampled learners and teachers to gain more in-depth information about the training.

3.7.1 Automated Speech Training System

The Automated Speech Training System used as an instrument to collect data for this study was adapted from “Baldi” developed by Massaro (2003). It was experimented with seven students (2 boys and 5 girls) with hearing loss from the Jackson Hearing Centre and JLS middle school in Los Altos, California. After training for 360 hours, they noted remarkable improvement in both speech perception and production. For this study, the system was modified and fitted with tools to mitigate the problem widely encountered by learners who are hard-of-hearing in perceiving and producing speech. The tools were categorized into audio/verbal component which had a hearing assessment tool and sound amplification tool. The visual component had a speech training tool that used a 3-D interactive human head as a speech tutor for speech perception and production.

The system had a laptop-computer HP 630 Notebook PC manufactured in USA in 2012. The laptop computer, was connected to an amplifier TAKSTAR with UNF modified to amplify sounds to a range between 20dB and 102dB. The amplifier was fitted with stereo headphones Sony MDR-XB450AP (Appendix II). A stimulus (speech sounds) was simultaneously presented on the laptop monitor and through the headphones adjusted to a comfortable listening level as per the threshold of hearing of each learner. The automated speech training system carried out the assessment and training. The system used the pronunciations formed from 26 letters of English alphabet adopted from Summit Language Institute (2017) based on American English Phoneme Representation. The 26 letters of alphabet selected comprised 5 vowel sounds and 21 consonant sounds. Using this phoneme library, it was possible to create pronunciations for words based on English phonemes. The study targeted individual speech training needs of every learner. First, the system evaluated each learner's hearing acuity (intensity and pitch). This was important for the study because Caleffe-Schenck and Baker (2007) spelt out pitch (frequency) and intensity (decibel) required for perception and production of each speech sound. The resulting diagnosis captured parameters like the appropriate intensity and pitch required to train the learner. These parameters were recorded and used to adjust the audio component of the system to assist in training each speech sound to individual learner. (Appendix I (a) – (d)). At the end, pretest and post-test scores for each learner were recorded on a score sheet (appendix III) for statistical analysis.

The visual component used the same laptop to display visual articulation of the sounds. Speech sounds were articulated by the 3-D animated talking-head as the

virtual tutor. To ease the acquisition of these critical pronunciation, a semi-transparent ‘‘animated talking head’’ similar to ‘‘Baldi’’ (Massaro & Light, 2004) was created on the computer. The animations provided by the computer revealed how the mouth shape, lip movement and tongue placement work in concert to produce specific sounds and words. The animations provided the learner who is hard-of-hearing with a visual representation of how sounds and words were produced. Different orientations of talking head were utilized in order to provide optimal visual information to the learner. For example, a 45⁰ rotation and 30⁰ elevation used for sounds formed at the back of the mouth such as /k/ and /g/; a 15⁰ rotation and 15⁰ elevation was used for sounds produced with the tongue in front of the mouth such as /t/ and /d/; and a 15⁰ rotation and 0⁰ elevation was used for sounds produced by closing the mouth such as /p/, /b/ and /m/.

3.7.2 Interview for the Learners

According to Patten (2009), an interview is a method of field investigation whereby a researcher meets respondents and through interaction asks specific questions to find answers to the research problem. In this study, interview data was elicited using five open-ended questions to seek views from the learners who had been trained using ASTS. Interview questions were based on the research objectives. Learners were interviewed on: mode of communication they preferred, the method of training they preferred between ASTS and traditional methods (teachers), preference on visual and audio components of ASTS and its improvements, the challenges they face in communication and how speech training could be improved. The researcher used an interview guide to gather the information (Appendix IV).

3.7.3 Interview for Teachers

As stated in the statement of the problem, there was no speech training taking place formally using traditional methods or automated systems in schools for learners with hearing impairment in Kenya. Therefore, it was necessary to gather some information regarding speech training from the teachers. Their responses could have an influence on the effectiveness of ASTS. Interview for teachers about their opinions on speech training learners who are hard-of-hearing was conducted by the researcher. The interview comprised 8 questions meant to solicit information relevant to study objectives. The first four questions were to gather teachers' bio-data. The other four questions gathered information on: teachers' competence on speech training, speech training in their respective classes, challenging speech sounds, mode of communication preferred by the learners and their opinions on speech training of learners who are hard-of-hearing. The items were open-ended to enable the researcher obtain qualitative data for the study. According to Gall, Borg and Gall (1996), the use of interview is more appropriate in collecting qualitative data because it permits open-ended exploration of issues and elicits responses that are couched in the unique words of the respondents (Appendix V).

3.8 Pilot Study

A pilot study is a pre-testing approach designed to obtain preliminary information on how new research instrument work. Before embarking on the actual data collection, piloting of the ASTS was carried out at Kerugoya School for the deaf. The school admits learners with hearing impairments from diverse ethnic backgrounds and learners are taught in English like the learners in the selected schools for the study.

The school was selected because it was also under Starkey Ear Foundation speech training programme. The learners who were hard-of-hearing at Kerugoya came from different ethnic background and had similar speech characteristics as the sampled learners for the study. The piloting provided opportunity for the researcher to make adjustments to the system like unmasking some speech sounds which initially were not very clear to the learners. Patten (2009) emphasized that pilot studies are usually conducted with small sample sizes. Six learners who were hard of hearing were identified for piloting. Selected learners were pre-tested on their articulation of the sounds of 26 letters of English alphabet to identify their speech deficits. This was followed by 4 weeks training on speech sounds identified to be deficient. The training was conducted by the researcher. Each learner was trained for 2 sessions per week for a period of 4 weeks. At the end they were post-tested with a similar test to pre-test. The results of the piloting showed that after speech training using ASTS, there was significant improvement in speech production ($t=4.86$, $p=0.0001$) (Appendix IX).

3.8.1 Validity

In order to ascertain the internal validity for this study, the researcher used ASTS for speech training during piloting which demonstrated positive experimental effects among the six learners who were hard-of-hearing. Social validity was enhanced through; first, selection of a dependent variable (speech enhancement) that has a high social importance. Enhancement of speech contributes to social inclusion of learners with hearing impairment.

The researcher critically inspected the different components of the system to ascertain its face validity. He then examined the content of speech sounds he intended to train

by listening to their production and critically watching their articulation from the computer to ascertain whether on its “face”, the system appeared to be closely related to what the researcher wished to measure. Further, the researcher examined the content validity of the system to ascertain whether it was suitable for the study. To enhance the content validity, expert opinion and judgment from university supervisors was sought. Their suggestions were considered and used to improve the system. The system being an improved and modified model of a system used by Massaro, (2003) also enhanced the validity.

3.8.2 Reliability

To determine the reliability of the automated speech training system in this study, parallel-forms reliability technique was used. Horner, Corr, Halle, McGree, Odom, and Wolery, (2005) recommended parallel-forms reliability technique when determining reliability in a single-subject research. During piloting, same group of participants was used for both pre-test and post-test and the measurement procedure addressed the same construct which was speech enhancement for learners who are hard-of-hearing. One way of testing such reliability is using a t-test, similarity of means and standard deviations between the two groups (Horner et. al., 2005). In this study’s piloting at Kerugoya School for the deaf, learners’ sound articulations, both at pre-test and post-test, were recorded with a sound recorder and 3 trained teachers for the deaf who were the judges listened to the recorded voices for each learner. For any intelligible sound, the learner was awarded a score of one and for any unintelligible sound a zero. Any sound recognized by the 3 teachers was judged as an articulated sound. The 3 teachers who were not involved in the training were recruited and

briefed on the purpose of the study in order to minimize the potential of experimenter bias which is a threat to both internal validity and reliability (Horner et al., 2005). 2-sample t-test was used to analyze the results. During piloting, the result showed that there was a significant improvement ($t = 4.86, P < 0.0001$) in learners pronunciation after ASTS speech training. This implied that the instrument was adding value to learners' articulation of the selected speech sounds and was fit to be used for the data collection.

3.9 Data Collection Techniques

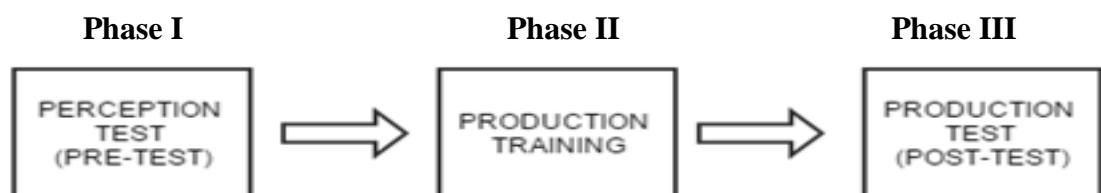
Data collection refers to gathering information to serve or prove some facts (Kombo, 2006). In this study, the researcher obtained research authorization letter from Kenyatta University and National Commission for Science Technology and Innovation (NACOSTI) after approval of the proposal by the Graduate school. Secondly, the researcher proceeded to inform the County Commissioner Nairobi County and Regional coordinator of Education Nairobi of his intended research. Finally, preliminary contacts were made with the head teachers of the selected schools to discuss the purpose of the study and thereby creating rapport with them. Orodho (2009) asserts that it is important for a researcher to have a practical appreciation, familiarity and rapport with the community of respondents.

3.9.1 Training of Research Assistants

In view of the complexity of the study, two research assistants were engaged in the data collection process. Like the researcher, the assistants engaged for the study were trained teachers for the deaf hence well versed in sign language interpretation for ease of communication with the participants. Prior to embarking on data collection, four

days training was planned for research assistants on the operations of the system and the whole purpose of the study. The first two days were spent on training the assistants on operations of the audio component of the system and the other two days were spent on manipulations of the visual component. The training involved going through the selected sounds one by one using both components of the system. After the training, the research assistants were also involved in piloting the instrument where they applied the learnt skills practically. Mugenda and Mugenda (2003) advise that research assistants should be trained if objective and reliable information is to be obtained from research participants. The research assistants helped the researcher to train the participants. Since the ASTS was only one, arrangements were made to visit each school on its own day.

In order to achieve both speech perception and production in a learner, data collection process was broken down into 3 phases as shown below.



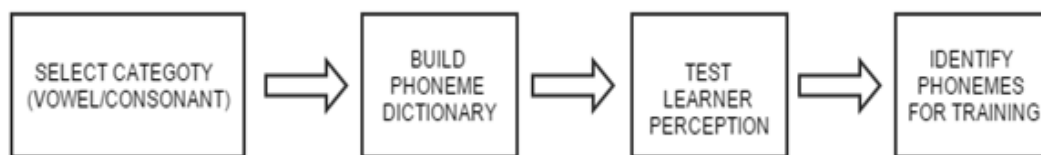
Data generated at each of the first two phases was utilized in the next phase

3.9.2 Speech Perception Pre-test Phase

The audio component of ASTS established hearing threshold of each learner i.e. intensity in terms of decibels and pitch in terms of frequencies in order to determine degree of amplification required for training. The system introduced each of the 26 speech sounds from a phoneme dictionary, through the headphones to each learner individually. The learner was expected to listen to the amplified sound without seeing

its printed form and produce it. This activity was meant to ensure that when the same sound and word were later presented in print, the learner would have previous experience with the sound, word and its correct pronunciation. It was also meant to train the learner to maximize his/her listening skills using the audio component within Automated Speech Training System.

The sound was repeated 3 times to ensure its perception. Learners' responses were recorded using an audio recorder for evaluation by the judges. A profile was built from the results for each learner, detailing speech impediments experienced by the learner. This profile assisted in identifying speech sounds for training as summarized in the following diagram.



3.9.3 Speech Production Training Phase

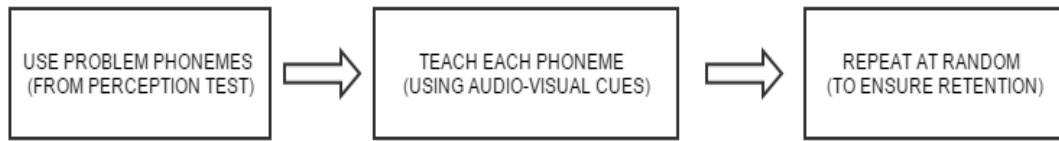
This phase used the results of the perception pre-test to create a custom training curriculum specifically suited to address the needs of the learner. The Automated Speech Training system (ASTS) used audio-visual cues in a step by step lesson plan to train the learner how to recognize and produce sounds they were unable to produce during pre-test. Four activities took place simultaneously in this phase; the sound was presented at a level above the learner's hearing threshold, the virtual teacher (animated talking head) displayed its articulation, the printed form of the sound accompanied by the word in which the sound was used was displayed on the computer screen, pictorial representation of the word was also displayed.

During the training, the sounds were repeated at random and placement of the target sound in the word varied to ensure retention. The Automated Speech Training System was operated by the researcher or research assistant in a 1:1 context, 20 minutes per session, and 2 sessions per week. Kenya Institute of Education (1979) recommended 20 minutes speech training session for individual speech training and 30 minutes for group speech training session. The course of training took 12 weeks, thus each learner had 40 minutes of training per week which translated to 480 minutes for the whole course. In case of learner's absence from school for any reason, the scheduled training lesson was presented at the next meeting.

As with the traditional speech training method proposed by Ling (1999), and also used by Massaro and Light (2004), each sound was trained at the segment and word level. Every word used was within the normal speaking vocabulary of hearing learners and was accompanied by a pictorial representation to enhance understanding. For example, for the sound /k/ the word used was 'cat' accompanied by a picture of a cat.

The learner was trained on how to produce the target sound segment. Different training methods were used to train all the difficult sounds identified during pretest. During all training lessons, the learner was instructed on how to produce the sounds being trained. The learners were also required to produce the sound in isolation as well as in words. Even though the experimenter or assistant was present during each lesson and could have been considered a source of distraction, the learner was encouraged to attend to the computer screen and look at the animated face as it

articulated the sounds and at the same time listen through the headphones. Training phase was summarized as per the following diagram.



3.9.4 Speech Production Post-Test Phase

At the end of 12 weeks, each learner was post-tested by the researcher. This phase tested the learner's ability to effectively perceive and reproduce all the 26 sounds of English alphabet. The test was similar to pre-test where the learner was supposed to listen and produce the sound. The speech produced by each learner was recorded on a sound recorder. A panel comprising 6 teachers with normal hearing (3 trained teachers for the deaf and 3 trained regular teachers of English language) was formed to objectively evaluate the audio-taped speech sounds produced by the learners. The panel was briefed on the purpose of the study and their role. The panel's task was to listen to each speech sound produced by each learner and individually give a score of one for any identified sound and zero for any unidentified sound. Any letter sound identified by five or more than five out of six panel members, the learner was judged as having been able to articulate it and any letter sound identified by less than five out of six panel members, the learner was judged as being unable to articulate it. The results were analyzed to determine the effectiveness of ASTS and to analyze other objectives of the study.

At the end of training session, learners who had undergone the training using ASTS were interviewed by the researcher. To ease comprehension of the interview

questions, the researcher conducted the interviews in English, both spoken and signed with the research assistants recording the learners' responses in a notebook. The learners were free to choose their preferred mode of communication during the interview. The teachers in the selected special units were also interviewed by the researcher on their opinions about speech training learners who are hard-of-hearing. The purpose of the interview was to complement the quantitative data collected using ASTS.

3.10 Data Analysis Techniques

Using Statistical Package for Social Sciences (SPSS version 22.0), the demographic information of the 32 sampled learners was analyzed by means of descriptive statistical technique which included percentages and analysis of variance (one way ANOVA). Descriptive statistics enable researchers to simplify and present data in an organized and meaningful form (Orodho, 2009). Quantitative data obtained in objective one to four using the ASTS was analyzed using Statistical Package for Social Sciences (SPSS) inferential statistical tests such as paired sample t-test, two sample t-tests, correlation analysis and regression analysis. Learners' speech perception and production before training and the effectiveness of the Automated Speech Training System in enhancing speech among learners who are hard of hearing was analyzed using paired sample t-test and two sample t-test, comparison of effectiveness of ASTS with traditional speech training methods was analyzed using two sample t-test, and the extent to which the value addition of ASTS was influenced by selected demographic factors was analyzed using percentages, two sample t-test, correlation analysis and regression analysis (linear regression). Finally, descriptive

statistical technique was used to analyze objective five and six of the study. To analyze views of learners and teachers, a thematic analysis approach was applied to identify patterns through a rigorous process of data familiarization, data coding, and the development and revision of key themes.

3.11 Logistical and Ethical Considerations

In research, logistics involve all the activities and actions that the researcher must undertake to ensure successful completion of the study. After obtaining research permit from NACOSTI, the researcher through the head teachers obtained parental informed consent for their children to participate in the study by signing the informed consent form since all the participants were below 18 years old (appendix VIII). The form had been approved by the University Ethical Review Committee. The informed consent form was read to the parents and interpreted in the language the parent could understand. After ensuring the parent had understood, he/she signed in the space provided, and those who could not write were allowed to use their thumb prints. Although the parents consented on behalf of their children's participation, the consent form and the purpose of the study were read to the learners to the effect that a learner was free to participate or not to participate and even to quit the study at any time at will even if the parent had consented (appendix VII). Thus participation in the study was voluntary. The researcher assured the head teachers that the schools were to be identified using pseudonyms in order to protect their image. To protect the identity of learners and teachers during the interview, code numbers only known by the researcher and the assistants were used. The right to privacy demands that direct consent for participation must be obtained from the participants (Orodho, 2009). The

researcher assured all the respondents of confidentiality and anonymity. Assurance was given to the effect that the information and data collected was not to be used for any other purpose than for the study and that it was to be kept confidentially. According to Mugenda and Mugenda (2003), lack of confidentiality and mishandling of information provided by the respondents may cause them some physical or psychological harm. The study was carried out by the researcher and two assistants. All the participants were accorded the same treatment and informed on the purpose of the study and how its findings would be used to benefit learners who are hard of hearing. According to Mugenda and Mugenda (2003), it is highly unethical for researchers to fail to disclose the real purpose of the study fearing that the respondents may decline to participate in the study.

CHAPTER FOUR

PRESENTATION OF FINDINGS, INTERPRETATION AND DISCUSSION

4.1 Introduction

This chapter presents the findings, interpretations and discussion according to the research objectives. The purpose of this study was to investigate the effectiveness of an Automated Speech Training System (ASTS) in enhancing perception and production of speech among learners who are hard of hearing in selected schools in Starehe and Kasarani sub-counties of Nairobi City County Kenya.

The study was guided by the following objectives:

- i) To establish the level of speech perception and production of learners who are hard-of-hearing before using Automated Speech Training System.
- ii) To establish the effects of Automated Speech Training System on enhancing speech among learners who are hard of hearing.
- iii) To compare the effects of Automated Speech Training System with traditional methods of speech training on perception and production of speech among learners who are hard-of-hearing.
- iv) Find out the role played by selected demographic factors in the effectiveness of ASTS in enhancing speech among learners who are hard-of-hearing.
- v) To establish the views of learners on communication modes and Speech training using traditional methods and ASTS.
- vi) To find out the opinions of teachers on speech training of learners who are hard-of-hearing.

4.2 General and Demographic Information

This section presents general and demographic information of respondents. Respondents' description was analyzed using frequency and percentages and presented in figures and tables. There are two sub-sections under this section, with the first sub-section presenting demographic information for learners and the second sub-section dealing with teachers.

4.2.1 Demographic Characteristics of Learners

Learners' gender, age and degree of hearing loss in the right and left ears were established. These characteristics were considered because they could have some bearing on speech enhancement which is the dependent variable of the study.

Gender of Learners Sampled

Equal number of male and female was used in this study; 16(50.0%) males and 16(50.0%) females, though gender distribution varied from school to school. School A had 5(45.5%) males and 6(54.5%) females, school B 4(36.4%) males and 7(63.6%) females while school C had 7(70%) males and 3(30%) females as presented in figure 4.1.

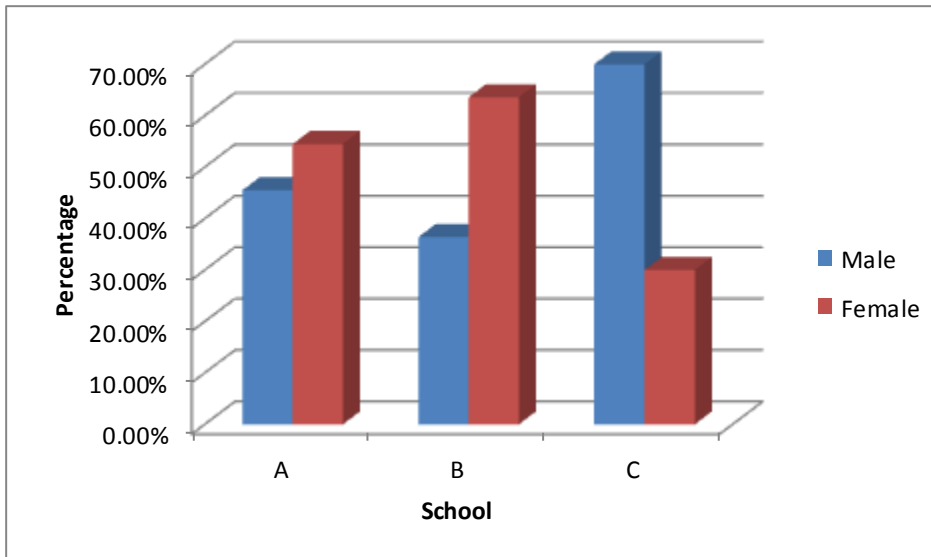


Figure 4.1: Gender distribution of Learners per school

From table 4.1, school A and school B had 11 learners each while school C had 10 learners. The variance in gender distribution was due to admission criteria whereby only learners with hearing impairment are admitted into the units regardless of the gender. For the study sample, all the learners who were hard-of-hearing were sampled purposively regardless of the gender.

