Empowering the Text Based Understandability of Students with Hearing Impairments

By

M.U.Kannangara (Registration Number: 2014/IS/040)
S.S. Thrimahavithana (Registration Number: 2014/IS/082)
V.N.Yasoda (Registration Number: 2014/IS/093)

This dissertation is submitted to the University of Colombo School of Computing
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University of Colombo School of Computing
35, Reid Avenue, Colombo 07,
Sri Lanka

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Declaration

We, M. U. Kannangara (2014/IS/040), S. S. Thrimahavithana (2014/IS/082) and V. N. Yasodha (2014/IS/093) hereby certify that this dissertation entitled Empowering the Text based Understandability of Students with Hearing Impairments is entirely our own work and it has never been submitted nor is currently being submitted for any other degree.

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Date	Signature (M. U. Kannangara)
……	……
Date	Signature (S. S. Thrimahavithana)
……	……
Date	Signature (V. N. Yasoda)

I, W. V. Welgama, certify that I supervised this dissertation entitled Empowering the Text based Understandability of Students with Hearing Impairments conducted by M. U. Kannangara, S. S. Thrimahavithana and V. N. Yasoda in partial fulfillment of the requirements for the degree of Bachelor of Science Honours in Information Systems.

……	……
Date	Signature of Supervisor

I, A. R. Weerasinghe, certify that I supervised this dissertation entitled Empowering the Text based Understandability of Students with Hearing Impairments conducted by M. U. Kannangara, S. S. Thrimahavithana and V. N. Yasoda in partial fulfillment of the requirements for the degree of Bachelor of Science Honours in Information Systems.

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Date	Signature of Supervisor

Abstract

Imparting and exchanging of information is a human need. Language is the key to satisfy that need. People usually communicate using their native or foreign languages and they use their vocal tones and the hearing ability in communicating with each other. But hearing impaired people face lots of problems in communicating owing to their hearing inability. Their reading and understandability have also been poor due to this disability. Deaf people use their own communicating methods and one of the most common is sign language.

The Sri Lankan deaf community uses Sri Lankan sign language. Only a very few deaf people can be seen in higher job positions in Sri Lanka as in most other countries. The believed reason for that is their lower performance at examinations. Sri Lankan deaf students learn Sri Lankan sign language in schools but technological advances have not yet reached these schools. In particular, while there are various developments for other language translations, no developments for translations have been used for Sinhala text to Sinhala sign language conversion.

This thesis presents the observations made by evaluating deaf students using a computational tool named Sign Language Translator which translates Sinhala text to Sri Lankan sign language. A comparison among the current examination systems for the hearing impaired was carried out and an examination method was suggested with the proposed IT based solution. The Methodology consists of a control group that was subjected to an examination with the ordinary process of examinations and an experimental group that was exposed to the same examination with the proposed IT based solution which gives a sign language interpretation for the questions given in the examination paper. Matara Rohana Special School was selected for the test and the sample was a student group of Grade 7 class. The students were given a test on the Grade 7 Buddhism subject curriculum.

The results obtained in the study showed that the control group had an average mark of 37.75 while the experimental group had an average of 33.75. However, when the marks of the two groups were compared with their previous term test marks, the percentage decrease of marks of the students who used the Sign Language Translator with an average of 8.25, was comparatively lower than the students who used the ordinary method with an average of 16. This shows that a computational tool that converts text to sign language is needed for the increase of text based understandability of students with hearing impairments.

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ASL – American Sign Language

BSL – British Sign Language

SLSL – Sri Lankan Sign Language

Chapter 1 – Introduction

1.1 Background

Linguistics could be identified as the scientific study of language. According to the Ethnologue catalogue of world languages, which is one of the best linguistic resources, there are around 6909 living languages around the world including vocal and sign languages. General people communicate with each other using their native or foreign languages and they use their vocal tones and the hearing ability in communicating with each other. However, there are certain groups of people who are not able to listen to others due to some hearing impairments. Eventually this will make them helpless in communicating their ideas with others.