Age of the Learners

The average age of the learners was 11.88 ± 0.432 years (mean \pm standard error). The sample was highly heterogeneous in terms of age with youngest learner aged 8 years old while the eldest was 17 years of age. Figure 4.2 summarizes age distribution of learners.

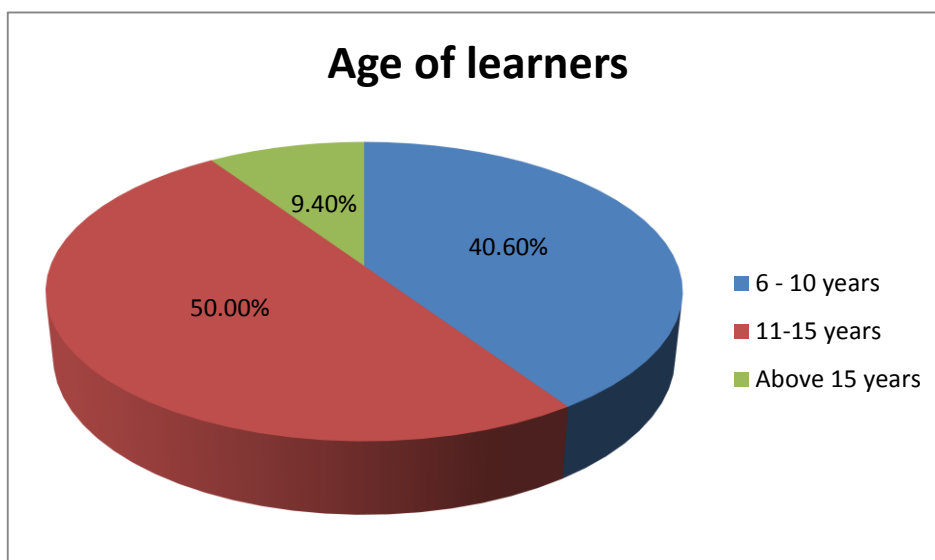


Figure 4.2: Age distribution of the learners in years

Figure 4.2 indicates that half of the learners 16(50.0%) were in the age bracket of 11 – 15 years. 13(40.63%) of the learners were in the age bracket of 6 – 10 years while 3(9.4%) were in the bracket of 15-20 years of age.

Degree of Hearing Loss of the Right and Left Ear

Averages of pure-tone hearing threshold levels for each learner in the sample at 250Hz, 500Hz, 1000Hz, 2000Hz and 4000Hz for each ear were established prior to commencement of speech training. The average degree of hearing loss of the right ear of the sampled learners was 50.87dB. In school A, the average degree of hearing loss of the right ear was 49.27 ± 4.01 dB (mean \pm SE). In school B, the degree of hearing loss of the right ear was 50.09 ± 4.18 dB (mean \pm SE) while it was 53.50 ± 5.93 dB (mean \pm SE) in school C.

In the left ears of the sampled population, the average degree of hearing loss was 52.94 ± 2.81 dB (mean \pm SE). In school A, the mean degree of hearing loss in the

learners left ear was 51.09 ± 4.36 dB. In school B it was 54.27 ± 3.52 dB while in school C the mean degree of hearing loss in the left ear was 53.50 ± 6.95 dB.

Table 4.1: Degree of hearing loss of the right and the left ear of learners in dB

School	No of Learners	Degree of hearing loss of right ear	Degree of hearing loss of left ear
School A	11	49.27 ± 4.01 dB	51.09 ± 4.36 dB
School B	11	50.09 ± 4.18 dB	54.27 ± 3.52 dB
School C	10	53.50 ± 5.93 dB	53.50 ± 6.95 dB
F-value		0.220	0.110
P-value		0.804	0.894

ANOVA done at 95% confidence interval

Table 4.1 shows that the average hearing loss of the sampled learners falls within universally accepted levels of moderate hearing loss. Categorized according to WHO (2008) levels of hearing, moderate hearing loss ranges from 41dB to 55dB.

4.2.2 Demographic Characteristics of Teachers

The 13 teachers used in the study were asked to give their experience in teaching learners with hearing impairment and their teaching qualifications. These were crucial to the study in that they gave the indication of the level of preparedness and professionalism in their career.

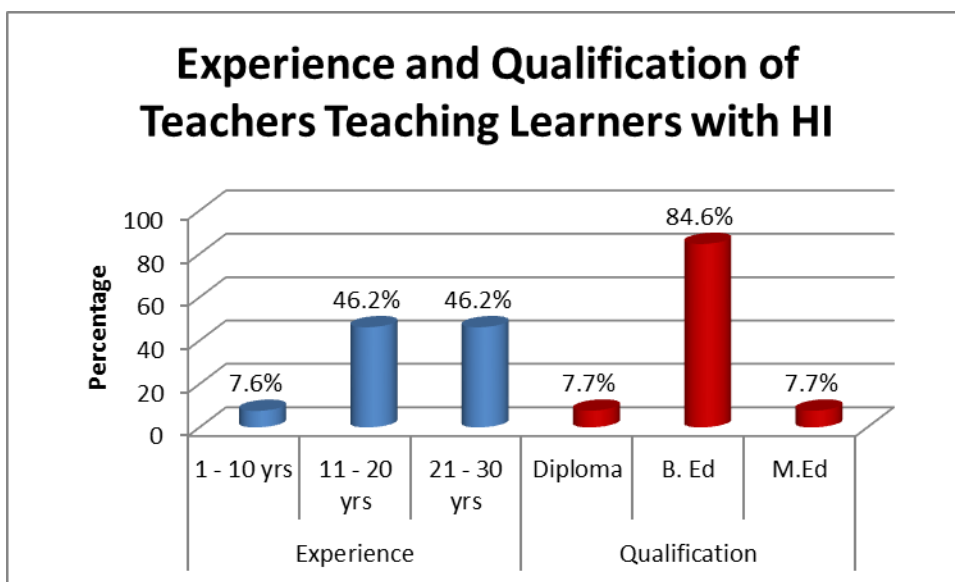


Figure 4.3: Teaching Experiences and Qualification of Teachers

From Figure 4.3, majority of the teachers had an experience of over 10 years with equal number of teachers having experience of 11-20 and 21-30 years. Only one teacher had an experience of less than 10 years in teaching learners with hearing impairment.

The qualifications of sampled teachers were as indicated in Figure 4.3. From the figure, the teaching qualifications ranged from diploma to master of education. Majority of the teachers had bachelor of education in special needs education. One teacher had a diploma in special needs education and one had master of education in special needs education.

4.3 Speech Perception and Production before Training

Since perception of speech sounds precedes production, it follows that speech sounds that are most difficult to hear are also more difficult to articulate. To establish the level of speech perception and production of the sampled learners before training as

per objective one, a pre-test was conducted on all the selected sounds which comprised five vowels and twenty one consonants and results analyzed.

4.3.1 Learners' Pre –Test Results

Learners were pre-tested on articulation of twenty six speech sounds of English Alphabet as guided by objective one of the study. Results were recorded as ‘correct’ for any articulated sound and ‘wrong’ for a sound not articulated before use of an Automated Speech Training and ranked from the most articulated sound to the least articulated sound as shown on Table 4.2.

Table 4.2: Learners articulation of the selected sounds before ASTS (pre-test)

Letters of the Alphabet	Sounds of the alphabet	Number and (%) “correct” (n = 32)	Number and (%) “wrong” (n = 32)	Rank (1-most articulated)
A	/a/	29 (90.6%)	3 (9.4%)	1
B	/b/	24 (75.0%)	8 (25.0%)	3
C	/k/	16 (50.0%)	16 (50.0%)	11
D	/d/	10 (31.3%)	22 (68.8%)	16
E	/e/	23 (71.9%)	9 (28.1%)	4
F	/f/	14 (43.8%)	18 (56.3%)	13
G	/g/	8 (25.0%)	24 (75.0%)	18
H	/h/	20 (62.5%)	12 (37.5%)	8
I	/i/	21 (65.6%)	11 (34.4%)	7
J	/dʒ/	7 (21.9%)	25 (78.1%)	17
K	/k/	16 (50.0%)	16 (50.0%)	11
L	/l/	12 (37.5%)	20 (62.5%)	15
M	/m/	22 (68.8%)	10 (31.3%)	5
N	/n/	20 (62.5%)	12 (37.5%)	8
O	/o//	26 (81.3%)	6 (18.8%)	2
P	/p/	18 (56.3%)	14 (43.8%)	10
Q	/kw/	6 (18.8%)	26 (81.3%)	20
R	/r/	16 (50.0%)	16 (50.0%)	11
S	/s/	21 (65.6%)	11 (34.4%)	6
T	/t/	13 (40.6%)	19 (59.4%)	14
U	/u/	22 (68.8%)	10 (31.3%)	5
V	/v/	19 (59.4%)	13 (40.6%)	9
W	/w/	14 (43.8%)	18 (56.3%)	12
X	/ks/	7 (21.9%)	25 (78.1%)	19
Y	/j/	18 (56.3%)	14 (43.8%)	10
Z	/z/	19 (59.4%)	13 (40.6%)	9

From Table 4.2, majority of the learners (90.6%) were able to articulate sound /a/ correctly and 81.3% were able to articulate /o/. Fewer learners (18.8%) during the pre-test were able to articulate sound /kw/ while 21.9% were able to articulate sounds /dʒ/ and /ks/. The pre-test result therefore showed that articulation of the sounds from the most articulated to the least articulated sound was; /a/, /o/, /b/, e/, /m/, /u/, /s//kw/.

4.3.2 Learners' Articulation of Vowels and Consonants Before ASTS

The learners' ability to correctly articulate vowel sounds /a/, /e/, /i/, /o/ and /u/ and all selected consonant sounds at the pretest result was established. The findings revealed that it was significantly easier ($t = 4.70$, $P = 0.001$) for the learners to articulate the vowel sounds, mean 24.20 learners with a standard error of 1.2 than for the learners to articulate the consonant sounds, mean 15.38 with a standard error of 1.5.

The pre-test was carried out in order to assist in diagnosing speech deficits of each individual learner before training which would form the basis of speech training. According to Oster (2010), diagnosis of individual speech deviations should form the basis of speech training and the first stage should be assessment of the deviations that needs to be corrected in order to increase the intelligibility of a child's speech. Learners pre-tested in this study had been undergoing speech training using traditional methods either formally or informally prior to the commencement of the study. Results of the pre-test showed that learners had some speech deficits which this study intended to address using ASTS. The results support review conducted by National Council for Special Education (2009) which showed that participation in traditional

speech training does not result in learners who are hard-of-hearing attaining literacy achievements equivalent to their hearing peers.

The findings of the pre-test also support the findings of Geffner and Rothman (1980) who observed that one of the common features of speech among learners with hearing impairment is that consonant sounds are more affected than vowel sounds. Therefore, learners with hearing impairment find it easier to articulate vowel sounds than consonant sounds.

4.4 Effects of ASTS in Speech Enhancement among selected learners

In order to establish effects of ASTS in enhancing speech among learners who are hard-of-hearing based on objective two of the study, post-test results were analyzed for all the selected sounds. Then, pre-test and post-test results for the vowel sounds and consonant sounds were analyzed to find out whether there was any significant difference between pre-test and post-test results. The consonant sounds analyzed were voiceless, voiced, plosive, fricative and nasal sounds.

4.4.1 Learners' Articulation of Selected Sounds after ASTS Training (Post-test)

Learners' perception of each of the selected sounds was established during pre-test. Sounds identified during pre-test to be challenging to learners formed the curriculum for speech training using ASTS for each individual learner. After ASTS training which took 12 weeks, a test similar to pre-test was administered to learners on articulation of alphabet sounds and the results recorded as correct for any articulated sound and wrong for a sound not articulated. Speech sounds were analyzed as per the learners ability to articulate or inability to articulate each sound and then ranked from the most articulated to the least articulated sound as shown on Table 4.3.

Table 4.3: Learners articulation of all the selected sounds after ASTS training

Letters of Alphabet	Sounds of the alphabet	Number and (%) "correct" (n = 32)	Number and (%) "wrong" (n = 32)	Rank (1-most correctly pronounced)
A	/a/	32 (100%)	0 (0.0%)	1
B	/b/	32 (100%)	0 (0.0%)	1
C	/k/	32 (100%)	0 (0.0%)	1
D	/d/	15 (46.9%)	17 (53.1%)	11
E	/e/	32 (100%)	0 (0.0%)	1
F	/f/	27 (84.4%)	5 (15.6%)	6
G	/g/	12 (37.5%)	20 (62.5%)	12
H	/h/	24 (75.0%)	8 (25.0%)	7
I	/i/	32 (100%)	0 (0.0%)	1
J	/dʒ/	18 (46.9%)	14 (43.8%)	11
K	/k/	32 (100%)	0 (0.0%)	1
L	/l/	17 (53.1%)	15 (46.9%)	10
M	/m/	32 (100%)	0 (0.0%)	1
N	/n/	29 (90.6%)	3 (9.4%)	4
O	/o/	32 (100%)	0 (0.0%)	1
P	/p/	32 (100%)	0 (0.0%)	1
Q	/kw/	11 (34.4%)	21 (65.6%)	13
R	/r/	24 (75.0%)	8 (25.0%)	7
S	/s/	31 (96.9%)	1 (3.1%)	2
T	/t/	20 (62.5%)	12 (37.5%)	8
U	/u/	30 (93.8%)	2 (6.3%)	3
V	/v/	30 (93.8%)	2 (6.3%)	3
W	/w/	18 (56.3%)	14 (43.8%)	9
X	/ks/	10 (31.3%)	22 (68.8%)	14
Y	/j/	24 (75.0%)	8 (25.0%)	7
Z	/z/	28 (87.5%)	4 (12.5%)	5

Table 4.3 indicates that at the post-test, all the learners (100%) were able to articulate sounds /a/, /b/, /k/, /e/, /i/, /m/, /o/, and /p/ but were not able to articulate some other sounds. For example, (68.8%) were not able to articulate sound /ks/, (65.6%) sound /kw/, (62.5%) sound /g/ and (53.1%) sound /d/. Ranking was done based on the number of learners who were able to articulate each sound starting with the sound articulated by most learners to the least.

In comparison of the pre-test and post-test results, learners had improvement in the articulation of sound /k/ which at pre-test was articulated by half of the learners and at

post-test by all the sampled learners. Other improvement was observed in articulation of sounds /e/, /i/, /m/, /o/ and /p/ among others.

4.4.2 Testing of Hypothesis one

Ho1 There is no significant difference in speech production among learners who are hard-of-hearing before speech training using ASTS (pre-test) and after using ASTS (post-test) in selected schools in Nairobi City County.

The hypothesis sought to find out whether there was any significant difference in speech production among the learners who are hard-of-hearing after speech training using automated speech training system.

A comparison of the learners' speech articulation before the use of ASTS with their articulations after use of ASTS training was done by subtracting the number of learners able to articulate speech sounds in pre-test from learners able to articulate in post-test. The analysis was done using Paired sample t-test as indicated on Table 4.4.

Table 4.4: Learners articulation of the selected sounds before and after training

Letters of the alphabet	Sounds of the alphabet	Number before ASTS and (%) "correct" (n = 32) A	Number after ASTS (%) "correct" (n = 32) B	Enhanced/Variation (B – A)
A	/a/	29 (90.6%)	32 (100%)	+3
B	/b/	24 (75.0%)	32 (100%)	+8
C	/k/	16 (50.0%)	32 (100%)	+16
D	/d/	10 (31.3%)	15 (46.9%)	+5
E	/e/	23 (71.9%)	32 (100%)	+9
F	/f/	14 (43.8%)	27 (84.4%)	+13
G	/g/	8 (25.0%)	12 (37.5%)	+4
H	/h/	20 (62.5%)	24 (75.0%)	+4
I	/i/	21 (65.6%)	32 (100%)	+11
J	/dʒ/	7 (21.9%)	18 (46.9%)	+11
K	/k/	16 (50.0%)	32 (100%)	+16
L	/l/	12 (37.5%)	17 (53.1%)	+5
M	/m/	22 (68.8%)	32 (100%)	+10
N	/n/	20 (62.5%)	29 (90.6%)	+9
O	/o/	26 (81.3%)	32 (100%)	+6
P	/p/	18 (56.3%)	32 (100%)	+14
Q	/kw/	6 (18.8%)	11 (34.4%)	+5
R	/r/	16 (50.0%)	24 (75.0%)	+8
S	/s/	21 (65.6%)	31 (96.9%)	+10
T	/t/	13 (40.6%)	20 (62.5%)	+7
U	/u/	22 (68.8%)	30 (93.8%)	+8
V	/v/	19 (59.4%)	30 (93.8%)	+11
W	/w/	14 (43.8%)	18 (56.3%)	+4
X	/ks/	7 (21.9%)	10 (31.3%)	+3
Y	/j/	18 (56.3%)	24 (75.0%)	+6
Z	/z/	19 (59.4%)	28 (87.5%)	+9

NB: -ve indicate a decrease in the number of learners; +ve indicate an improvement in the number of learners during ASTS training. Mean number of learners pre-test = 17.08 ±1.20; Post ASTS training = 25.23 ± 1.49. t = 11.60, P = 0.0001.

The results in Table 4.4 show that there was a significant difference (t = 11.60, P = 0.0001) in the speech enhancement based on the number of learners producing correct articulation of speech sounds (pre-test mean 17.08, post ASTS test mean 25.23) t-test conducted at 95% confidence interval.

The implication of this finding was that the null hypothesis stating that there was no significant difference in speech production among learners who are hard-of-hearing

before speech training using ASTS (pre-test) and after speech training using ASTS (post-test) in selected schools in Nairobi City County was rejected.

4.4.3 Learners' Articulation of the Vowel Sounds (/a/, /e/, /i/, /o/, /u/) Before and After Training

Comparison of learners' articulation of vowel sounds before and after ASTS speech training was done. Before training, majority of learners were able to articulate vowel sounds /a/ (90.6%) and /o/ (81.3%) while /, 71.9% were able to articulate sound /e/, 65.6% were able to articulate sound /i/, 81.3% and 68.8% were able to articulate sound /u/ as indicated on Table 4.5.

Table 4.5: Learners articulation of the vowel sounds before and after ASTS training

Letters of the alphabet	Vowel Sounds	Before ASTS n (%) "correct" (n = 32) A	After ASTS n (%) "correct" (n = 32) B	Enhanced/Variation (B - A)
A	/a/	29 (90.6%)	32 (100%)	+3
E	/e/	23 (71.9%)	32 (100%)	+9
I	/i/	21 (65.6%)	32 (100%)	+11
O	/o/	26 (81.3%)	32 (100%)	+6
U	/u/	22 (68.8%)	30 (93.8%)	+8

NB: +ve indicate an improvement in the number of learners after ASTS training. Mean number of learners pre-test = 24.20 ± 1.5; Post ASTS training = 31.6 ± 0.4. t = 4.88, P = 0.008.

As shown in table 4.5, number of the learners' articulations of vowel sounds increased after ASTS speech training. At this time, all the learners (100%) were able to articulate the vowel sounds /a/, /e/, /i/ and /o/. The challenge was only noted in articulation of sound /u/. Using paired-sample t-test, there was a significant improvement in the number of learners able to correctly articulate the vowel sounds (t = 4.88, P = 0.008).

4.4.4 Learners' Articulation of the Consonant sounds before and after Training

Before ASTS training, the most articulated consonant sounds were /b/ and /m/ at 75.0% and 68.8% of the learners respectively as shown in Table 4.6.

Table 4.6: Learners articulation of the consonants before and after ASTS training

Letter of the alphabet	Consonant Sounds	Number before ASTS and (%) "correct" (n = 32) A	Number after ASTS (%) "correct" (n = 32) B	Enhanced/Variation (B – A)
B	/b/	24 (75.0%)	32 (100%)	+8
C	/k/	16 (50.0%)	32 (100%)	+16
D	/d/	10 (31.3%)	15 (46.9%)	+5
F	/f/	14 (43.8%)	27 (84.4%)	+13
G	/g/	8 (25.0%)	12 (37.5%)	+4
H	/h/	20 (62.5%)	24 (75.0%)	+4
J	/dʒ/	7 (21.9%)	18 (46.9%)	+11
K	/k/	16 (50.0%)	32 (100%)	+16
L	/l/	12 (37.5%)	17 (53.1%)	+5
M	/m/	22 (68.8%)	32 (100%)	+10
N	/n/	20 (62.5%)	29 (90.6%)	+9
P	/p/	18 (56.3%)	32 (100%)	+14
Q	/kw/	6 (18.8%)	11 (34.4%)	+5
R	/r/	16 (50.0%)	24 (75.0%)	+8
S	/s/	21 (65.6%)	31 (96.9%)	+10
T	/t/	13 (40.6%)	20 (62.5%)	+7
V	/v/	19 (59.4%)	30 (93.8%)	+11
W	/w/	14 (43.8%)	18 (56.3%)	+4
X	/ks/	7 (21.9%)	10 (31.3%)	+3
Y	/j/	18 (56.3%)	24 (75.0%)	+6
Z	/z/	19 (59.4%)	28 (87.5%)	+9

NB: -ve indicate a decrease in the number of learners; +ve indicate an improvement in the number of learners during ASTS training. Mean number of learners pre-test = 15.38 ± 1.17 ; Post ASTS training = 23.71 ± 1.68 . $t = 10.194$, $P = 0.0001$.

Table 4.6 shows that after training all learners, (100%) were able to articulate /b/, /k/, /m/ and /p/. The highest improvement was observed on articulation of sound /k/ which improved from 50% to 100%. There was a significant improvement in the number of learners able to correctly articulate the consonant sounds ($t = 10.194$, $P = 0.0001$).

4.4.5 Effect of ASTS Speech Training on the Vowels Sounds Compared to Consonant sounds

A comparison of the post-test result after using ASTS speech training on the vowel sounds to that of the consonant sounds was done using a two sample t-test. Mean number of learners who were able to articulate the consonant sounds after training was 23.71 ± 1.7 while the mean number of learners who were able to articulate the vowel sounds was 31.60 ± 0.40 . This showed that there was a significant difference in the influence of ASTS training on the vowel sounds and the consonant sounds ($t = 4.58$, $P = 0.001$). It was easier for the learners to articulate the vowel sounds than articulate the consonant sounds. Effect on the consonant sounds therefore was a variation of 8.33 as compared to the effect on ASTS on the vowel sounds which gave a variation of 7.40.

A comparison of pre-test and post-test results shows that it was significantly easier for the sampled learners to articulate vowel sounds than consonant sounds. This is a common feature associated with speech of persons with hearing impairment where consonant sounds are more affected by the impairment than vowel sounds (Geffner & Rothman, (1980). This finding concurs with investigations conducted by Rhoades (2006) which revealed that vowel sounds are produced correctly more often than consonant sounds by children with hearing impairment. However, Tobey, Geers, Brenner, Altuna and Gabbert (2003) while investigating factors associated with development of speech in children with cochlear implant found that accuracy of phoneme production was higher for consonant sounds (68.0%) than for vowel sounds

(61.6%). It can be inferred that the difference in this case was because the two interventions i.e. ASTS and cochlear implantation are different.

4.4.6 Learners' Articulation of the Voiceless Consonants before and after

Training

The selected voiceless consonant speech sounds were /f/, /k/, /s/, and /t/. Before ASTS speech training, 59.4% of the learners were able to articulate sound /k/, 65.6% were able to articulate /s/, 43.8% were able to pronounce /f/ and 40.3% were able to pronounce /t/ as shown in Table 4.7.

Table 4.7: Learners pronunciation of the voiceless consonants before and after ASTS training

Letter of the alphabet	Voiceless Sounds	Number before ASTS and (%) "correct" (n = 32) A	Number after ASTS (%) "correct" (n = 32) B	Enhanced/Variation (B - A)
F	/f/	14 (43.8%)	27 (84.4%)	+13
K	/k/	16 (50.0%)	32 (100%)	+16
S	/s/	21 (65.6%)	31 (96.9%)	+10
T	/t/	13 (40.6%)	20 (62.5%)	+7

NB: -ve indicate a decrease in the number of learners; +ve indicate an improvement in the number of learners during ASTS training. Mean number of learners pre-test = 16.75 ± 1.931 ; Post ASTS training = 27.50 ± 2.723 . $t = 7.485$, $P = 0.005$.

From Table 4.7, the number of the learners' articulations improved after ASTS speech training. At this time, all the learners (100%) were able to articulate the voiceless sound /k/ while majority of the learners were able to articulate sounds /f/ and /s/. The challenge was only noted in the articulation of sound /t/ articulated by 62.5% of the learners. There was a significant improvement in the number of learners who were able to correctly articulate the voiceless sounds ($t = 7.485$, $P = 0.005$).

4.4.7 Learners' Articulation of Voiced Sounds Before and After ASTS Training

The result showed that, before ASTS speech training, 75.0% of the learners were able to articulate sound /b/, 68.8% were able to articulate sound /m/, 62.5% were able to articulate sound /n/ and 59.4% were able to articulate sound /v/ and the same number were able to articulate sound /z/ correctly as shown in Table 4.8.

Table 4.8: Learners articulations of voiced sounds before and after ASTS training

Letter of the alphabet	Voiced Sounds	Number before ASTS and (%) "correct" (n = 32) A	Number after ASTS (%) "correct" (n = 32) B	Enhanced/Variation (B - A)
B	/b/	24 (75.0%)	32 (100%)	+8
D	/d/	10 (31.3%)	15 (46.9%)	+5
G	/g/	8 (25.0%)	12 (37.5%)	+4
J	//dʒ/	7 (21.9%)	18 (46.9%)	+11
L	//l/	12 (37.5%)	17 (53.1%)	+5
M	/m/	22 (68.8%)	32 (100%)	+10
N	/n/	20 (62.5%)	29 (90.6%)	+9
R	/r/	16 (50.0%)	24 (75.0%)	+8
V	/v/	19 (59.4%)	30 (93.8%)	+11
W	/w/	14 (43.8%)	18 (56.3%)	+4
Y	/j/	18 (56.3%)	24 (75.0%)	+6
Z	/z/	19 (59.4%)	28 (87.5%)	+9

NB: -ve indicate a decrease in the number of learners; +ve indicate an improvement in the number of learners during ASTS training. Mean number of learners pre-test = 15.75 ± 1.60; Post ASTS training = 23.250 ± 2.03. t = 9.950, P = 0.0001.

Table 4.8 above shows that the number of the learners increased after ASTS speech training. At post-test, all the learners (100%) were able to articulate the voiced sounds /b/ and /m/. Majority were able to articulate voiced sounds /n/, /r/ /v/, /j/ and /z/. The challenge was mainly noted in articulation of sound /g/ which was articulated by 37.5% and sound //dʒ/ which was articulated by 46.5% of the learners. There was a significant improvement in the number of learners able to articulate the voiced sounds (t = 9.950, P = 0.0001).

Although significant enhancement was noted for both voiceless and voiced sounds, more enhancements were observed for voiceless sounds than voiced sounds. Before commencement of ASTS training, learners had learnt to articulate voiced sounds better than voiceless sounds. Effect of ASTS on the voiceless sounds was a variation of 10.75 as compared to the effect of ASTS on the voiced sounds which gave a variation of 7.5. The study noted that training using ASTS enhanced more voiceless sounds which can be attributed to effects of audio and visual components of ASTS used by the learner simultaneously. Comparing the two types of consonant sounds, it can be inferred that it was easier for the learners to articulate voiced sounds through other traditional methods than voiceless sounds.

4.4.8 Learners' articulations of Plosive Sounds before and after Training

The plosive sounds selected were /p/, /t/, /k/, /b/, /d/, /g/. Plosive sounds are consonant sounds which involve, first, a stricture of the oral cavity that allows no air to escape from the vocal tract and, second, the compression and release of the air. So, there are four phases in the production of plosive sounds: closure, hold, release and post-release. Before ASTS speech training, 75.0% of the learners were able to pronounce sound /b/ correctly, sound /d/ 31.3%, sound /g/ 25.0% and sound /k/ 50.0% as shown in Table 4.9.

Table 4.9: Learners pronunciation of plosive sounds before and after ASTS training

Letter of alphabet	Plosive Sounds	Number before ASTS and (%) "correct" (n = 32) A	Number after ASTS (%) "correct" (n = 32) B	Enhanced/Variation (B - A)
B	/b/	24 (75.0%)	32 (100%)	+8
D	/d/	10 (31.3%)	15 (46.9%)	+5
G	/g/	8 (25.0%)	12 (37.5%)	+4
K	/k/	16 (50.0%)	32 (100%)	+16
P	/p/	18 (56.3%)	32 (100%)	+14
T	/t/	13 (40.6%)	20 (62.5%)	+7

NB: +ve indicate an improvement in the number of learners during ASTS training. Mean number of learners pre-test = 15.33 ± 2.5 ; Post ASTS training = 23.83 ± 3.8 , $t = 1.88$, $P = 0.098$.

From Table 4.9, articulation of sound /b/ improved to 100%, sound /d/ 46.9% and sound /g/ 37.5% after ASTS speech training. The highest improvement in plosive sounds was observed in articulation of sound /p/ before ASTS speech training, 56.3% were able to pronounce it correctly while after ASTS speech training, the result showed that 100% were able to get its articulation. Using two sample t-test, however, the result showed that there was no significant difference in the pronunciation of the plosives, $t = 1.88$, $P = 0.098$.

The results indicate that in terms of manner of sound articulation, voiceless plosive sounds, /p/, /t/, and /k/ were enhanced better than voiced plosive sounds, /b/, /d/ and /g/. In terms of the place of articulation of sound, bilabial plosive sounds /b/ and /p/ were more enhanced than alveolar plosive sounds, /t/ and /d/ or velar plosive sounds /k/ and /g/. From the results it can be inferred that bilabial plosive sounds are more visible compared to other plosive sounds. The most noticeable difference between the

voiceless plosive and voiced plosive sounds is aspiration which comes in the post-release phase of the voiceless plosive sounds.

4.4.9 Learners' Articulation of Fricative Sounds before and after Training

The fricative sounds selected were /f/, /h/, /s/, v/, /z/. Fricative sounds are characterized by a ‘‘hissing’’ sound which is produced by the air escaping through a small passage in the mouth. Before ASTS speech training, 43.8% of the learners were able to articulate sound /f/, sound /h/ 62.5% and sound /s/ 65.6% as shown in Table 4.10.

Table 4.10: Learners pronunciation of fricatives before and after ASTS training

Letter of alphabet	Fricative Sounds	Number before ASTS and (%) ‘‘correct’’ (n = 32) A	Number after ASTS (%) ‘‘correct’’ (n = 32) B	Enhanced/Variation (B – A)
F	/f/	14 (43.8%)	27 (84.4%)	+13
H	/h/	20 (62.5%)	24 (75.0%)	+4
S	/s/	21 (65.6%)	31 (96.9%)	+10
V	/v/	19 (59.4%)	30 (93.8%)	+11
Z	/z/	19 (59.4%)	28 (87.5%)	+9

NB: +ve indicate an improvement in the number of learners during ASTS training. Mean number of learners pre-test = 18.60 ± 1.20 ; Post ASTS training = 28.00 ± 1.20 , $t = 5.46$, $P = 0.001$.

Table 4.10 indicates that articulation of sound /f/ improved to 84.4%, followed by sound /v/ where only 59.4% of the learners could pronounce it during pretest. This improved to 93.8% after ASTS speech training then sound /s/ 96.9% after ASTS speech training. The ability of the learners to articulate fricatives significantly improved after ASTS speech training using two sample t-test, $t = 5.46$, $P = 0.001$.

The results indicate that voiceless labiodental fricative sound /f/ and voiceless alveolar fricative sound /s/ were enhanced more than voiced labiodental fricative sound /v/ and voiced alveolar fricative sound /z/. The least enhanced fricative sound was glottal /h/. In comparison, voiceless fricative sounds were better improved than voiced fricative sounds after training using ASTS.

4.4.10 Learners' Articulations of Nasal Sounds Before and After ASTS Training

Nasal sounds were /m/ and /n/. The basic feature of a nasal sound is that air escapes through the nose and the main difference between the selected nasals is the point where the air is stopped in the mouth. Sound /m/ is a bilabial nasal sound while sound /n/ is an alveolar nasal sound. Before ASTS speech training, 68.8% of the learners were able to pronounce sound /m/ whereas 62.5% were able to pronounce sound /n/. Table 4.11.

Table 4.11: Learners pronunciation of nasal sounds before and after ASTS training

Letter of alphabet	Nasal Sounds	Number before ASTS and (%) "correct" (n = 32) A	Number after ASTS (%) "correct" (n = 32) B	Enhanced/Variation (B - A)
M	/m/	22 (68.8%)	32 (100%)	+10
N	/n/	20 (62.5%)	29 (90.6%)	+9

Table 4.11 shows that after ASTS speech training, all learners (100%) were able to articulate sound /m/ while 90.6% were able to articulate sound /n/. The results after training using ASTS indicate that sound /m/ was articulated by 10 more learners while

sound /n/ was articulated by 9 more learners. Comparing the two, sound /m/ is more visible on the lips than sound /n/.

Overall for this objective, the variables examined in testing the effectiveness of ASTS were vowels and consonants which included voiceless, voiced, plosives, fricatives and nasal sounds. In comparison, the results showed that using the ASTS, there was a significant improvement in all the variables except plosive sounds. The researcher noted that although there was minimal improvement for plosive sounds compared to other selected consonants, all the selected learners were able to articulate sounds /b/, /k/ and /p/. From the results, the learners had acquired articulation of plosive sounds more than other selected variables prior to commencement of ASTS training, hence minimal improvement. This observation is in support of a study by Trujillo (2014) whose findings showed that plosive sounds are the easiest sounds to teach and learn in an English course.

The main goal of this study was to implement and investigate the effectiveness of ASTS as a speech trainer for speech perception and production for learners who are hard of hearing. The learners' ability to perceive and produce sounds of all the selected twenty six sounds of English alphabet did change from pre-test to post-test. A second analysis revealed an improvement in perception and production of vowel sounds, consonant sounds, voiceless sounds, voiced plosive sounds, fricative sounds and nasal sounds though in varying degrees. Although the training method was the same for the different categories of sounds, an analysis of pre-test versus post-test ratings revealed an improvement for each category.

Automated Speech Training System is similar in some respects to Electropalatography (EPG), which has been considered useful in clinical settings because it provides direct visual feedback (in the form of a computer display) on the contact between the tongue and the palate during speech production. Although the visual feedback from the EPG was deemed to be extremely important to the significant improvement in production, there have been very few systematic evaluations of its effectiveness. Comparing EPG and ASTS which was used in the current study, ASTS appears to have been more successful, with $t=11.60$, $p=0.0001$ in the speech enhancement based on the number of learners producing correct articulation of speech sounds.

ASTS was adopted from “Baldi” which has been suggested to be an effective tutor for speech training of learners with hearing impairment. Baldi could speak slowly and show supplementary articulatory features, such as vibration of the neck to show voicing among other features (Massaro, 2004). During implementation of Baldi, perception and production of speech improved for each of the 7 learners. To demonstrate the success of Baldi further, speech production also generalized to new words not included in the training lessons (Massaro & Light, 2004). Although some considerable improvements in speech perception and production were registered with Baldi, articulatory difficulties were identified by the teachers of the learners with hearing loss unlike in the current study where ASTS was used to pre-test the learners who were hard of hearing. From the articulatory deficits identified by the teachers, only eight speech segments were designed by the researcher for training using Baldi contrary to the current study in which twenty six sounds of English alphabet were pre-

tested and post-tested after training. Although Baldi like EPG provided visual feedback (in the form of a computer display), both did not provide audio component which amplifies the sound to the learner's hearing level as in the current study.

The findings of this study also support the study by Assefa in Ethiopia. Assefa applied animated talking head technology in Mekanissa School for the deaf in Ethiopia to train learners Amharic language speech sounds (Assefa, 2006). The findings of the study revealed that out of 30 learners (15 males and 15 females), 70% were able to produce sounds articulated on the lips accurately but the researcher reported that the system was incomplete because it could not display the vocal tract in which most sounds are articulated. To some extent, the findings of Assefa's study are consistent with the current study, learners were able to articulate sounds formed at the lips for example sounds /b/ 100%, /p/ 100%, and /m/ 100% better than sounds formed at the alveolar for instance sounds /t/ 62.5% and /d/ 46.9% velar or even at the glottal for example sound /h/ 75% despite the system displaying the tract. Wankhede (2014) recommends that, to design a speech training aid, vocal tract areas need to be estimated with consistency and appropriate dynamic response. For learners with hearing impairment, appropriate displays, cartoons or games based on dynamically varying vocal tract shape need to be devised. He further opines that obtaining realistic shapes for children in various age groups is a must so that a designed speech training aid could be used by children from any age group effectively. This is different from the current study where ASTS was used to train all the subjects though they were of different ages.

However, the present findings suggest that ASTS is an effective tutor for speech training learners who are hard of hearing. There are other advantages of ASTS that were not exploited in the present study. ASTS can be used with different platforms like smart phones, tablets, among others anywhere and anytime, used as frequently as desired, and modified to suit individual needs as suggested by one learner:

“My parents can buy me the system so that i can learn sounds at home”. Other two learners said that “our teachers should use the system to teach us how to talk”.

ASTS also proved beneficial even though some learners in this study were continually receiving speech training from their teachers and speech therapists before and during the time of this study. ASTS offered unique features that can be added to the curriculum of speech training.

Results of the post-test speech productions were significantly higher than pre-test results, indicating significant enhancement of speech sound production. Given that in the study there was no control group, it is possible that some of this enhancement occurred independently of ASTS or was simply based on routine practice. However, the results provided some evidence that at least some of the improvement could be attributed to ASTS. From these results, it can be concluded that speech training using ASTS was a significant contributing factor to the speech enhancement observed in speech production ability among the selected learners.

4.5 Comparison of the Effects of ASTS with Traditional Methods of Speech Training

Before and during the current study, eleven learners sampled from school A were being speech trained formally using traditional speech training methods while twenty one learners selected from schools B and school C were not. Therefore, by the end of the study, learners from school A had experienced speech training using traditional methods and ASTS but learners from schools B and school C had experienced speech training using ASTS only. Guided by objective three of the study, analysis was done by comparing; pre-test results of school A with schools B and C, post-test results of school A with schools B and C, deviation of post-test to pre-test in learners' achievements and pre-test and post-test results of school A with schools B and C in articulation of vowel and consonant sounds.

4.5.1 Comparison of Pre-test and posttest Results School A with Schools B and C

Comparison of the pre-test results of the learners who were being speech trained using traditional speech training methods (school A) to the ones who had no formal speech training(schools B and C) was done using two sample t-test as shown in Table 4.12.

Table 4.12: Learners articulation of the sounds before and after traditional and ASTS speech training

Letters of the alphabet	Sounds of the alphabet	Pretest		Post test	
		Traditional speech learners trained (n = 11)	ASTS learners trained (n = 21)	Traditional speech learners trained (n = 11)	ASTS learners trained (n = 21)
A	/a/	11 (100%)	18 (85.7%)	11 (100%)	21 (100%)
B	/b/	8 (72.7%)	16 (76.2%)	11 (100%)	21 (100%)
C	/k/	6 (54.5%)	10 (47.6%)	11 (100%)	21 (100%)
D	/d/	5 (23.8%)	5 (45.5%)	8 (72.7%)	7 (33.3%)
E	/e/	8 (72.7%)	15 (71.4%)	11 (100%)	21 (100%)
F	/f/	5 (45.5%)	9 (42.9%)	9 (81.8%)	18 (85.7%)
G	/g/	1 (9.1%)	7 (33.3%)	3 (27.3%)	9 (42.9%)
H	/h/	8 (72.7%)	12 (57.1%)	10 (90.9%)	14 (66.7%)
I	/i/	9 (81.8%)	12 (57.1%)	11 (100%)	21 (100%)
J	/dʒ/	4 (36.4%)	3 (14.3%)	7 (63.6%)	11 (52.4%)
K	/k/	6 (54.5%)	10 (47.6%)	11 (100%)	21 (100%)
L	/l/	3 (27.3%)	9 (42.9%)	5 (45.5%)	12 (57.1%)
M	/m/	10 (90.9%)	12 (57.1%)	11 (100%)	21 (100%)
N	/n/	8 (72.7%)	12 (57.1%)	10 (90.9%)	19 (90.5%)
O	/o/	9 (81.8%)	17 (81.0%)	11 (100%)	21 (100%)
P	/p/	8 (72.7%)	10 (47.6%)	11 (100%)	21 (100%)
Q	/kw/	2 (18.2%)	4 (19.0%)	5 (45.5%)	6 (28.6%)
R	/r/	5 (45.5%)	11 (52.4%)	7 (63.6%)	17 (81.0%)
S	/s/	8 (72.7%)	13 (61.9%)	11 (100%)	20 (95.2%)
T	/t/	3 (27.3%)	10 (47.6%)	6 (54.5%)	14 (66.7%)
U	/u/	8 (72.7%)	14 (66.7%)	11 (100%)	19 (90.5%)
V	/v/	8 (72.7%)	11 (52.4%)	11 (100%)	19 (90.5%)
W	/w/	3 (27.3%)	11 (52.4%)	6 (54.5%)	12 (57.1%)
X	/ks/	3 (27.3%)	4 (19.0%)	5 (45.5%)	5 (23.8%)
Y	/j/	7 (63.6%)	11 (52.4%)	8 (72.7%)	16 (76.2%)
Z	/z/	8 (72.7%)	11 (52.4%)	9 (81.8%)	19 (90.5%)
	Mean ± SE (%)	57.20 ± 4.94	51.75 ± 3.41	80.4 ± 4.5	78.0 ± 4.9
	T-test result	0.91		0.36	
	P-value	0.368		0.723	

As indicated in Table 4.12, the pre-test result of the analysis showed that learners who were undergoing speech training formally using traditional methods before commencement of the study (school A) had a higher mean of 57.20 ± 4.94 compared to learners who had no formal speech training (schools B and C) who had a mean of 51.75 ± 3.41 . However, the difference between the two groups of learners was not significant since ($t = 0.91$, $P = 0.368$) in the percentage number of learners who had

the articulation of the speech sounds in traditional speech training (mean $57.20 \pm 4.94\%$) from those who had no formal speech training (mean $51.75 \pm 3.41\%$). The analysis suggest that, although there was no formal speech training that was taking place in school B and school C, learners in the two schools were acquiring speech perception and production informally.