The people with hearing impairments who are also known as deaf people represents more than 5% of the global population while this percentage in numbers represents around 466 million[1]. Among this 466 million, 34 million are children [1]. Sri Lankan context had about 9% of hearing impaired people by 2013[2] and that percentage might have increased during the last 5 years. Main problem that should be considered is that a considerable amount of children represents this deaf community while there are school going children among them.

Sri Lanka has about 5 deaf schools which provide free education for deaf students and sign language is the main communication medium that is used in these schools for teaching the students. Sign language is a language that uses manual communication signals to convey the meaning. This can include simultaneously employing hand gestures, movement, orientation of the fingers, arms or body and facial expressions to convey speaker's ideas[3].These schools are also like the schools where general students attend and the only difference is teaching using the sign language.

Though these deaf students being taught the same syllabus and being given the same examinations can be considered as a good practice of equality, the major problem we identified after interviews and observations was the text based understandability matter which is risen as a result of education system which the hearing impaired students were compelled to adopt. Since normal students have a very good ability of reading text, they acquire significantly higher results in their examinations compared to deaf students. Digging deep into the reason for this, it was found that this less performance is caused because deaf students are very weak in reading text. It

brings out difficulties in exam situations and general academic work as well. In general terms it affects in many ways to many stakeholders of the research, not only the hearing impaired students but their family members and school staff members. This research addresses the founded problem of text understandability of deaf students and a solution to reduce this performance gap between normal students and deaf students. The research is to evaluate the existing methodologies that are currently being used to control the situation, come up with an IT based solution to see whether it can help this text based understandability problem to and to evaluate the success of that solution. The comments of the stakeholders will be taken throughout the research and will be evaluated to make a successful solution.

1.2 Problem Statement

Determine a solution which could address the matter of text based understandability of students with hearing impairments in order to ameliorate their literacy skills.

1.2.1. Major Research Problem:

How to improve the text based understandability of hearing impaired students?

According to the details gathered from interviews and observations at the National School for the Deaf and Blind, Rathmalana, students have a matter of text based understandability. Those students cannot remember the letters in the correct order that was there in the original word. That occurs because they are forced to study in Sinhala but not in the language they are familiar, which is the sign language. So that the school gives them an interpreter in exams to interpret the exam paper to them. Unfortunately, due to the less time remaining, interpreter interprets the whole exam paper in the very beginning of the exam. Students fail to understand each and every question effectively due to the speed of interpretation and especially they cannot keep remember all the questions interpreted until the end of the exam. Therefore it is important to see how we can improve the understandability of these students in order to make their literacy level high.

1.2.2. Sub Research Problems:

I. **What is the current procedure in teaching the text based content to the deaf students?**

Academic staff of the school is another major stakeholder of this research. The problem they face is that the students cannot grab the knowledge to the expected extent due to above mentioned matter. Although the teachers are talented they are not able to educate students well and also when the students score low marks in government exams such as ordinary level and advanced level exams, it is not good for the school's reputation as well. In order to support students to keep remember the words, teachers write them in big letters and paste on walls in the current situation. But it is not effective because teachers cannot waste time to write each and everything and paste in walls. And practically they cannot paste the whole syllabus on walls. Also, teachers cannot do this in examinations because it can be taken as an examination offence. So, there is a great difficulty in teaching the text based content to deaf students.

II. What are the difficulties deaf students face in understanding the text based context?

When it comes to the student base of deaf school, they could be divided into four categories called profound, severe, mild and normal. Profound students struggle hearing even loudest sounds while the severe students could mean struggle to hear a loud sound or a conversation. Mild students could struggle to hear sounds like clock ticking and normal hearing range including sounds as quiet as a tap dripping. Some of the students are hearing impaired from the birth and some are not. Some are able to catch the lip gestures and understand the vocals. Since the student base is very different from each other, the understandability of text also differs in a major range. Therefore, it is not easy to give a proper solution which could cater all the requirements of the stakeholders. To provide a proper solution, the difficulties all these students face in reading and understanding text based content should be understood.