4.5.2 Comparison of Post-test Results School A with Schools B and C

Comparison of post-test results were done by testing hypothesis two of the study

Testing of Hypothesis 2

Ho2 There is no significant difference in speech production between learners speech trained using traditional methods and learners' speech trained using Automated Speech Training System.

The hypothesis sought to find out if there was any significant difference between the learners who, before the commencement of the study had been speech trained formally using traditional methods and learners who had not received any formal speech training. Therefore, by the end of study one group of learners had speech trained using both traditional methods and ASTS (school A) while the other group had speech trained using ASTS only (schools B and C). The results on table 4.12 indicate that learners who had been speech trained using both traditional methods and ASTS by the end of the data collection period had a higher mean of 80.4 ± 4.5 compared to the learners who had been speech trained using ASTS only, by the end of data collection period who had a mean of 78.0 ± 4.9 . These results showed a difference of 2.4 in mean in favour of learners who had been speech trained using both methods (school A). Comparing the pre-test and post-test means for learners who

were speech trained using both traditional and ASTS methods (school A), there was a difference of 23.2 in means. The same comparison of pre-test and post-test for learners who were only speech trained formally using ASTS (schools B and C) revealed a difference of 26.25 in mean. The two comparisons of the means show a difference of 3.05 in favour of the learners who, by the end of data collection period had been speech trained using ASTS only (schools B and C). The comparisons reveal that ASTS enhanced speech for both groups of learners although more enhancements were realized among learners who had no formal speech training and therefore received speech training using ASTS only. However, using two sample t-tests statistics to analyze the data, table 4.12 shows that post-test result of the learners who had both traditional speech training and ASTS (mean 80.4 ± 4.5) were found to be not significantly different ($t = 0.36$, $P = 0.723$) from post-test results of the learners who had ASTS speech training only (mean 78.0 ± 4.9). The percentage of the respondents was used in this comparison to normalize the data for comparison other than the actual number of individuals since the n-value of those who were subjected to ASTS speech training only ($n = 21$) were not the same as the n-value for those who used both traditional speech training and ASTS training ($n = 11$). An example of 8 learners who used traditional speech training and ASTS speech training gave a 72.7% of the 11 total learners who used traditional training. This percentage was therefore used in comparison with those who used ASTS training only where a sample e.g. of 9 learners was 42.9% out of 21 total learners who used ASTS training.

The implication of this finding was that although a difference in speech enhancement was realized among learners who had no formal speech training (schools B and C)

and learners who had formal speech training (school A), the difference was not significant. Therefore, the null hypothesis stating that there is no significant difference in speech production between learners speech trained using traditional speech raining methods and learners speech trained using Automated Speech Training System was accepted.

4.5.3 Deviation of the Post-test from Pre-Test in Learners' Articulations

Using two sample t-tests, the analysis showed that there was no significant difference in articulation between learners who had undergone traditional speech training formally and learners who had not. Therefore the study established the effect of ASTS by getting the deviation in the articulations of learners who had no formal speech training hence were subjected to ASTS training only during Post-test result from pre-test results as shown in Table 4.13.

Table 4.13: Deviation in the learners pronunciation of the sounds before and after ASTS speech training

Letters of the alphabet	Sounds of the alphabet	ASTS learners trained (n = 21) A	ASTS learners trained (n = 21) B	Deviation B-A
A	/a/	18 (85.7%)	21 (100%)	+3
B	/b/	16 (76.2%)	21 (100%)	+5
C	/k/	10 (47.6%)	21 (100%)	+11
D	/d/	5 (45.5%)	7 (33.3%)	+2
E	/e/	15 (71.4%)	21 (100%)	+6
F	/f/	9 (42.9%)	18 (85.7%)	+9
G	/g/	7 (33.3%)	9 (42.9%)	+2
H	/h/	12 (57.1%)	14 (66.7%)	+2
I	/i/	12 (57.1%)	21 (100%)	+9
J	/dʒ/	3 (14.3%)	11 (52.4%)	+8
K	/k/	10 (47.6%)	21 (100%)	+11
L	/l/	9 (42.9%)	12 (57.1%)	+3
M	/m/	12 (57.1%)	21 (100%)	+9
N	/n/	12 (57.1%)	19 (90.5%)	+7
O	/o/	17 (81.0%)	21 (100%)	+4
P	/p/	10 (47.6%)	21 (100%)	+11
Q	/kw/	4 (19.0%)	6 (28.6%)	+2
R	/r/	11 (52.4%)	17 (81.0%)	+5
S	/s/	13 (61.9%)	20 (95.2%)	+7
T	/t/	10 (47.6%)	14 (66.7%)	+4
U	/u/	14 (66.7%)	19 (90.5%)	+5
V	/v/	11 (52.4%)	19 (90.5%)	+8
W	/w/	11(52.4%)	12 (57.1%)	+1
X	/ks/	4 (19.0%)	5 (23.8%)	+1
Y	/j/	11(52.4%)	16 (76.2%)	+5
Z	/z/	11(52.4%)	19 (90.5%)	+8
	Mean ± SE (%)	51.75 ± 3.41a	78.0 ± 4.9b	26.25

Mean values are significantly different at $P \leq 0.05$ as denoted by different letters. T-value = 4.39, $P = 0.0001$, $df = 44$

As shown in Table 4.13, a significant improvement ($t = 4.39$, $P = 0.0001$) in the numbers of learners who were able to articulate all the sounds, hence positive deviations. In particular, higher number of learners (11 learners) was able to correctly pronounce sounds /p/ and sound /k/ after ASTS speech training than before.

The results of this study showed that though there was no significant difference between the learners who had prior traditional speech training methods with those who had no formal speech training, hence were subjected to ASTS speech training

only, there was a positive deviation of 26.25 among learners who were speech trained using ASTS only. The positive deviation confirmed earlier results that there was significant enhancement in speech articulation of the selected sounds comparing learners articulation of sounds before and after training using ASTS. The findings of this study are consistent with the findings reported by ASHA (2002) which showed that there was no difference between computerized and non-computerized speech training methods. However, in the current study, deviation of the post-test from pre-test results of learners who had no formal traditional speech training indicates a significant improvements ($t=4.39$, $p=0.0001$) in the number of learners who were able to articulate all the sounds, hence positive deviations.

The results of the current study also support findings of Coleman, MacLauchlan, Cihak, Martin and Wolbers (2015) in which they concluded that computer-assisted speech training was equally effective as teacher-provided speech training. Overall, in the current study, there was significant difference between the pre-test and post-test results; thereby indicating that there was speech enhancement in using ASTS. However, in comparison to previous studies, teacher-assisted speech training (traditional methods) cannot be ignored totally as the findings indicate that there was no significant difference ($t = 0.90$, $P = 0.368$) in the percentage number of learners who had the correct articulation of the sounds of alphabets in traditional speech training methods (mean $57.20 \pm 4.94\%$) from those who were subjected to ASTS speech training only (mean $51.75 \pm 3.41\%$).

According to Coleman, MacLauchlan, Cihak, Martin and Wolbers, (2015), one of the well-noted benefits of computer-assisted instruction is increased student motivation.

Based on the social validity assessment and anecdotal observations during intervention, computer-assisted instruction seemed to be more enjoyable to learners. Similar observations were made in the current study. At first, all the learners were excited that the speech training was done by a virtual teacher embedded in the computer who produced audible sounds equal to or above their hearing threshold. At the end of each training session learners often asked for more time for training while two learners enquired on how their parents could acquire the system for further training at home. Even the learners, who had not been sampled, expressed their willingness to train. Based on the findings of this study, ASTS can be a classroom tool used to increase independence during speech training for learners who are hard of hearing but may not be an appropriate solution for all learners hence need for combining ASTS with teacher-assisted speech training (traditional methods).

As noted by Coleman, MacLauchlan, Cihak, Martin and Wolbers, (2015), the number of sessions required for participants to acquire speech also could be an area of concern. In teaching deaf students vocabulary using computer-assisted instruction, Barker (2003) weighed the amount of time spent using technology for vocabulary instruction as well as the expense of technology with potential benefits and argued that technology is a high-tech memorization tool and therefore deaf learners need particular help from the teacher to supplement the multimodal technology.

In the current study, even though it took the learners a relatively large number of sessions to learn articulation of selected English alphabetical sounds they had deficits in, each speech training session took only twenty minutes. The researcher observed that if the amount of training time were increased per session, learners could acquire

more speech sounds. In a speech training context, when maintaining tight control of research conditions is not necessary, the use of computer-assisted speech training would supplement, not supplant, teacher-provided speech training (Coleman et al., 2015). Providing ASTS for learners to practice speech articulation after explicit training from the teacher would allow learners who often require adult assistance during speech training to practice independently.

The findings of the current study are as well in tandem with observations made by Oster (2010) that computer-aided speech training can be used as a valuable expansion of traditional speech training of severely hard-of-hearing children. As noted earlier, the current study was born out of realization that there was no speech training curriculum in Kenya currently. The findings of the current study support the conclusions made by Bernstein, Goldstein and Mahshie (2002) which emphasizes the need of developing a curriculum incorporating both traditional and computer-based speech training methods. According to Bernstein, Goldstein and Mahshie (2002), introduction of training aids that use sophisticated signal analysis based on knowledge of acoustic phonetics and/or speech physiology, implies the need for therapists with adequate understanding of acoustic phonetics and speech physiology of speech of persons with hearing impairment. Introduction of such aids also suggests the need for education of those who are in a position to purchase training aids for clinics and school systems. They also noted that these needs cannot be addressed adequately in the laboratory alone but must be addressed by the larger professional community.

The findings of the current study support the conclusion made by The National Council for Special Education (2009) that oral approaches to speech training can

support adequate language development by some but not all children with hearing loss, even given technological advances and early identification.

4.6 Influence of Selected Demographic Factors on Speech Enhancement

Studies have shown that speech development among learners with hearing impairment is influenced by various factors. This study sought to find out whether selected demographic factors played any role in the effectiveness of ASTS in enhancing speech among learners who are hard-of-hearing. Therefore, based on objective four of the study, the study sought to answer these questions; how was effectiveness of ASTS in enhancing speech among learners who are hard of hearing influenced by gender, age, audiological status and number of siblings in the family? Can the selected demographic factors predict speech enhancement of a learner who is hard of hearing training using ASTS? First, learners' articulation of sounds by gender at pre-test and post-test were compared to find out whether there was any difference between male and female learners in enhancement of speech. Then, Correlation and regression analysis were done to establish influence of age, gender, degree of hearing loss for the right and left ears and number of siblings in the family on articulation of sounds of alphabet after training using ASTS.

4.6.1 Learners' Pre-test Articulation by Gender

Since the study comprised equal number of male and female learners, the Comparison of learners' articulation of sounds by gender is as shown in Table 4.14.

Table 4.14: Learners, articulations of sounds before ASTS by Gender

Letter of the alphabet	Sound of the alphabet	Male Number and (%) “correct” (n = 16)	Female Number and (%) “correct” (n = 16)
A	/a/	14 (87.5%)	15 (93.8%)
B	/b/	12 (75.0%)	12 (75.0%)
C	/k/	7 (43.8%)	9 (56.3%)
D	/d/	4 (25.0%)	6 (37.5%)
E	/e/	14 (87.5%)	9 (56.3%)
F	/f/	7 (43.8%)	7 (43.8%)
G	/g/	4 (25.0%)	4 (25.0%)
H	/h/	9 (56.3%)	11 (68.8%)
I	/i/	11 (68.8%)	10 (62.5%)
J	/dʒ/	5 (31.3%)	2 (12.5%)
K	/k/	7 (43.8%)	9 (56.3%)
L	/l/	7 (43.8%)	5 (31.3%)
M	/m/	12 (75.0%)	10 (62.5%)
N	/n/	13 (81.3%)	7 (43.8%)
O	/o/	13 (81.3%)	13 (81.3%)
P	/p/	9 (56.3%)	9 (56.3%)
Q	/kw/	5 (31.3%)	1 (6.3%)
R	/r/	8 (50.0%)	8 (50.0%)
S	/s/	12 (75.0%)	9 (56.3%)
T	/t/	6 (37.5%)	7 (43.8%)
U	/u/	11 (68.8%)	11 (68.8%)
V	/v/	9 (56.3%)	10 (62.5%)
W	/w/	8 (50.0%)	6 (37.5%)
X	/ks/	4 (25.0%)	3 (18.8%)
Y	/j/	11 (68.8%)	7 (43.8%)
Z	/z/	8 (50.0%)	11 (68.8%)
	T value	0.85	
	P –value	0.401	

Table 4.14 indicates that during pre-test, more male learners correctly articulated sounds /a/ and /e/ (87.5%) while more of the female learners (93.8%) correctly articulated sound /a/. Male learners mainly had problem with sounds /d/, /g/, /ks/ which merely 25.0% of the male learners were able to articulate correctly. Most of the female learners had problems in articulating sound /kw/ which was only correctly articulated by 6.3% of the female learners. Female learners similarly had difficulty in articulating sound /j/ which was correctly articulated by 12.5% and sound /ks/ which was correctly articulated by 18.8% of the female learners. Two sample t-test was used

to compare pre-test of the male learners with pre-test of the female learners. The result showed that there was no significant difference in the pre-test result of the male learners from that of the female learners ($t = 0.85$, $P = 0.401$).

4.6.2 Learners' Post-test Articulations by Gender

After speech training using ASTS, learners' articulations were compared to establish whether gender played a role in speech enhancement among learners who are hard-of-hearing as shown in Table 4.15.

Table 4.15: Learners articulation of sounds after ASTS by Gender

Letter of the alphabet	Sound of the alphabet	Male Number and (%) "correct" (n = 16)	Female Number and (%) "correct" (n = 16)
A	/a/	16 (100%)	16 (100%)
B	/b/	16 (100%)	16 (100%)
C	/k/	16 (100%)	16 (100%)
D	/d/	6 (37.5%)	9 (56.3%)
E	/e/	16 (100%)	16 (100%)
F	/f/	13 (81.3%)	14 (87.5%)
G	/g/	8 (50.0%)	4 (25.0%)
H	/h/	11 (68.8%)	13 (81.3%)
I	/i/	16 (100%)	16 (100%)
J	/dʒ/	9 (56.3%)	9 (56.3%)
K	/k/	16 (100%)	16 (100%)
L	/l/	8 (50.0%)	9 (56.3%)
M	/m/	16 (100%)	16 (100%)
N	/n/	16 (100%)	13 (81.3%)
O	/o/	16 (100%)	16 (100%)
P	/p/	16 (100%)	16 (100%)
Q	/kw/	8 (50.0%)	3 (18.8%)
R	/r/	12 (75.0%)	12 (75.0%)
S	/s/	16 (100%)	15 (93.8%)
T	/t/	11 (68.8%)	9 (56.3%)
U	/u/	15 (93.8%)	15 (93.8%)
V	/v/	14 (87.5%)	16 (100%)
W	/w/	9 (56.3%)	9 (56.3%)
X	/ks/	5 (31.3%)	5 (31.3%)
Y	/j/	13 (81.3%)	11 (68.8%)
Z	/z /	14 (87.5%)	14 (87.5%)
	t-value	0.29	
	P – value	0.776	

From Table 4.15 above, post-test evaluation showed that all male learners were able to pronounce sounds /a/ /b/, /k/, /e/, i/, /k/, m/, /n/, /o/, /p/ and /s/. All of the female learners (100.0%) were able to pronounce sounds /a/, /b/, /k/, /e/, /i/, /k/, /m/, /o/, /p/ and /v/. Male learners mainly had problems with sounds /ks/ and /d/ which merely 31.3% and 37.5% respectively of the male learners were able to pronounce correctly. More of the female learners had problems articulating sounds /g/ and /ks/ which were only correctly articulated by 25.0% and 31.3% of the female learners respectively. Using a two sample t-test to compare the post-test result of the female learners with the post-test result of the male learners, the results showed there was no significant difference ($t = 0.29$, $P = 0.776$). After comparing learners' articulations by gender during pre-test and post-test separately, gender comparison was done as indicated in Table 4.16.

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Table 4.16: Learners articulations Before and After ASTS training

Letter of the alphabet	Sound of the alphabet	Male		Female	
		Pretest Number (%) "correct" (n = 16)	Posttest Number (%) "correct" (n = 16)	Pretest Number (%) "correct" (n = 16)	Posttest Number (%) "correct" (n = 16)
A	/a/	14 (87.5%)	16 (100%)	15 (93.8%)	16 (100%)
B	/b/	12 (75.0%)	16 (100%)	12 (75.0%)	16 (100%)
C	/k/	7 (43.8%)	16 (100%)	9 (56.3%)	16 (100%)
D	/d/	4 (25.0%)	6 (37.5%)	6 (37.5%)	9 (56.3%)
E	/e/	14 (87.5%)	16 (100%)	9 (56.3%)	16 (100%)
F	/f/	7 (43.8%)	13 (81.3%)	7 (43.8%)	14 (87.5%)
G	/g/	4 (25.0%)	8 (50.0%)	4 (25.0%)	4 (25.0%)
H	/h/	9 (56.3%)	11 (68.8%)	11 (68.8%)	13 (81.3%)
I	/i/	11 (68.8%)	16 (100%)	10 (62.5%)	16 (100%)
J	/dʒ/	5 (31.3%)	9 (56.3%)	2 (12.5%)	9 (56.3%)
K	/k/	7 (43.8%)	16 (100%)	9 (56.3%)	16 (100%)
L	/l/	7 (43.8%)	8 (50.0%)	5 (31.3%)	9 (56.3%)
M	/m/	12 (75.0%)	16 (100%)	10 (62.5%)	16 (100%)
N	/n/	13 (81.3%)	16 (100%)	7 (43.8%)	13 (81.3%)
O	/o//	13 (81.3%)	16 (100%)	13 (81.3%)	16 (100%)
P	/p//	9 (56.3%)	16 (100%)	9 (56.3%)	16 (100%)
Q	/kw/	5 (31.3%)	8 (50.0%)	1 (6.3%)	3 (18.8%)
R	/r/	8 (50.0%)	12 (75.0%)	8 (50.0%)	12 (75.0%)
S	/s/	12 (75.0%)	16 (100%)	9 (56.3%)	15 (93.8%)
T	/t/	6 (37.5%)	11 (68.8%)	7 (43.8%)	9 (56.3%)
U	/u/	11 (68.8%)	15 (93.8%)	11 (68.8%)	15 (93.8%)
V	/v/	9 (56.3%)	14 (87.5%)	10 (62.5%)	16 (100%)
W	/w/	8 (50.0%)	9 (56.3%)	6 (37.5%)	9 (56.3%)
X	/ks/	4 (25.0%)	5 (31.3%)	3 (18.8%)	5 (31.3%)
Y	/j/	11 (68.8%)	13 (81.3%)	7 (43.8%)	11 (68.8%)
Z	/z /	8 (50.0%)	14 (87.5%)	11 (68.8%)	14 (87.5%)
	Mean number± SE	8.92± 0.62	12.77± 0.72	8.15 ± 0.66	12.46 ± 0.81
	t-value	4.06		4.13	
	P-value	0.0001*		0.0001*	

*significant difference in the means at $P \leq 0.05$

Table 4.16 shows that use of ASTS speech training significantly improved speech of the male learners ($t = 4.06$) and that of the female learners ($t = 4.13$). This result showed that more female learners had improved speech sound production after use of ASTS than the male learners Table 4.19.

In the current study, although there was no significant difference between male and female learners' articulations of selected sounds, more female learners had more enhanced speech than male learners. The findings concur with the findings of Tobey,

Geers, Brenner, Altuna and Gabbert (2003) in which overall scores for female subjects (69.3%) were higher than for male subjects (57.6%) in speech production. In their study female learners had more accurate consonant production (71.0%) than male learners (65%) although there was no gender difference in vowel production.

Stelnikov et al. (1998) found out that female use the neuro network of predictive and integrative analysis of speech to a larger extent than male hence female speech-read words better than male and the findings of this study concur with their findings. Although the difference in articulation of sounds between male learners and female learners was not significant in the current study, female learners had more enhanced speech than male learners after training using ASTS. From the analysis, since there was no significant difference between male and female learners in pre-test and post-test, then it can be inferred that speech training using ASTS was not influenced by gender. The system had similar effects to male and female learners.

4.6.3 Correlation Analysis of the Study

In establishing the effect of demographic characteristics of the learners on enhanced speech, a correlation analysis was conducted. The learners speech enhancement increased with the increase in the age of the child ($r = 0.180$, $P = 0.324$). Speech enhancement reduced with an increase in degree of hearing of the ears (right ear, $r = -0.137$, left ear, $r = -0.218$) and decreased with increase in the number of sibling in the family ($r = -0.231$). Enhancement of the speech was higher among the male learners than in the female learners, hence the negative correlation value ($r = -0.120$, $P = 0.515$).

Table 4.17: Correlation matrix showing relationship between learners demography with speech

		Enhanced speech	Age of child	Gender of respondents	Degree of hearing loss right ear	Degree of hearing loss left	No sibling
Enhanced speech	r-value	1	.180	-.120	-.137	-.218	-.231
	Sig. (2-tailed)		.324	.515	.455	.230	.204
Age of child	r-value	.180	1	-.337	-.129	-.235	-.117
	Sig. (2-tailed)	.324		.059	.482	.196	.524
Gender of respondents	r-value	-.120	-.337	1	.182	.064	-.322
	Sig. (2-tailed)	.515	.059		.318	.729	.073
Degree of hearing loss, right ear	r-value	-.137	-.129	.182	1	.849**	.177
	Sig. (2-tailed)	.455	.482	.318		.000	.332
Degree of hearing loss left	r-value	-.218	-.235	.064	.849**	1	.323
	Sig. (2-tailed)	.230	.196	.729	.000		.072
No sibling	r-value	-.231	-.117	-.322	.177	.323	1
	Sig. (2-tailed)	.204	.524	.073	.332	.072	
	N	32	32	32	32	32	32

** . Correlation is significant at the 0.01 level (2-tailed).

From Table 4.17, age had a positive effect on speech training using ASTS. The older the child, the more he/she benefited from using the system ($r=0.180$). Considering the gender of the learners, male learners had enhanced speech more than the female learners hence ($r=-0.120$) in a scale of (1-male, 2-female). As far as the degree of hearing loss was concerned, learners whose degree of hearing loss was high had a lower enhanced speech hence negative correlation values. As the number of siblings in the family increased, speech enhancement decreased ($r=-0.231$).

4.6.4 Regression Model of the Study

The correlation analysis above indicated the trend of the demographic influence on speech enhancement and therefore to establish the influence of learners' demography on speech enhancement using Automated Speech Training System (ASTS), linear regression analysis was carried out. Although the correlation value showed no significant relationship in the demography with the speech enhancement ($P > 0.05$), the possible model therefore is;

$$Y = \text{constant} + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

Where Y = Enhanced speech

X_1 = Age of the child

X_2 = gender

X_3 = degree of hearing loss of right ear

X_4 = degree of hearing loss of left ear

X_5 = Number of siblings in the family

β = is the beta coefficient of the enhanced speech using ASTS

ε = Error term

Using standardized beta coefficient, the Regression model yielded R^2 value of 34.6 and the model fitted was therefore;

$$Y = 0.846 + 0.048X_1 - 0.192X_2 + 0.170X_3 - 0.265X_4 - 0.231X_5$$

Table 4.18: Regression table showing the influence of the demographic of the ASTS speech training

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.846	.129		6.539	.000
	age of child	.002	.007	.048	.229	.821
	gender of respondents	-.031	.036	-.192	-.869	.393
	degree of hearing loss right	.001	.002	.170	.459	.650
	degree of hearing loss left	-.001	.002	-.265	-.689	.497
	no sibling	-.064	.059	-.231	-1.087	.287

a. Dependent Variable: average post test result

It was noted that degree of hearing loss in the right ear had a beta coefficient value of positive 0.170, in the presence of other factors, however when degree of hearing loss of the right ear was tested on its own without other factors with the learners' speech articulation, the result gave a standardized beta value of -0.137, showing that when the degree of hearing loss of the right ear was lower, articulation of speech sounds was better.

The findings of the current study in which learners' speech enhancement correlated positively with increase in age, decreased with increase in degree of hearing loss concur with the findings of Yoshinaga-Itano (2003), Yoshinaga-Itano and Sedey (2000) and Oster (2002). In their findings, primary predictors of speech development of deaf and hard-of-hearing children included chronological age and degree of hearing loss among others. The findings show that speech enhancement decreased with increased number of siblings in the family. It can be inferred from this observation that in a family where there are more siblings, the learner who is hard-of-hearing does not get a lot of attention in terms of speech compared to families with fewer siblings.

Sign language being the alternative mode of communication is rarely known by most members of the hearing society including most siblings hence the learner who is hard of hearing, being the minority is encouraged to use the oral communication of the majority siblings.

4.7 The Views of Learners on Communication Mode and Speech Training using Traditional Methods and ASTS

Guided by objective five of the study learners who are hard of hearing were required to; state which mode of communication they preferred between oralism, manualism or both, to state which method of training they preferred between traditional and ASTS, evaluate different components of the Automated Speech Training System, state the challenges they face in communication and their suggestions for improvement of speech training. The researcher interviewed the sampled learners on individual basis. This was done for the purpose of gathering accurate qualitative information that provided true expression on the situation under investigation. A semi-structured interview guide was used to collect data and presented it in figures and narrative form. The learners were free to use any mode of communication (sign language, speech or both) one was comfortable with to express themselves. The researcher was well versed in both modes. Learners' expressions were typical of language used by learners with hearing impairment which has a different structure from English and was presented in interpreted version by the researcher for ease of comprehension. Learners' responses are presented in Kenyan Sign Language (KSL) which has a different word order structure from English and then translated into English structure by the researcher.

4.7.1 Communication Mode Preferred By Learners Who Are Hard of Hearing

The study sought to establish the views of learners on their preferred mode of communication between oralism and manualism. This was important because speech training (both individual and group speech training), speech/lip-reading, articulation readiness, use of residual hearing and auditory training, form the basis of oralism. Learners' preference could inform their attitude towards speech training using ASTS which could influence its effectiveness. Learners stated that their mode of preference was mostly influenced by the mode of communication used in the family and school. Majority of the learners liked communication using speech or both speech (oralism) and signing (manualism) (40.6%). 18.8% preferred using only sign language in communication.

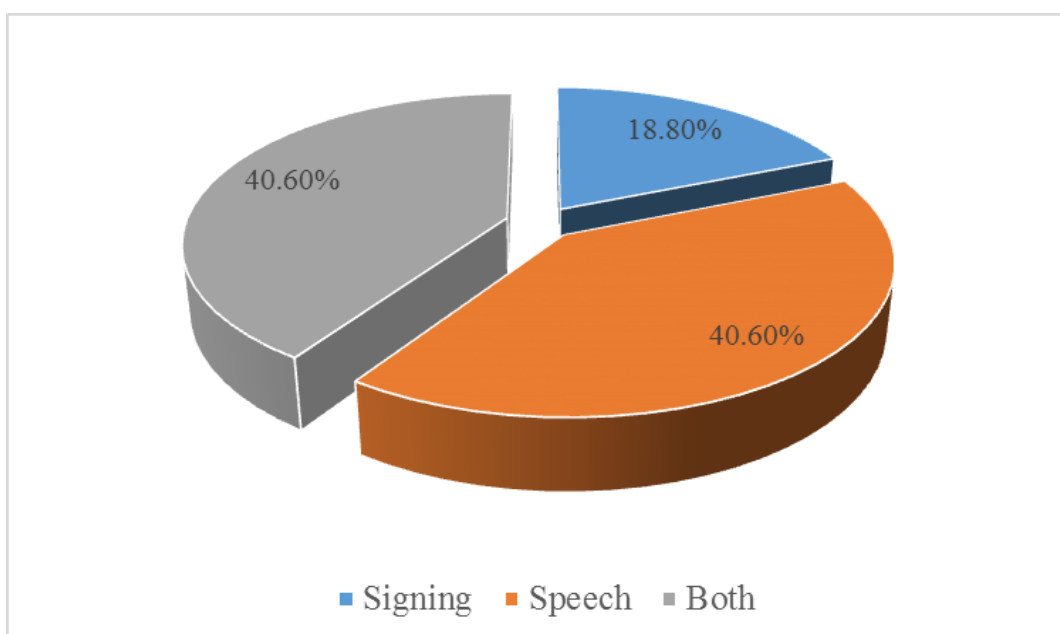


Figure 4.4: Communication mode preferred by the learner

A few of the sampled responses from the learners include the following. When learner **(LHoH/01/2017)** was asked the mode of communication she preferred, she stated with a lot of concern:

Home people there sign language know nothing// Me lip-read talk but problems there// Them forget me deaf// Mother mine like learn sign language if time there// Me now like talk why? teacher tell us talk talk//

(At home nobody understands sign language. I try to lip-read and talk though I find some problems. Sometimes they forget that I am deaf. My mother would like to learn sign language if given an opportunity. I am now used to talking and I like it because our teacher encourages us to talk).

The same question about the mode of communication preferred was asked learner **(LHoH/02/2017)** and he remarked with excitement:

Sounds some me hear with hearing aid me talk talk enjoy// Home me talk well school me sign language use why? Children many talk nothing// Both speech/ sign language good//

(I can hear some sounds with my hearing aid and I enjoy talking. At home I talk well but in school I use sign language because not all children can talk. Both speech and sign language are good).

Learner **LHoH/03/2017** had almost similar comments which he responded casually:

True/ me hear many sounds talk well hearing aid not there// Home we talk/ school sign language/ finger spelling learn. Me like talk//

(Yes, can hear many sounds without hearing aid and can talk. At home we talk but in school we learn sign language and finger spelling. I like talking).

Learner **LHoH/08/2017** had a different view and he confidently commented:

Sign language good// Deaf people many talk possible// Home brother mine sign me understand// Stories many we together share//

(sign language is good. many deaf People cannot talk. My Brother signs to me at home. We share many stories together).

Learner **LHoH/05/2017** summed it all by saying:

Sign language, speech both good// Home me talk a lot// School me talk/ sign. School/ children some talk nothing sign only//

(Both sign and speech are good. At home I use speech a lot. In school i use both speech and sign language. At school some children cannot use speech they can only sign).

Another learner **LHoH/32/2017** whose preference of mode of communication was speech confidently stated:

Me many sounds hear well// Me enjoy a lot talk with hearing people// Sign language hard// My deafness small// In school children hearing me talk well// Many me undrestand well and play together//

(I can hear many sound well. I enjoy talking with hearing people. Sign language is hard. I am partially deaf. In school hearing children communicate with me. I understand them and we play together).

From the responses, it was clear that the mode of communication preferred by each learner was influenced by home, school and learner's own experiences. Learners used different modes of communication depending on the communication modes in the environment.

The results of the current study support the findings of Yoshinaga-Itano and Sedey (2000) who stated that mode of communication used in the family accounted for a very small amount variance in speech production of children with hearing loss. In their study, among learners who developed speech, 50% had families who had chosen sign language and 50% came from families who had chosen oral speech. Similar observation was found in the current study. It can be inferred that in the current study, the mode of communication preferred by the learners had very little effect on their speech training. The researcher is of the view that learners' preferences were based on

the modes used by their teachers who used both sign language and speech in class. Among the two modes of communication; sign language (manualism) and speech (oralism), speech is almost spontaneous to most people whereas sign language requires rigorous skills to learn and use.

Okombo, Akaranga, Mweri and Adera (2006) observed that in Kenya, most parents and teachers of learners with hearing impairment lack signing skills and thus prompt learners to use other modes of communication. This meant that the mode of communication mostly in use is speech which could have informed the participants' choice. The learner in the current study were sampled from special units in regular schools where they interact with other hearing learners. The findings suggest use of total communication in teaching and learning of learners with hearing impairment though this study was based on the realization that the speech component of total communication was not being given adequate attention in the current curriculum in Kenya.

The findings also support Hsing and Lowenbraun (1997) and Khairuddin, Miles and McCracken (2018) who revealed that most of the learners interviewed preferred teachers using a combination of speech and sign language.

4.7.2 Speech Training Method preferred by Learners Who are Hard of Hearing

Learners were asked to state which among the two, speech trained by the teachers (traditional methods) and use of Automated Speech Training System they preferred. 12.5% of the learners preferred teachers, 56.3% preferred ASTS while 31.3% preferred both teacher and ASTS.

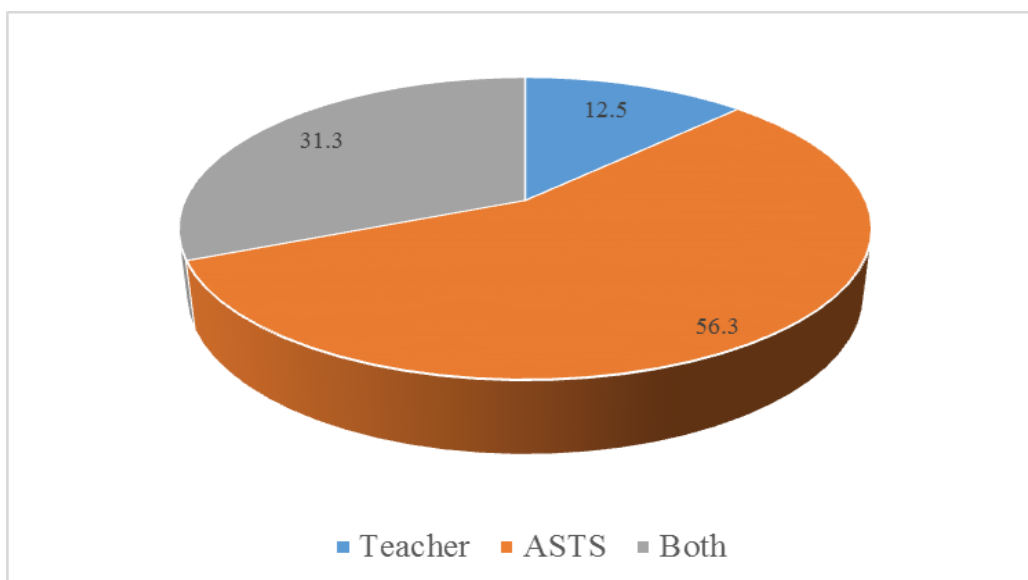


Figure 4.5: Learners' preferred method of speech training

After speech training, learners had the following observations on the methods of speech training.

When asked to state the method of speech training he preferred, Learner **LHoH/09/2017** was excited to state:

Me computer use today first time// Teacher in there talk well// Dad mine buy me computer ask learn speech home possible. Me excited a lot//

(It is my first time to use computer. The teacher in the computer talks well. I will ask my dad to buy me one to learn speech at home. I am very excited).

Another learner (**LHoH/10/2017**) who looked less bothered had a different opinion:

Me like teacher in class// Speech she teach well// Computer boring// We speech learn always//

(I like my teacher in class. She teaches speech well. Computer is boring. We learn speech always).

On the same question of preferred method of speech training, learner **LHoH/06/2017** happily commented:

Teacher speech training/ computer speech training both good// In class teacher teach us speech always// Me first learn speech difficult but practice practice me understand// Me like two method continue// Both help us learn speech a lot //

(Both speech training by the teacher and the computer are good. In class the teacher always train us to talk. At first I find it difficult but with practice I understand. I would like both methods to continue. They can help us to acquire a lot of speech).

Learner **LHoH/11/2017** confidently preferred both methods and commented:

We start learn speech before computer come// Me feel both good// Teacher our computer use sometimes// Dad mine computer has// Me him tell computer teach me talk use//

(We started learning speech even before the computer came. To me both are good. Our teacher should also use computer sometimes. My dad has a computer. I will tell him to teach me to talk using it).

Learner **LHoH/04/2017** was the most excited and had the following remarks on preferred method of speech training:

School our computer buy speech us teach// Computer good// If computer there/ teacher rest// me hear sound many well computer use//

(Our school should buy computers to teach us speech. They are good. Teachers can rest if we get computer. I can hear sounds well using computer).

It was established that majority (66.7%) of the learners who had ASTS training only preferred it to traditional speech training. Learners who had undergone traditional speech training preferred both ASTS and use of both traditional speech training (teacher) and speech training using ASTS. Analysis using chi-square test showed that there was no significant difference in preferred method of training between ASTS

trained learners and the traditional methods trained learners ($\chi^2 = 4.245$, $P = 0.120$) as shown in Figure 4.6.

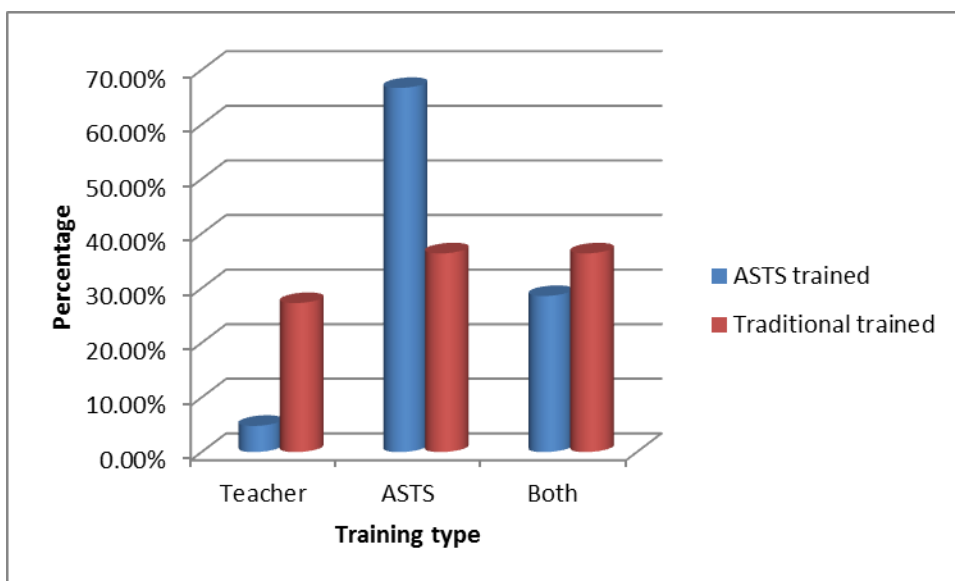


Figure 4.6: Preferred method of speech training by learners

The responses reveal that there was some degree of excitement in using computer especially from learners who had not been speech trained formally hence most of them preferred speech training using ASTS to the traditional speech training methods. The researcher established that there was no speech training in the current curriculum which means they had not been speech trained formally using traditional method, hence their preference. Majority of learners who initially had been speech trained using traditional speech training methods and then ASTS during the study preferred both methods. Their preferences were informed by the experiences they got from both methods.

The findings support earlier results of this study which showed no significant difference between learners who had been speech trained using traditional methods formally and who had not.

Findings of the current study are in support of conclusions made by Bernstein, Goldstein and Mahshie (2002) and Sugano et al. (2004) that any speech training system cannot substitute the teachers in school because teaching must be conducted by a teacher. Although majority of the respondents in the current study preferred speech training using ASTS (56.3%), learners who had undergone traditional speech training formerly and then speech trained using ASTS preferred both speech training by the teacher and ASTS since they had an experience of both methods.

4.7.3 The Views of Learners on different Components of ASTS

The Automated Speech Training System had two major components; verbal/audio component and visual component. After training, learners were asked to state which among the two they preferred and which one they thought needed improvement. Equal number of learners (37.5%) stated that their speech articulation was enhanced by audio/verbal component while the same number of learners stated that their speech enhancement was by visual component. However, 21.9% of the learners felt that both verbal and visual components of ASTS enhanced their speech as indicated on figure 4.7

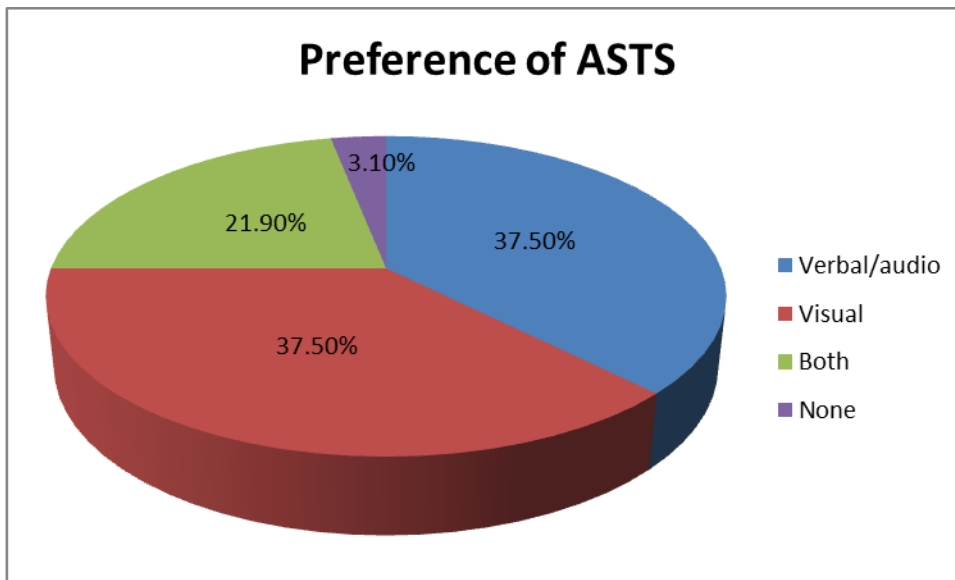


Figure 4.7: Learners opinion on the component of ASTS that help in articulation

The findings support earlier findings in objective two of the study which showed that there was significant enhancement of speech after using ASTS. When the learners were asked on the component of ASTS that they would like to be improved, 62.5% stated they would like visual component improved. 12.5% of the learners would like verbal/audio component improved while 21.9% would like to have both visual and verbal/audio improved.