III. What is the best solution to improve the understandability of these students?

Understanding the difficulties with the deaf students in reading opens up a path to clarify the way they are dealing with these text based content and that understanding will be useful to think how this gap can be reduced. So the next step in addressing the research problem will be implementing a good solution that will be easy to use by the deaf students and that will solve the difficulties in reading with the deaf students.

IV. What is the progress of the implemented solution with respect to the current process of understanding?

After introducing the solution that was addressed in the previous research question, it is

important to evaluate the progress of the solution to conclude whether the suggested solution is a success or not. Evaluation of the progress will be calculated using two groups of students who are following the normal procedure of understanding the text and the students who are using the introduced solution. The difference of these two groups should be calculated as the last step of the research to see whether improve the text understandability of deaf students can be improved in order to reduce the performance gap between them and normal hearing students and what the progress of the research is.

1.3 Project Motivation

Sri Lanka, being a developing country is far more advanced and quick in entering to the information era competing with developed countries and producing information technology experts. Though there is a huge development in the country in information area, deaf people have not gained any advantage of that and the government has not provided them with sufficient facilities to increase the productivity of their lives. That is very unfair in the context of deaf people. Especially government has not involved in the problems faced by the deaf students and ministers or any other responsible people in the country has not looked into developing the education system of deaf students which has become a major reason that deaf students quit their studies after Ordinary Level examination. Still the teachers and the principals of deaf schools believe that if there is a proper education system introduced for deaf students, they can be dragged higher in their education and position them in higher ranks in the country. They believe in the ability of deaf students as equal as it is with blind students who achieve more than deaf students.

In other countries, they have introduced a lot more facilities for deaf people and students such as software for translating their languages into the appropriate sign languages they use. Howver, in Sri Lanka there is no any tool available which translates Sinhala text in to Sri Lankan Sign Language and no any tool to help deaf students in examinations such as the Braille method for blind students. When studying the problems these deaf students face, we observed that they are very poor in understanding written text and answering the questions due to that lack of understandability. Images of some answer scripts of students with such lack of understanding are shown below to verify the problem they face in examinations.

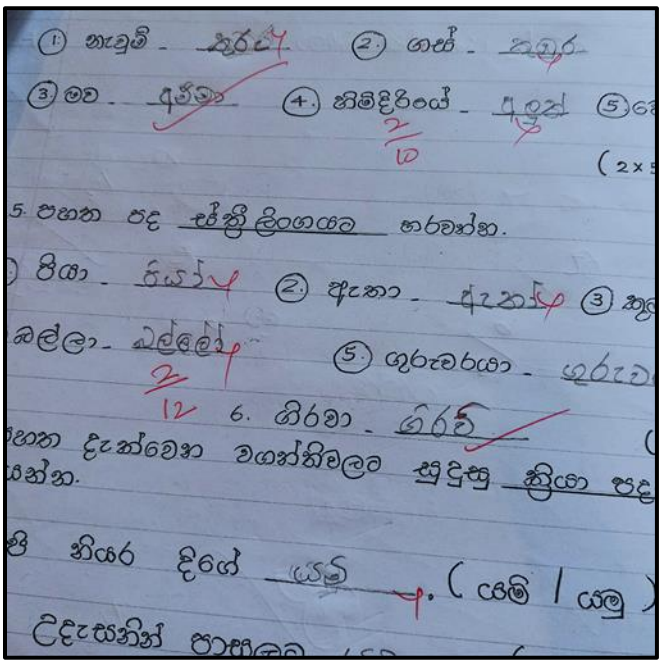


Figure 1 - Answer Script 1

As shown in *Figure 1* the students were asked to convert the given terms into the feminine term of each of them. But the student has not provided the answers correctly. For example the student has stated the feminine of the Dog as Dogs. This is due to the reason that the student has been unable to understand the instructions given in text. They have understood the conversion into feminine version as the conversion into plural form.

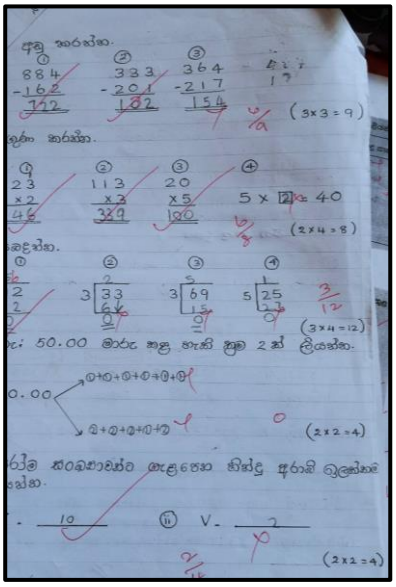


Figure 2 - Answer Script 2

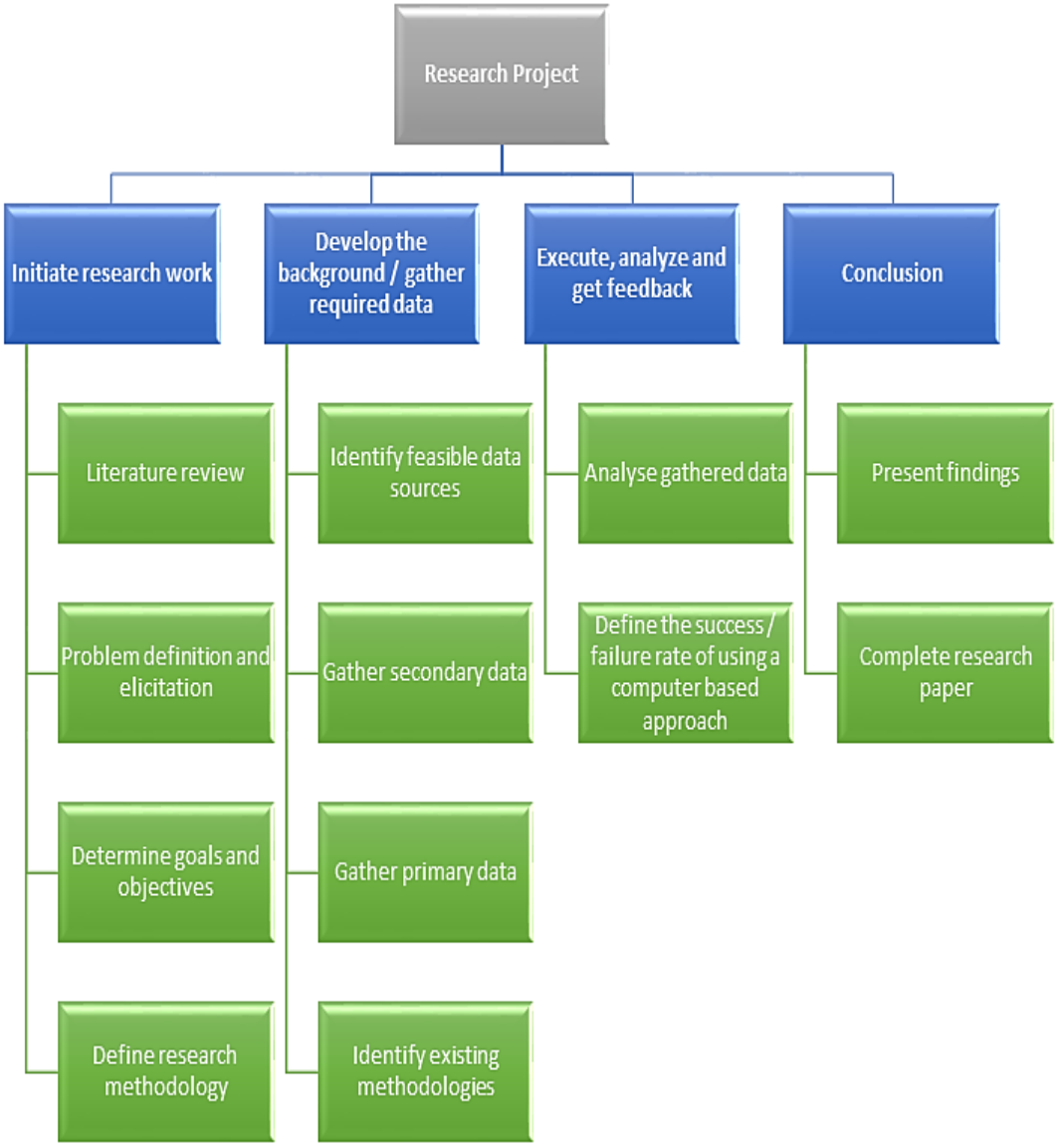
Figure 2 shows that the student has been unable to answer the question of methods to change the money of worth LKR 50. He has given a very different answer due to his inability to understand the instructions. At the same time, this also shows that students are able to answer the