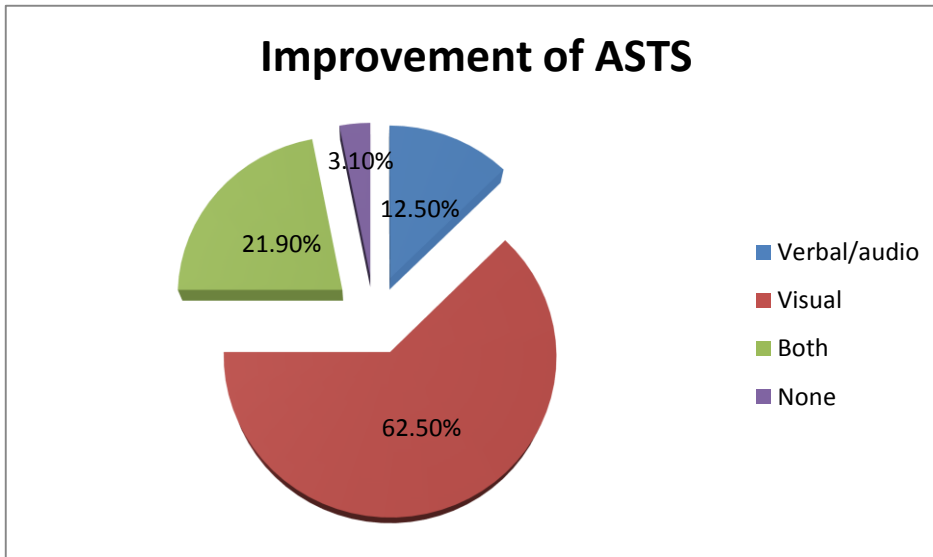


Figure 4.8: Learners opinion on the component of ASTS that they would like improved

Individual learners were interviewed and the following are some of their views on the component of ASTS they would like to be improved. Learner **LHoH/05/2017** who looked well composed explained:

Computer good but some mouth parts me see nothing// Me hear sound many well but see how sound make problem// If seeing part improve okay//

(Computer is good but some parts of the mouth are not visible. I can hear many sounds well but seeing how they are formed is a problem. If the visual component can be improved it will be okay).

Learner **LHoH/07/2017** simply stated this opinion:

Problem me have some sound hearing// Example sound /f/, /v/. Computer there me problem read /b/, /p/. Both parts improve possible//

(I have a problem hearing some sounds. For example sounds /f/ and /v/. From the computer had a problem reading sounds /b/ and /p/. Both components can be improved).

Learner **LHoH/15/2017** looked disturbed as she complained:

Hearing problem me have nothing but computer reading problem big sound /k/, /g/, /j// Seeing part improve can//

(I have no problem with hearing but reading the computer especially sounds /k/, /g/, /j/. Visual component can be improved learner)

Learner **LHoH/20/ 2017** was quick to remark:

Sound reading problem small sound hearing problem big// Hearing part improve can//

(Reading the sounds was not a big problem but hearing the sounds was a problem. Audio component can be improved).

In earlier findings of this study, speech sounds especially sounds that were not very visible in production fared relatively poorer in production compared to more visible sounds. The findings corroborate the perception of the learners that every component requires some improvements, in particular the visual component. These results are consistent with Wankhede's (2014) recommendations that, in designing a speech training aid, vocal tract areas need to be estimated with consistency and appropriate dynamic response. He also opined that obtaining realistic shapes for children in various age groups is a must so that a designed speech training aid could be used by children from any age group effectively. Therefore, these findings point that in order to enhance all speech sounds of learners who are hard of hearing, some improvements are mandatory.

The findings of the current study are in line with the findings of Blamey, Cowan, Alcantara, Whitford and Clark (2010) who observed that when visual component is added to any other component of speech training, a significant improvement occurs.

In their study of comparing speech perception using combinations of different components, they also reported that auditory component produced a significant improvement for all sounds except closed-set vowel recognition. Among visual, auditory and tactile components in speech training, they concluded that visual and auditory components were integrated more effectively for speech enhancement.

4.7.4 Challenges Faced by the Learners in Communication

Learners noted some challenges when communicating. These included; inability to produce sounds (34.4%), people ignoring them (31.3%), few people know sign language (21.9%) and some sounds are hard for them to pronounce (12.5%) as shown on figure 4.9 below.

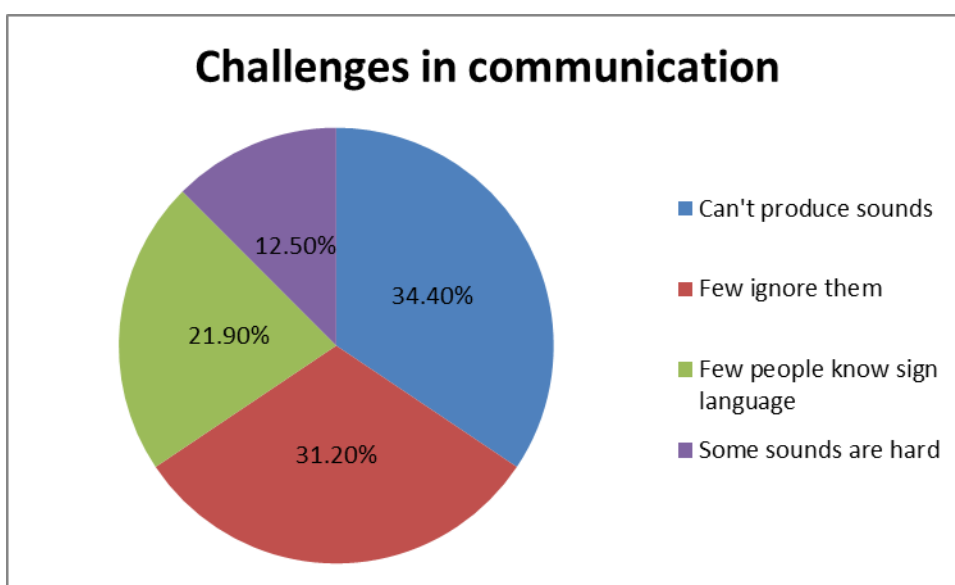


Figure 4.9: Challenges when communicating using either signing or speech

The interviewed learners complained that outside school and home environments, some people ignore them. For instance in the public vehicles sometimes when making enquiries on the fare charged and destinations, some conductors ignored them.

Learner **LHoH/23/2017** with a lot of concern had the following complain:

Me conductor give shillings one hundred from town// Change he me give must was shillings fifty but time me remind him ignore// Other people talking he money theirs give he pretend understand complain mine nothing// Me write him paper other too complain//

(I gave the conductor one hundred shillings as I was coming from town. He was supposed to give me a change of 50 shillings but when reminded him, he just ignored me. He was giving others who were talking but for me he pretended not to understand my complain until I wrote for him and other passengers intervened).

Others explained how they were trying to produce some sounds which were difficult for them to produce. These were the same sounds which were difficult to them to speech-read as explained by learner **LHoH/17/2017**:

Though me talk like sound some problem big example /g/, /ks/. Time people talk fast fast me read sound problem. Teacher mine slowly talk time she teach speech. Lips her read possible//

(Though I like talking, some sounds are difficult to articulate like sounds /g/ and /ks/. When people talk very fast I am unable to lip-read sounds. My teacher talks slowly during speech training, so we can read her lips).

Apart from their teachers, sign language was a challenge to many people whom they needed to communicate with. Learner **LHoH/13/2017** strongly stated:

People many sign zero even school here but teachers ours// Home mine them force me write communication easy make// Communication then hard why? Somethings me write know nothing// Them sometimes guess me do what//

(Not many people can sign apart from our teachers even in this school. Even at home they force me to write in order to ease communication. This makes communication difficult since there are some words I cannot write. Sometimes they guess but I can't help).

The conclusion that could be drawn from these responses of the participants was that there are some misunderstandings when learners with hearing impairments communicate with hearing people. The implication of this finding is that learners with hearing impairment face frustrations especially when communicating with hearing

people. These observations are similar to the experiences reported by Khairuddin, Miles and McCracken (2018) when they interviewed deaf learners on their experiences in Malaysia. Okombo, Akaranga, Mweri and Adera (2006) reported that many people don't understand sign language as observed by one of the learners in this interview.

4.7.5 Learners Suggestions for Improvement of Speech Training

The learners suggested that the schools should give them computers and they should continue learning using ASTS. They felt that time for speech training using ASTS was short although teachers always encouraged them to communicate using speech. In school C, the learners were encouraged to interact with the hearing through speech and the learners felt that their teachers could supplement their training by using ASTS. Some of the learners felt that they can hear when people speak to them loudly. Some of the learners interviewed were born deaf and some became deaf at early ages before they acquired English. However, their parents encouraged them to use speech because they did not know sign language. A few individual responses had been selected to be representative of general views of the learners.

One learner **LHoH/25 2017** noted that:

If computer school give, speech train improve// Children deaf speech important why? Hearing people many sign language know nothing// Speech training continue good//

(If schools can provide computers they can improve our speech training. Speech is important to children with hearing impairment because many hearing people don't know sign language. It is good to continue with speech training).

This was supported by learner **LHoH/23/2017** who felt that were it not for time factor she would have improved her speech even better.

Computer speech training time short// Me learn many speech sounds before know nothing// Me deaf half benefit a lot why? Sounds hear see same time// Teacher mine continue speech train//

(Time for speech training using computer was short. I have learnt many sounds which I didn't know before. I am partially deaf and have benefited a lot because I can hear and see the articulation at the same time. My teacher can continue with speech training).

Learner **LHoH/14/2017** also commented that: Speech training good why?

Teachers our talk encourage in school// Future we hearing children talk well. Home same parents brother sister talk well// If speech training continue better//

(Our teachers encourage us to use speech in school. In future we will communicate well with hearing children. Even at home, we will be able to communicate well with our parents, brothers and sisters. It is better to continue with speech training).

The above responses express importance of speech training especially to learners who are hard-of-hearing. Speech training will enhance learners' ability to communicate with hearing members of the society. The findings support Lawal, Karia, Buttars, Larsen, Mulwafu and Mukara (2016) who asserted that speech training was a plausible method to improve hearing-impaired children's ability to communicate verbally. Being a linguistic minority group in the society, verbal communication provides them with opportunities for improved socioeconomic status and inclusion into the larger society.

4.8 Teachers' Opinions on Speech Training of Learners who are Hard-of-Hearing

To establish opinions of teachers on speech training of learners who are hard-of – hearing as sought by objective six of the study, teachers were required to state whether or not; they had done any course on speech training during their studies, they do speech training in their classes, challenging speech sounds to learners, mode of communication they thought would benefit learners who are hard-of-hearing and their opinion on speech of learners who are hard-of-hearing.

4.8.1 Teachers' Qualifications in Speech Training

9(69.2%) of teachers (3 from school A, 2 from school B and 4 from school C) had undertaken a course in speech training during their diploma training at Kenya Institute of Special Education (KISE) while 4(30.8%) who had not gone through KISE had not. The 4 teachers who had not done speech training course had joined universities directly without going through KISE and speech training was not part of the courses they took at the university. One teacher **THoHL/07/2017** remarked:

I did not undertake any course in speech training in the university but have been hearing my colleagues talk about it. At first had thought it is just a matter of signing and talking at the same time until my colleagues explained to me what it entails. Now I know it's more than just talking. The current curriculum has no provision for speech training though I feel its important especially to learners who are hard-of-hearing.

Teachers who had done diploma in special education from Kenya Institute of Special Education (KISE) said they acquired useful skills and even had speech kits but since the curriculum had no provision for speech training; they could not utilize those skills maximally. One of them **THoHL/09/2017** stated:

Speech training and other specialized courses like articulation readiness, auditory training, individual speech and group speech were part of the diploma course at KISE. I was examined in them and passed the examination but after joining this school, i realized it was not in the syllabus provided by KICD. However, though speech training is not slotted in our teaching time table, during my free time i speech train the learners I feel can benefit from speech. I wish the curriculum can be revised to accommodate speech training and other specialized areas for the benefit of all learners and especially those who are hard-of-hearing.

For effective speech training in the schools, teachers need to be trained specifically on speech training. As per the teachers' perceptions, this is lacking in some of the training institutions that offer special needs education in Kenya.

4.8.2 Speech Training in the Selected Schools

The objective also aimed to establish whether teachers were training learners in speech before commencement of the study. In school A, all learners (hard-of-hearing and deaf) were being speech trained by their teachers and staff from Starkey Ear Foundation for the last 3 years. In their teaching time tables speech sessions were slotted. One of them (THoHL/06/2017) explained:

Though I was trained at KISE, we were in-serviced on speech training by the Starkey Ear Foundation and I enjoy practicing the skills. Learners especially the ones who are hard-of-hearing seem to enjoy the speech training sessions. Normally, we use total communication in class but for the hard-of-hearing sometimes we withdraw sign language completely for the learners to communicate in speech. Since we started the programme, learners especially the ones who are hard-of-hearing try to express themselves in speech though their speech is not very intelligible compared to normally hearing peers.

In school B, two teachers had undertaken speech training in their diploma at KISE. There was no speech training taking place though one teacher was trying to incorporate speech during English lesson. The other 3 teachers did not attempt to

speech train with a reason that the syllabus from KICD had not programmed it. One teacher (**THoHL/011/2017**) said:

During my English lesson I try to speech train since I know importance of speech especially to learners who are hard-of-hearing. I use the speech kit I got from KISE during my diploma training. Learners who are hard-of-hearing respond very well and of late some are trying hard to express themselves in speech. I am encouraging my colleagues to do the same but they say the curriculum we follow cannot allow one to speech train.

Another teacher (**THoHL/10/2017**) from school B said;

I have come to know importance of speech especially to learners who are hard-of-hearing though I was not trained on how to do it. I would enjoy to speech train if we could be facilitated with skills and equipment. I feel speech training should be part of the curriculum for learners with hearing impairment. I feel learners who have some residual hearing and cannot express themselves in writing can use their speech if trained for communication even outside school environment.

In school C, all teachers including those who had not done any course in speech training used to train but due to understaffing, they stopped. It was left to individual teacher's initiative. It was noted that teachers encouraged learners to express themselves in speech. Teachers complained that the adapted curriculum they were following could not allow them to speech train. It was in favour of manual communication. One of them (**THoHL/02/2017**) had the following remarks:

In our school speech training was always slotted in our teaching timetable but through teachers' initiative. It was compulsory for our learners to communicate in speech. When they transferred some teachers the workload increased and speech training was no longer possible. KICD is silent on speech training. They insist we teach all subjects using total communication but from my experience, it cannot help our children to talk especially hard-of-hearing who have benefit of using their residual hearing. They need to be taught how to articulate sounds of speech through a well planned speech training programme.

From the sentiments that were emanating from teachers, it was clear that speech training was essential to learners who are hard-of-hearing. However due to lack of a

proper curriculum to guide them, speech training was left for individual school and teachers to train if they wished. The teachers expressed the need for speech training learners who are hard-of-hearing. Lack of harmonized speech training programmes in the schools could have had some effects on the pre-test and post-test results during the study.

4.8.3 Challenging Speech Sounds to Learners who are Hard-of-Hearing

Teachers were asked to identify the most challenging sounds for learners who are hard-of-hearing to produce based on their observations of the learners. All the teachers interviewed stated that it varied from individual learner to individual learner depending on factors like time of onset of the impairment. However, comparatively majority 12(92.3%) stated that vowels were easier than consonants, 11(84.6%) reported that consonants were easier than voiceless consonants and 10(76.9%) noted that plosive consonant were easier than fricative consonants. They all concurred that sounds that are visible on the lips had very little challenge to the learners. On individual speech sounds, all the teachers (100%) identified sounds, /kw/, /g/, /dʒ/ and /ks/ as the most difficult to produce. These findings confirmed earlier findings of the study during pre-test and post-test in which vowel sounds were easier to articulate than consonant sounds and more visible sounds were easily articulated by learners than non-visible sounds. Likewise, the most challenging sounds for learners to articulate that were identified by teachers emerged as challenging too during pre-test and post-test.

4.8.4 Teachers Opinions on Mode of Communication preferred by Learners

Further, the study sought to establish the mode of communication preferred by learners who are hard of hearing. Most of the teachers 7(53.8%) said their learners preferred oralism, 5(38.5%) said learners preferred both oralism and manualism and 1(7.7%) said they preferred manualism. In school A, learners who are hard-of-hearing struggled to communicate to their teachers using speech. One teacher (THoHL/03/2017) reported that:

In my class, learners who are hard-of-hearing cannot sign to me. They try hard to speak even if some sounds are not intelligible but I can understand because I am used to their speech. In the field when playing with hearing peers there is a boy who communicates in speech and the peers respond also in speech. We are planning to integrate the boy in the mainstream but first we want to prepare the mainstream teachers. I always encourage my learners especially with residual hearing to communicate through speech.

In school B, teacher THoHL/02/2017 commented:

Most learners in my class prefer both manualism and oralism because majority of the members of the class are profoundly deaf and cannot produce any speech sound. When talking to me or any other hearing person they try to use speech mostly if I insist. They seem to be more comfortable when using both. My observation is that learners, whose hearing loss is just mild, are more comfortable in speech compared to learners with higher degree of hearing loss.

In school C teacher (THoHL/06/2017) had the following opinion:

To me the mode preferred by learners depends with several factors including learner's interest, motivation from home and school, speech training and cognitive ability among others. Speech production is not easy to learners with hearing impairment hence some prefer sign language. With amplification learners who are hard-of-hearing ought to use speech. From my observation, Speech production is not easy. In addition to speech training, learners have to be encouraged to use speech in school and at home. Due to the current curriculum which gives speech training little attention, learners tend to prefer manual communication in school.

Most of the interviewees were all in agreement that learners who are hard-of-hearing preferred oral communication compared to manual communication. For instance teacher **THoH/11/2017** said:

In our school learners who are hard-of-hearing enjoy talking though they know sign language. Some of their speech is not very intelligible but if one pays attention can understand. Their parents confine to us that at home they communicate orally although they miss some sounds. When one becomes used to their speech sounds, it is easier to understand their communication. In class when reading on their own, one can hear their voices.

A small difference was observed from the teachers compared to learners' preferences on mode of communication. In the finding of objective five, equal number of learners (40.60%) had expressed that both speech and sign language were their preferred modes of communication while 38.5% of the teachers indicated that both oralism and manualism were the learners' preferred modes of communication. However, despite the difference the findings support total communication which incorporates oralism and manualism. These findings are consistent with the findings of Hsing and Lowenbraun (1997) in which teachers recommended both oralism (speech) and manualism (sign language) as major components of total communication.

4.8.5 Teachers Opinions on inclusion of speech training in the curriculum

When asked to give their opinions on speech of learners who are hard-of-hearing, teachers gave the following responses:

THoHL/01/2017 said:

I think we should have a curriculum for speech training of learners who are hard-of-hearing. With intensive training learners who are hard-of-hearing should be able to talk almost like normally hearing children.

Another teacher (**THoHL/02/2017**) stated that she was positive about speech training but felt that she had not mastered sufficient speech training skills to handle the training. She stated:

Speech training is beneficial to learners who are hard-of-hearing. I admire my colleague doing it but I am not fully trained to do it. If an in-service course can be organized it can assist me and others who shy away from speech training. The KICD should re-introduce it because it can help learners also to master English language skills.

Another respondent **THoHL/03/2017** expressed the following comments:

Learners who are hard-of-hearing should be placed in their own class with their own curriculum. Articulation readiness, auditory training and speech training should be the first lessons in the morning daily. Other lessons can be taught thereafter. Learners who have acquired speech seem to enjoy something others don't have.

Another response regarding speech was obtained from **THoHL/04/2017**. She remarked:

A parent has been asking me for a school where his child can be taught how to talk. He feels our school is not doing enough since before joining the school, the child could express himself in speech but seems to be losing that speech progressively. It is the high time speech training was made compulsory in all schools for learners with hearing impairment. When I joined special school there was speech training but how it was slowly withdrawn, teachers were not consulted.

Another teacher **THoHL/05/2017** had a slightly different opinion. She stated:

Speech training should be incorporated in the on-going schools lap-top project. The digital content provided only caters for hearing learners. Also the new curriculum being launched should consider speech needs of learners who are hard-of-hearing. I support speech training.

Responses from the teachers revealed that they were willing to speech train learners who are hard-of-hearing. Most of the teachers had a wealth of experiences teaching learners with hearing impairment. Teachers' responses were consistent with the researcher's own experience. Earlier as an assessor with Educational Assessment and

Resource Centre (EARC) for children with hearing impairment, the researcher encountered some of the parents of children who are hard-of-hearing who insisted on having their children placed in schools where speech training was a part of the curriculum. Similar perceptions of teachers were reported by Hsing and Lowenbraun (1997) when they studied perceptions of teachers on communication policies for the deaf in Malaysia.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

In the previous chapter, the collected data were analyzed, findings presented and discussed. In this chapter, the main aim is to present the summary of the findings, and make conclusions and recommendations of the study. The chapter comprises three sub-sections namely, summary of findings, conclusions and recommendations.

5.2 Summary of the Main Findings

5.2.1 Demographic Characteristics of Respondents

Three special units for learners with hearing impairment integrated in regular schools were involved in the study. In one of the units, traditional speech training was taking place while in the other two units; no formal speech training was taking place. From the three units, 32 learners (16 males and 16 females) who were hard-of-hearing were purposively sampled for the study. The mean age of the sampled learners was 11.8 with the youngest at 8 years and the oldest at 17 years. The mean degree of hearing loss in the right ear for the sampled learners was 50.88dB and for the left ear was 52.94dB. 13 teachers were also purposively sampled and all were female.

5.2.2 Speech Sounds Articulation of Learners before Training

According to the study findings from objective one, the study revealed that it was significantly easier ($t = 4.70$, $P = 0.001$) for the learners to articulate the vowel sounds, mean 24.20 learners with a standard error of 1.2 than for the learners to articulate the consonant sounds mean 15.38 with a standard error of 1.5 in pre-test.

The study also found that majority of the learners (90.6%) were able to articulate sound /a/ correctly and 81.3% were able to articulate sound /o/. Fewer learners (18.8%) during the pre-test were able to articulate sound /kw/ while 21.9% were able to articulate sounds /dʒ/ and /ks/.

5.2.3 Effects of ASTS on Speech of Learners Who are Hard of Hearing

With regard to objective two of the study, the findings established that overall there was a significant enhancement of speech ($t=11.60$, $p=0.0001$). In comparison, speech articulations of the sampled learners before and after training using ASTS registered improvement in different categories of speech namely; vowels and consonants which included voiceless, voiced, plosive, fricative and nasal sounds. The findings further revealed that all the sampled learners were able to articulate speech sounds /a/, /b/, /c/, /e/, /i/, /m/, /o/, and /p/ after training. The most difficult sound to articulate both at segment and word level after training was sounds /ks/ and /kw/.

5.2.4 Comparison of ASTS with Traditional Speech Training Methods

According to the study findings from objective three, during pre-test, there was a difference in articulation of speech sounds between learners who had undergone formal speech training and learners who had not. The difference favoured learners who had undergone formal speech training although the enhancement was not significant. Likewise, after speech training both groups using ASTS, both groups of learners enhanced their speech. More enhancements of speech sounds were noted among the learners who had not been speech trained formally using traditional methods compared to learners who had been speech trained formally. Comparing the pre-test and post-test results in speech perception and production between learners

who had initially undergone speech training using traditional methods and those who had no initial formal speech training, there was speech enhancement although it was not significant. Similarly, analysis of vowels and consonants showed a difference but was not significant. Learners who had been exposed to traditional speech training had no significant difference after training using ASTS from those who only received ASTS training in production of vowels and also the consonant sounds. However, comparing speech articulation of learners who had no formal speech training, there was a positive deviation of 26.25 after speech training using ASTS. A comparison of pre-test and post-test results for learners who had not been speech trained formally using traditional methods showed a significant difference in speech enhancement among learners who were hard-of-hearing.

5.2.5 Influence of selected Demographic Factors on Speech Enhancement

As per objective four, demographic factors selected for this study included gender, age, degree of hearing loss (right and left ear) and number of siblings in the family. Pre-test results showed no significant difference in speech articulation between male and female. Similarly, post-test results indicated no significant difference in speech articulation between males and females. However, the findings revealed that more females had improved speech after training using ASTS. Overall, using correlation matrix, average post-test result were positively influenced by the learners age ($r=180$, $p=0.324$), gender of the learner ($r=-0.120$, $p=0.515$) and the average hearing loss for the right ear ($r=-0.137$, $p=0.455$) and left ear ($r=-0.218$, $p=0.230$). Also speech enhancement improved with decreased number of siblings in the family ($r=-0.231$, $p=0.204$).

5.2.6 The Views of Learners on Communication modes and Speech Training

As for objective five, majority of the sampled learners preferred to communicate using either speech or both speech and sign language. After training using ASTS, majority (56.3%) preferred ASTS to traditional speech training methods while 31.3% preferred both ASTS and traditional methods. The findings further revealed that majority (66.7%) of learners who had no initial formal speech training preferred ASTS to traditional speech training methods. Some of the learners who initially had been speech trained using traditional methods preferred ASTS and others both traditional methods and ASTS. However, chi-square test showed that there was no significant difference between learners who preferred ASTS and traditional speech training methods. ASTS had two main components; verbal (audio) component and visual component. It was further revealed that equal number of sampled learners (37.5%) felt that each component of ASTS enhanced their speech while 21.9% of the learners felt that their speech was enhanced by a combination of both components. Majority of learners were of the opinion that visual component should be improved while 21.9% felt that both components needed to be improved. After speech training using ASTS, majority (93.7%) were able to articulate sound /b/ while the least articulated sounds were sounds /g/, /h/, /dʒ/, /l/ and /j/ which were articulated by 18.8% of the sampled learners. Some of the challenges in communication suggested by sampled learners included; inability to produce some sounds (34.4%, some people ignoring them (31.3%), few people understood sign language (21.9%) and difficulty in lip-reading some sounds (12.5%). The study also found out that after speech training using ASTS, learners suggested that they should be provided with computers and ASTS should be incorporated in speech training lessons, the time for training

using ASTS was short. Some learners said that they were always encouraged by their teachers and others by their mothers to use speech during communication.

5.2.7 Teachers opinions on Speech Training

With regards to objective six of the study, despite the fact that majority (69.2%) of the teachers had done a course in speech training the study revealed that learners were being speech trained in one school formally, a few other teachers were training informally. According to the sampled teachers, vowel sounds were easier to train than consonants. Sounds /kw/, /g/, /dʒ/, and /ks/ were the most difficult to train. Most teachers (69.2%) felt that learners who are hard-of-hearing were comfortable with oralism. Teachers were of the opinion that there is need to have a curriculum for speech training especially for learners who are hard-of-hearing.

5.3 Conclusions

The purpose of this study was to investigate the effectiveness of an Automated Speech Training System (ASTS) in enhancing perception and production of speech among learners who are hard of hearing in selected schools in Starehe and Kasarani sub-counties of Nairobi County Kenya. Guided by the objectives of the study, several conclusions were drawn from the study.

In relation to the study objective one, the study established that learners who were hard-of-hearing had speech deficits mainly due to the hearing loss. However, the study established that it was easier for the learners who were hard-of-hearing to articulate vowel sounds than consonant sounds. The findings of the current study

therefore made the researcher to conclude that hearing loss affects consonant sounds more than vowels.

The analysis of objective two in relation to effectiveness of Automated Speech Training System revealed that there was a significant enhancement of speech after using ASTS which utilizes 3-D animation technology with both visual and verbal/audio components. The present study therefore concluded that other than traditional methods of speech training, ASTS was a valuable speech trainer which could be incorporated in speech training learners who are hard of hearing. This was anchored in the theoretical framework of the study on cognition theory of multimedia learning by Mayer (2001). The theory which is grounded on the ability of human beings to process information through dual channels (visual and verbal/audio) has been demonstrated in this study.

For objective three of the study on comparison of ASTS and traditional speech training methods, the study established that during pre-test, learners who had undergone speech training using traditional methods had better articulation of speech sounds compared to learners who had no formal speech training. However it was noted that the difference was not significant. After training using ASTS, learners who had formal speech training showed higher improvement than learners who had no formal speech training although the difference was not significant. Although both groups showed improvements in articulation of speech sounds after training using ASTS, learners who had no formal speech training showed higher improvement which was also confirmed by the deviation results for learners who had no formal speech training which showed significant difference. The results demonstrated that

incorporating technology in speech training learners who are hard-of-hearing is important. Based on the findings of the study, it was concluded that though there was no significant difference between the two methods, ASTS enhanced speech among learners who are hard-of-hearing and therefore could be incorporated to supplement traditional methods to enhance speech among learners who are hard-of-hearing.

According to the findings based on objective four of the study, speech deficits increased with increase in the degree of hearing loss and therefore degree of hearing loss was a major predictor of speech articulation deficits by learners who are hard-of-hearing compared to age, gender and number of siblings in the family. The results of this study led the researcher to conclude that any effective speech enhancement should consider amplification of sounds among other factors.

From the qualitative analysis which was based on objective five of the study, learners preferred both speech (oralism) and sign language (manualism). Their preferences were informed by various factors including school and home environments. On speech training, learners preferred training using ASTS and traditional methods. During training, learners felt that their speech was enhanced by audio/verbal component and visual component of ASTS. Majority of learners opined that visual component of ASTS needed some improvement. Their main challenge in communication was inability to produce some sounds. Learners were of the opinion that schools should provide computers to assist them in speech training. The study therefore concluded that both oralism (speech) and manualism (sign language) play an important role in communication for learners who are hard-of-hearing and need to be emphasized.

Use of speech, residual hearing and amplification are some of the means advocated for by the philosophy. Since the ASTS could enhance selected speech sounds of learners who were hard of hearing, the study concluded that by improving the visual component and the audio/verbal components, more speech sounds could be enhanced. The visual component should display articulation of all the sounds clearly. The study also concluded that challenges faced by learners who were hard of hearing in communication could be addressed by incorporating 3-D animation technology in speech training.

Qualitative analysis of objective six of the study showed that (69.2%) were equipped with skills necessary for speech training though they were not utilizing them fully. In one school, learners were being speech trained formally. Teachers found vowel sounds easier to train than consonant sounds. Sounds /g/, /dʒ/, /kw/ and /ks/ were identified as the most challenging to train. In teachers' opinion, most learners who were hard-of-hearing preferred oralism in communication and they all agreed that speech training was necessary for learners who were hard-of-hearing. From the analysis, the study arrived at a conclusion that teachers needed to be fully equipped to speech train learners who were hard-of-hearing using both traditional methods and ASTS.

Finally, the researcher came to the conclusion that the study succeeded in achieving its purpose and objectives. The willingness and interest of the learners who are hard-of-hearing and teachers to participate in the study provided sufficient information to answer six key research questions formulated for the study. Speech training of learners who were hard-of-hearing was significant for their social inclusion, academic

advancement and improved socioeconomic status. The findings of this study have demonstrated promising benefits of using Information Communication Technology (ICT) to improve the use of verbal communication by children who are hard-of-hearing.

5.4 Recommendations

Based on the research findings of the study, the following recommendations were made with a view of enhancing speech among learners who are hard-of-hearing in Kenya.

5.4.1 Policy Recommendation

- 1) Based on the findings of objective one, it was recommended that the government should put in place policies and proper mechanisms of ensuring that speech training forms an integral part of curriculum for learners who are hard-of-hearing in order to address some of their communication challenges. Such policies will not only assist the learners in communication but also contribute to their academic pursuance and social inclusivity.
- 2) Objective two confirmed that there was significant enhancement of speech among learners who are hard-of-hearing after training using Automated Speech Training System which is one of the Computer Assisted Language Learning applications. The study therefore recommended that government should incorporate the new technology to the already existing methods of speech training in order to enhance speech of all learners who are hard-of-hearing. Kenya's vision 2030 recognizes the enabling role of Information Communication Technology (ICT) and anchors some of its key aspirations upon

the availability and adoption of computers for schools. In line with this vision, the study further recommended that government of Kenya should incorporate speech training component specifically tailored to meet the needs of learners who are hard-of-hearing within the digital curriculum.

- 3) Based on findings of objective three, there was speech enhancement among learners who are hard-of-hearing trained using Automated Speech Training System although the enhancement was not significant. The study therefore recommended that a specific curriculum for speech training be developed by (KICD), incorporating both traditional speech training methods and Automated Speech Training System in order to enhance speech among learners who are hard-of-hearing. In order to address communicative needs of learners who are hard-of-hearing fully, the study also recommended development of a specific speech training curriculum for this minority group. Article 21 of the Salamanca statement (UNESCO, 1994) recognizes that the particular communication needs of deaf learners can justify separate educational provision. The curriculum will enable learners who are hard of hearing to utilize their residual hearing as well as the benefit of amplification of speech sounds.
- 4) With regards to the findings of objective four, it was established that certain demographic factors have effect on speech of learners who are hard-of-hearing. The study therefore recommended that Ministry of Education should ensure that there are policies to guide intensive assessment to ascertain individual speech training needs of each learner since hearing impairment comprises a heterogeneous group with divergent communicative needs. The assessment should particularly focus on early intervention programmes to mitigate the

effects of hearing loss on speech articulation as early as possible in life. The study further recommended provision of amplification devices to learners who are hard-of-hearing in order to assist them in acquiring speech

- 5) Even though the findings on objective five established that learners who are hard-of-hearing preferred oral and manual communication, policy makers should not under-rate the concerns that emerged about lack of uniformity in speech training which is the base of oralism. The study therefore recommended that both oral and manual communications which are major components of total communication be given equal emphasis in the education of learners with hearing impairment. The emphasis will ensure speech training is programmed and scheduled in all teaching time-tables for learners with hearing impairment, especially for the benefit of learners who are hard-of-hearing in the same way manual communication benefits learners who are deaf.
- 6) In relation to the findings on objective six, the Ministry of Education should make a deliberate effort to equip teachers with necessary skills for speech training since they expressed their willingness to speech train learners who are hard-of-hearing. The study recommended that in-service courses be organized to cater for teachers who did not acquire speech training skills during their pre-service training. The study further recommended harmonization of teacher training curriculum which will incorporate use of Information Communication Technology in speech training.

5.5 Recommendations for Further Research

The current study on effectiveness of Automated Speech Training System in enhancing speech among learners who are hard-of-hearing in selected schools in

Nairobi City County could be the first of its kind in Kenya on this field of study. The following areas could be exploited for future studies to enrich literature in the area of speech training in Kenya.

- i) This study was limited to learners who are hard of hearing. There is need to conduct a similar study on learners who are deaf since currently in Kenya, most learners with hearing impairment are placed in the same schools.
- ii) The current study was conducted in Nairobi City County thereby compromising generalizability of the findings. Therefore, replication of a similar study in other counties is recommended.
- iii) Basically, even though the study achieved its purpose of investigating the effectiveness of ASTS, it was limited to only twenty six speech sounds of English alphabet and therefore there is need to investigate its effectiveness on all English speech sounds and also other languages.
- iv) The study dealt with learners who are hard of hearing but there are other categories of learners who have speech deficits like learners with cerebral palsy, autism and intellectual disabilities among others and therefore a study is recommended.

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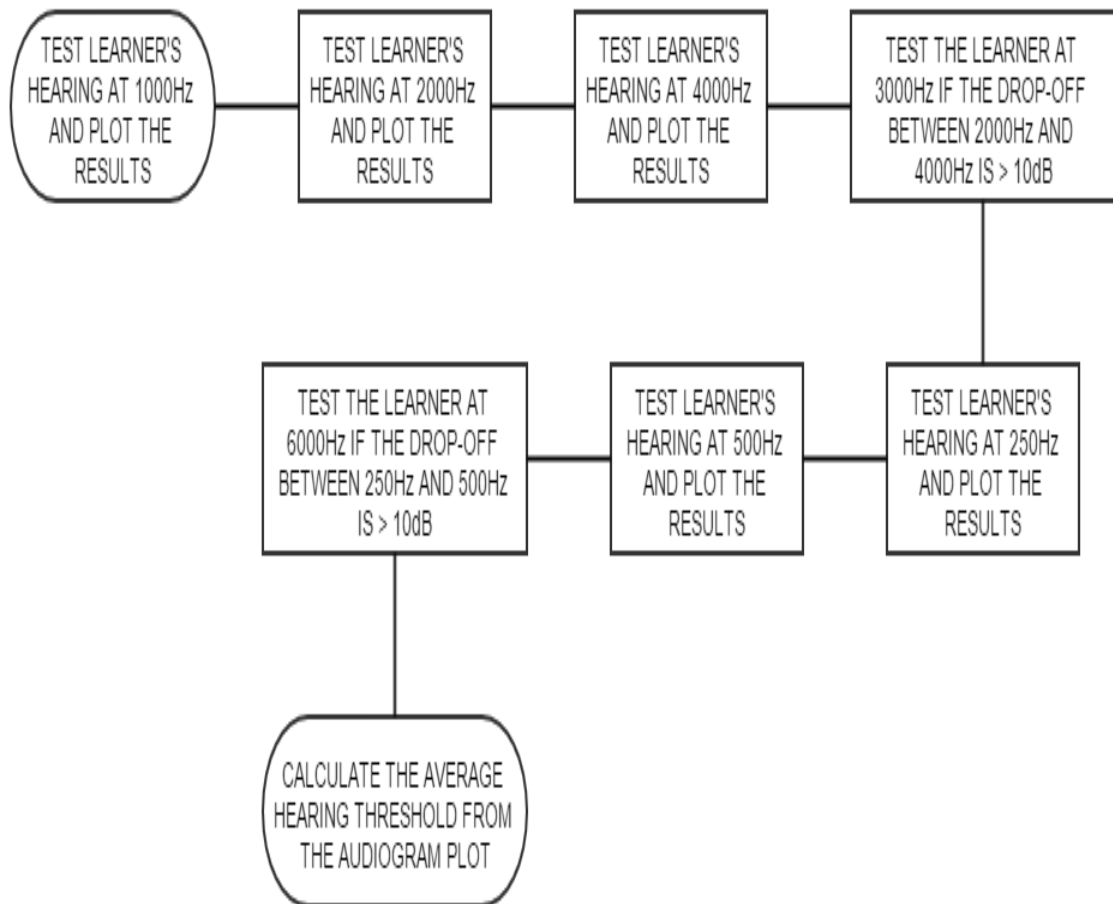
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APPENDICES

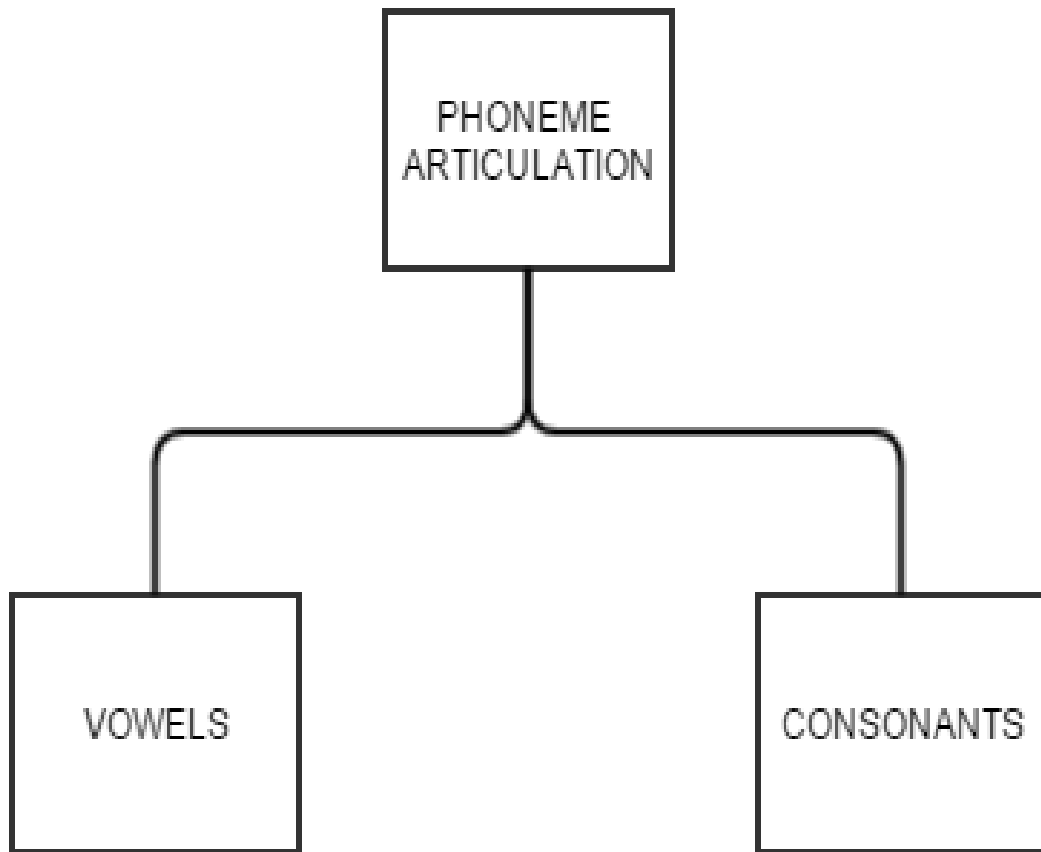
APPENDIX I

HEARING ASSESSMENT AND SPEECH TRAINING

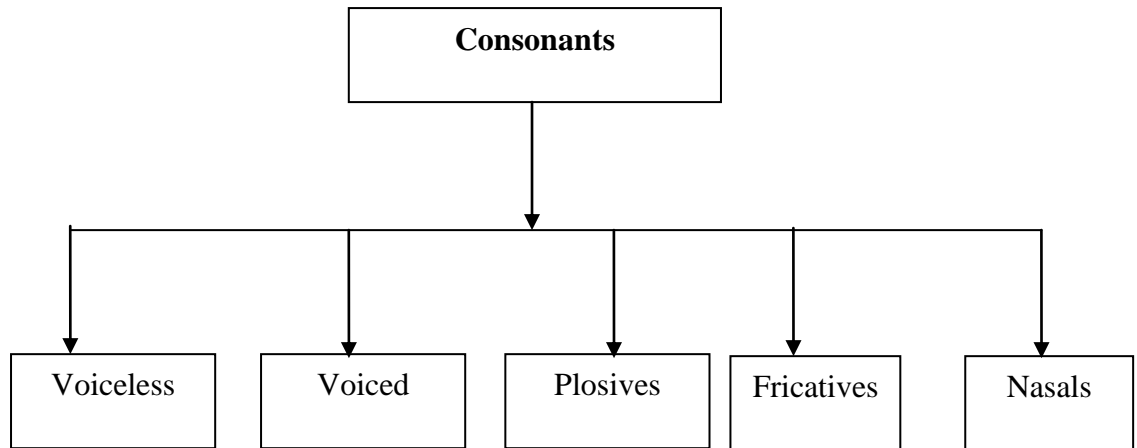
(a) A schematic diagram showing hearing test sequence



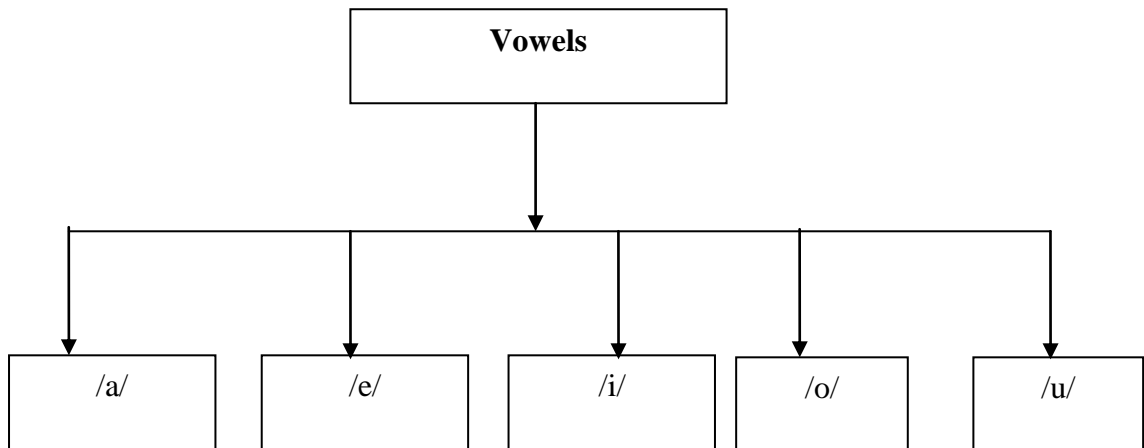
(b) Phoneme(speech sounds) Categories



(c) Consonant sounds categories



(d) Vowel sounds



APPENDIX II
AUTOMATED SPEECH TRAINING SYSTEM



Headphones **Stored speech sounds in a Flash Disk** **Laptop** **Amplifier**

APPENDIX III

SCORE SHEET FOR PHONEME/SOUND CATEGORIES

Name of the learner _____

Speech Sounds	Pre-test	Post-test
/a/	<input type="checkbox"/>	<input type="checkbox"/>
/b/	<input type="checkbox"/>	<input type="checkbox"/>
/c/	<input type="checkbox"/>	<input type="checkbox"/>
/d/	<input type="checkbox"/>	<input type="checkbox"/>
/e/	<input type="checkbox"/>	<input type="checkbox"/>
/f/	<input type="checkbox"/>	<input type="checkbox"/>
/g/	<input type="checkbox"/>	<input type="checkbox"/>
/h/	<input type="checkbox"/>	<input type="checkbox"/>
/i/	<input type="checkbox"/>	<input type="checkbox"/>
/j/	<input type="checkbox"/>	<input type="checkbox"/>
/k/	<input type="checkbox"/>	<input type="checkbox"/>
/l/	<input type="checkbox"/>	<input type="checkbox"/>
/m/	<input type="checkbox"/>	<input type="checkbox"/>
/n/	<input type="checkbox"/>	<input type="checkbox"/>
/o/	<input type="checkbox"/>	<input type="checkbox"/>
/p/	<input type="checkbox"/>	<input type="checkbox"/>
/q/	<input type="checkbox"/>	<input type="checkbox"/>
/r/	<input type="checkbox"/>	<input type="checkbox"/>
/s/	<input type="checkbox"/>	<input type="checkbox"/>
/t/	<input type="checkbox"/>	<input type="checkbox"/>
/u/	<input type="checkbox"/>	<input type="checkbox"/>
/v/	<input type="checkbox"/>	<input type="checkbox"/>
/w/	<input type="checkbox"/>	<input type="checkbox"/>
/x/	<input type="checkbox"/>	<input type="checkbox"/>
/y/	<input type="checkbox"/>	<input type="checkbox"/>
/z/	<input type="checkbox"/>	<input type="checkbox"/>

APPENDIX IV

INTERVIEW GUIDE FOR LEARNERS

My name is Francis Muriuki Muriithi from Kenyatta University. This interview schedule is to help the researcher gather information on learners perceptions on communication modes they use and speech training. All information given shall be treated with utmost confidentiality. Thank you very much for accepting to participate in this interview.

1. Which among the following modes of communicating do you prefer? Oralism (speech) manualism (sign language). Both
2. You have been speech trained by your teachers and ASTS. Which one did you prefer?
3. ASTS had two components; audio and visual
 - a) Which among the two did you like?
 - b) Which component would you like to be improved to enable you understand sound better?
4. What problems do you face when communicating with other people?
5. How would you like speech training to be improved?

APPENDIX V

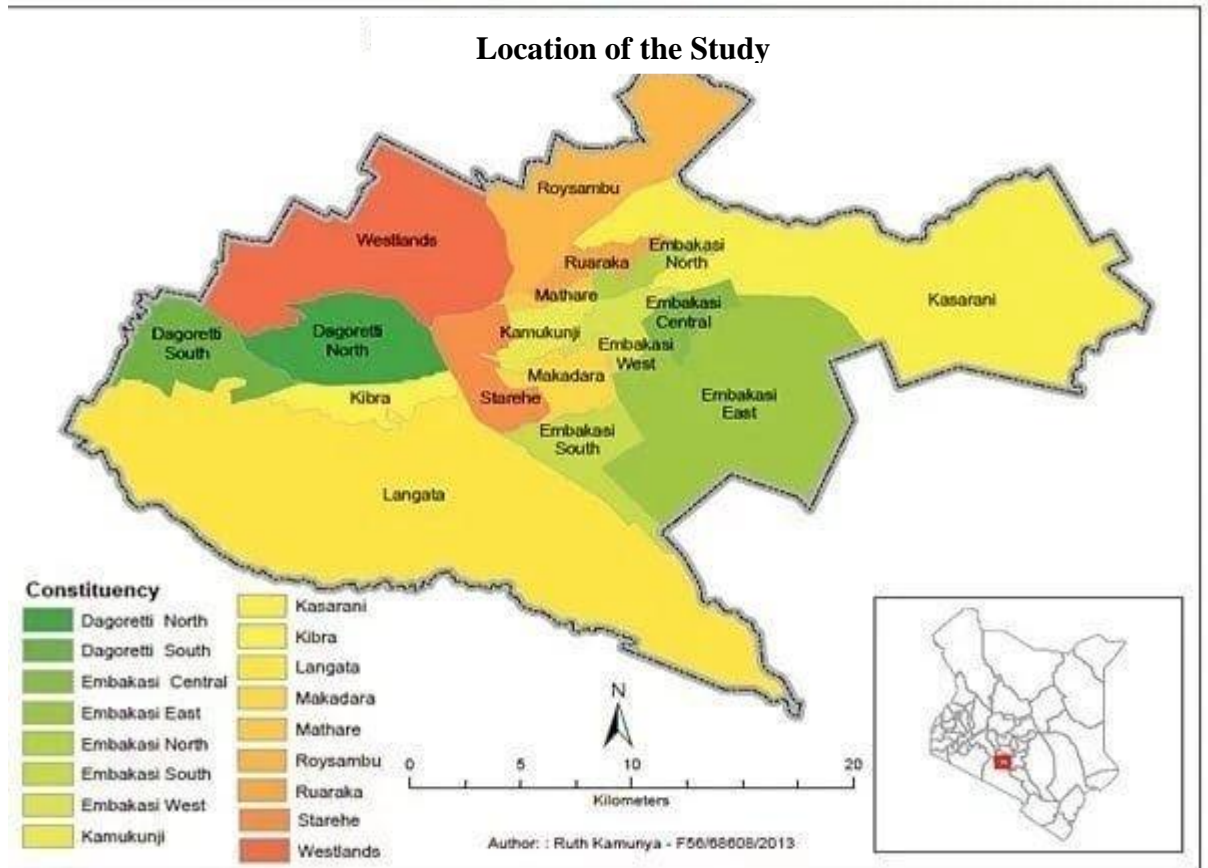
INTERVIEW GUIDE FOR TEACHERS

My name is Francis Muriuki Muriithi from Kenyatta University. This interview schedule is to help the researcher gather information on learners perceptions on communication modes they use and speech training. All information given shall be treated with utmost confidentiality. Thank you very much for accepting to participate in this interview.

1. Name of the school _____
2. Age: 25 Or below 26 – 35 36 -45 46-55
Above 55
3. For how long have you taught learners with hearing impairment?
4. Academic qualifications: Diploma B.Ed M. Ed
5. Have you done any course in speech training?
6. In the course your teaching, do you speech train your learners in class?
 - a)If yes above, from which are the easiest and most challenging sounds to train?
 - b)If no, why?
7. What is your opinion on the mode of communication preferred by learners?
8. What is your opinion on speech training learners who are hard of hearing?

APPENDIX VI

MAP OF NAIROBI COUNTY



APPENDIX VII

INFORMED ASSENT FOR CHILDREN

Project Title: Effectiveness of Automated Speech Training System in Enhancing Speech Among Hard of Hearing Learners in Selected Schools in Nairobi City County Kenya.

Protocol Number:

Principal Investigator: Francis Muriuki Muriithi

The investigator named above is doing a research study

These are some things he wants you to know about studies

I am asking you to be in a research study. Research is a way to test new ideas.

Research helps us learn new things.

Whether or not to be in this research is your choice. You can say Yes or No.

Whatever you decide is OK. I will still take good care of you.

Why am I being asked to be in this research study?

You are being asked to be in the study because you have been assessed and found to have hearing impairment ranging from mild to severe which is called hard of hearing.

What is the study about?

The investigator wants to train you to speak using an automated speech training system in order to enable you communicate with hearing people as well as the deaf using your speech.

What will happen during this study?

If you agree to be in this study, you will, be fitted with headphones through which English speech sounds will be amplified to your hearing level for you to hear them. The headphones are connected to an amplifier connected to a laptop. You will be required to observe each speech sound heard being articulated by a talking head on the laptop screen. Therefore, as you listen to the sound via the headphones, you will observe how that sound is produced from the laptop screen. You will imitate the articulation of each sound you hear as directed by the investigator. The training will take several sessions and after each session the investigator will record the sounds you are able to produce. The sounds you may have challenges to produce will be repeated several times.

Will the study hurt?

The training will not hurt but sometimes the sound may be amplified beyond your hearing level. This may make you feel a little uncomfortable. In such a case, tell the investigator to adjust the amplification.

What else should I know about the study?

If you feel afraid or uncomfortable, feel free to tell the investigator.

What are the good things that might happen?

People may have good things happen to them because they are in a research study. These are called “benefits”. The automated speech training system in this study will be used with you to try to find out whether it can enhance your speech. The investigator hopes to learn about an alternative way of enhancing speech of hard of hearing learners. The investigator might find out something that will help other

children like you. The whole training is aimed at enabling you to communicate with your family members and other people using speech. Enhanced speech can be used for learning.

What if I don't want to be in this study?

You do not have to be in the study if you do not want to.

Who should I ask if I have any questions?

If you have any questions about this study, you or your parent's can call Mr. Francis Muriuki Muriithi 0721253532, Supervisors Dr. Mary Runo 0721381513 and Dr. Patrick Karimi 0724241101 or the Kenyatta University Ethics Review Committee secretariat on kuerc@ku.ac.ke.

Do I have to be in the study?

No, you do not have to be in the study. Even if you say yes now, you can change your mind later. It is up to you. No one will be mad at you if you don't want to participate.

Signature

Before deciding if you want to be in the study, ask any questions you have. You can also ask questions during the time you are in the study.

If you sign your name below, it means that you agree to take part in this research study.

Your Name (printed)

Age

Your Signature

Date

Signature of Person Obtaining Consent

Date

Signature of Witness

Date

APPENDIX VIII

INFORMED CONSENT FOR PARENTS

My name is Francis Muriuki Muriithi. I am a Ph.D. student from Kenyatta University. I am conducting a study on **Effectiveness of Automated Speech Training System in Enhancing Speech among Hard of Hearing Learners in Selected Schools in Nairobi City County**. The information may be used by the Ministry of Education, Science and Technology in formulating policy for training learners who are hard of hearing as well as those with deafness speech to enhance their communication with members of the society.

Procedures to be followed

Participation in this study will require that I place headphones on the ears of your child through which he/she is expected to hear English speech sounds amplified to his/her hearing level. At the same time he/she will observe the articulation of each speech sound articulated by a talking head from the screen of a laptop computer. Also he/she is expected to imitate the production of each speech sound thereby enhancing his/her speech for communication.

You have the right to refuse your child's participation in this study. Your child will not be forced to participate. Participation will depend on your consent and the child's own assent.

Discomfort and risk

The researcher will conduct the training and no risk is envisaged.

Benefits

If your child participates in this study he/she will help me to investigate an alternative way of training learners who are hard of hearing to talk in order to enhance their speech for communication especially with hearing members of the family as well as the general society. They can as well use enhanced speech for learning.

Confidentiality

The training will be conducted in a private setting within the school. The information collected from your child will be kept in a locked cabinet for safe keeping at Kenyatta University. Everything will be kept private.

Contact information

If you have any questions you may contact me, on 0721253532 or my Supervisors Dr. Mary Runo on 0721381513 and Dr. Patrick Karimi on 0724241101 or the Kenyatta University Ethical Review Committee Secretariat on kuerc@ku.ac.ke.

Participant's statement

The above information regarding my child's participation in the study is clear to me. I have been given a chance to ask questions and my questions have been answered to my satisfaction. My child's participation in this study entirely depends on my consent and my child's assent. I understand that all records regarding my child will be kept private and that he/she can leave the study at any time. I understand that in case i or my child decides to leave the study he/she will not be affected in any way.

Name of parent

Signature or thumbprint

Date

Investigator's statement

I, the undersigned, have explained to the parent in a language he/she understands the procedures to be followed in the study and the risks and benefits involved.

Name of interviewer

Interviewer signature

Date

APPENDIX IX

Learners articulation of the sounds of alphabet before and after ASTS training during piloting

Letter of the alphabet	Number before ASTS and (%) “correct” (n = 6) A	Number after ASTS (%) “correct” (n = 6) B	Enhanced/Variation (B – A)
/a/	4 (66.7%)	6 (100%)	+2
/b/	4(66.7%)	6(100%)	+2
/c/	5 (83.3%)	6(100%)	+1
/d/	5(83.3%)	6(100%)	+1
/e/	4(66.7%)	6(100%)	+2
/f/	5(83.3%)	6(100%)	+1
/g/	0 (0.0%)	4(66.7%)	+4
/h/	5(83.3%)	5(83.3%)	0
/i/	4(66.7%)	6(100%)	+2
/j/	2(33.3%)	6(100%)	+4
/k/	5(83.3%)	6(100%)	+1
/l/	2 (33.3%)	4(66.7%)	+2
/m/	1(16.7%)	6(100%)	+5
/n/	5(83.3%)	6(100%)	+1
/o/	6 (100%)	6(100%)	0
/p/	5(83.3%)	6(100%)	+1
/q/	1(16.7%)	3(100%)	+2
/r/	5(83.3%)	6(100%)	+1
/s/	4(66.7%)	5(83.3%)	+1
/t/	4(66.7%)	5(83.3%)	+1
/u/	4(66.7%)	6(100%)	+2
/v/	6(100%)	6(100%)	0
/w/	2(33.3%)	6(100%)	+4
/x/	2(33.3%)	5(83.3%)	+3
/y/	4(66.7%)	6(100%)	+2
/z/	5(83.3%)	5(83.3%)	0

NB: +ve indicate an improvement in the number of learners after ASTS training. Mean number of learners pre-test = 3.81 ±0.32; Post ASTS training =5.54 ±0.16. t = 4.86, P = 0.0001.

APPENDIX X

RESEARCH AUTHORIZATION LETTER



NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone: +254-20-2213471,
2241349, 3310571, 2219420
Fax: +254-20-318245, 318249
Email: dg@nacosti.go.ke
Website: www.nacosti.go.ke
When replying please quote

9th Floor, Utalii House
Uhuru Highway
P.O. Box 30623-00100
NAIROBI-KENYA

Ref. No. **NACOSTI/P/17/87648/17354**

Date: **14th June, 2017**

Francis Muriuki Muriithi
Kenyatta University
P.O. Box 43844-00100
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on *“Effectiveness of automated speech training system in enhancing speech among hard of hearing learners in selected school in Nairobi City County, Kenya,”* I am pleased to inform you that you have been authorized to undertake research in **Nairobi County** for the period ending **13th June, 2018.**

You are advised to report to **the County Commissioner and the County Director of Education, Nairobi County** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.


GODFREY P. KALERWA MSc., MBA, MKIM
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Nairobi County.

COUNTY COMMISSIONER
NAIROBI COUNTY
P. O. Box 30124-00100, NBI
TEL: 341666

The County Director of Education
Nairobi County.

National Commission for Science, Technology and Innovation is ISO9001:2008 Certified



Republic of Kenya
MINISTRY OF EDUCATION
STATE DEPARTMENT OF BASIC EDUCATION

Telegrams: "SCHOOLING", Nairobi
Telephone: Nairobi 020 2453699
Email: rcenairobi@gmail.com
cdenairobi@gmail.com

REGIONAL COORDINATOR OF EDUCATION
NAIROBI REGION
NYAYO HOUSE
P.O. Box 74629 - 00200
NAIROBI

When replying please quote

Ref: RCE/NRB/GEN/1/VOL. 1

DATE: 20th July, 2017

Francis Muriuki Muriithi
Kenyatta University
P O Box 43844-00100
NAIROBI

RE: RESEARCH AUTHORIZATION

We are in receipt of a letter from the National Commission for Science, Technology and Innovation regarding research authorization in Nairobi County on "**Effectiveness of automated speech training system in enhancing speech among hard of hearing learners in selected school.**"

This office has no objection and authority is hereby granted for a period ending **13th June, 2018** as indicated in the request letter.

Kindly inform the Sub County Director of Education of the Sub County you intend to visit.



MAIN NGURU
FOR: REGIONAL COORDINATOR OF EDUCATION
NAIROBI

C.C

Director General/CEO
Nation Commission for Science, Technology and Innovation
NAIROBI

MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY

STATE DEPARTMENT OF EDUCATION

Telegrams: "Schooling" Nairobi
Email: deokasarani@gmail.com
Fax No: N/A
When replying please quote



REPUBLIC OF KENYA

SUB-COUNTY EDUCATION OFFICE,
KASARANI SUB COUNTY,
P.O Box 1274-00618,
RUARAKA.

REF: KAS/GF/13/646

DATE: 8TH SEPTEMBER 2017

THE HEADTEACHER

- BABA DOGO PRIMARY
- NJATHAINI PRIMARY

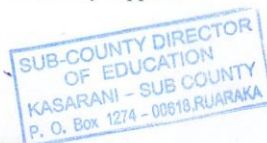
RE: RESEARCH AUTHORIZATION FOR FRANCIS MURIUKI MURIITHI

The above mentioned intends to carry out a research on "*Effectiveness of automated speech training system in enhancing speech among hard of hearing learners in selected school in Nairobi City County, Kenya*".

Authority has therefore been granted to him by the National Commission for Science, Technology and Innovation and the Sub-County Education office – Kasarani to carry out research as indicated NACOSTI/P/17/87648/17354 dated 14th June 2017. The research period ends on 13th June, 2018.

Please accord him the necessary support.

A handwritten signature in blue ink, appearing to read 'Victoria N. Mbwika'.



VICTORIA N. MBWIKA
SUB-COUNTY DIRECTOR OF EDUCATION
KASARANI

**MINISTRY OF EDUCATION
STATE DEPARTMENT OF BASIC EDUCATION**

Telegrams: "SCHOOLING", Nairobi
starehedeo@yahoo.com

When replying please quote



Sub County Director Education
Starehe
P.O. Box 30124 -00100
NAIROBI

Ref. No .EDU/ STA/AUT/8/17


Date: 15TH September, 2017

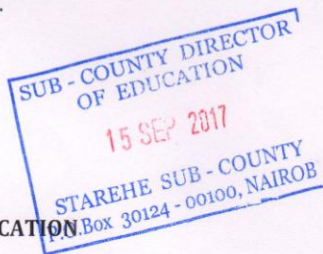
Francis Muriuki Muriithi
Kenyatta University
P.O. Box 43844-00100
NAIROBI

RE: RESEARCH AUTHORIZATION

Following your application for authority to conduct a research, on "Effectiveness of automated speech training system in enhancing speech among hard of hearing learners in selected school" in Racecourse primary school.

This office has no objection and authority is hereby granted for a period ending 13th June, 2018 as indicated in request letter.


MR JOSHUA MWANGI
SUB COUNTY DIRECTOR OF EDUCATION
STAREHE SUB COUNTY



APPENDIX XI
RESEARCH PERMIT

THIS IS TO CERTIFY THAT:
MR. FRANCIS MURIUKI MURIITHI
of KENYATTA UNIVERSITY , 985-10300
Kerugoya, has been permitted to
conduct research in Nairobi County

Permit No : NACOSTI/P/17/87648/17354
Date Of Issue : 14th June,2017
Fee Received :Ksh 2000

on the topic: EFFECTIVENESS OF
AUTOMATED SPEECH TRAINING SYSTEM
IN ENHANCING SPEECH AMONG HARD
OF HEARING LEARNERS IN SELECTED
SCHOOL IN NAIROBI CITY COUNTY,
KENYA.

for the period ending:
13th June,2018

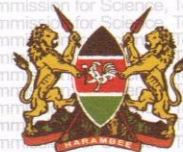



.....
Applicant's
Signature


.....
Director General
National Commission for Science,
Technology & Innovation

CONDITIONS

- 1. You must report to the County Commissioner and the County Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit.**
- 2. Government Officer will not be interviewed without prior appointment.**
- 3. No questionnaire will be used unless it has been approved.**
- 4. Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.**
- 5. You are required to submit at least two(2) hard copies and one (1) soft copy of your final report.**
- 6. The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice**



REPUBLIC OF KENYA



National Commission for Science
Technology and Innovation

RESEACH CLEARANCE

PERMIT

Serial No.A 1440

CONDITIONS: see back page