questions including signs like multiplication which is why they have been able to answer the mathematics multiplication questions correctly.

Therefore considering all these difficulties faced by the deaf students, the motivation was to help the deaf students to improve their performances through examinations using the technological advances available in Sri Lanka. Since these students are taught in Sinhala in many occasions and subjects, the research was directed towards translation of Sinhala text to Sri Lankan sign language and to see whether this translation tool helps the deaf students to score more in their examinations or not. The proof of concept used was a software application designed to convert text to sign language and it was customized to translate Sinhala and the motivation was gathered through the communication between the principal, teachers and students of MR/Rohana Special School.

1.4 Research Approach

This research will be conducted using a mixed approach where both qualitative and quantitative analysis will be carried on. Qualitative approach will be used in analyzing things like interviewing the teachers and the deaf students, analysing the behaviour of deaf students, analyzing the way they communicate subject matters in the classroom environment and out of the classroom environment, a thorough learning about the sign language they use and also the way they understand the questions in an exam paper and how they write answers. Quantitative approach will be used in the process of implementing an IT based solution to improve their text based understandability and concluding and evaluating the progress of the introduced solution with respect to the current process they are carrying out. The research process is stated in the following diagram in brief.



1.5 Research Goals and Objectives

Goal of this research is to reduce the performance gap in examinations between normal hearing students and deaf students through implementing an IT based solution which helps deaf students improve their text based understandability.

The objectives of the research are in two folds as:

- To identify and implement an IT based solution to improve the text based understandability of students with hearing impairments

In accordance with the given introduction about the research, one of the major objectives to achieve is to identify and implement an IT based solution to improve the text based understandability of the students with hearing impairments. The need for improving the text

based understandability is due to the findings of the previous researches, which provide sufficient evidences about the poor text based understandability in hearing impaired students. According to them, the reading of text and understanding the text is found very difficult for these students due to many factors. Therefore mainly the level of confidence and the examination marks of these students lie in a very lower level relative to the normal hearing students when considering the same educational syllabus. So, the need of identifying a solution to improve text based understandability has become a major objective of this study. Implementation of the identified solution in an IT based context is an extra extension for the above mentioned objective and that is done as a cause for increasing the effectiveness and efficiency of the understanding of text by hearing impaired students. Many researches around the world have proven that hearing impaired students have a very sharp eyesight and they are very efficient in extracurricular activities like sports, sawing and painting. Since they possess this special ability it is identified that they are interested in using technological tools. That factor has projected the objective of implementing a solution to this problem in to an information technology based approach.

- To evaluate the success of the implementation of the new solution relatively to the current interpreting methodologies

Implementing a solution for these hearing impaired students alone will not visualize the success of the research because the output of the implemented solution will be not clearly visible. Therefore, measuring the success of the implemented solution and to see whether the implemented solution is a valuable one for the hearing impaired community has become one of the main objectives of this study.

During the research, the major sample as a whole was subjected to a test to identify the current knowledge these students possess and the major sample was then divided into two groups as the control group and the experimental group. The experimental group was given a practical knowledge and training on how to use the implemented solution and they were given the hands on experience with that. Finally the two groups were given a test which was carried out in the current procedure for the control group while the implemented solution was used to deliver the test for the experimental group. That was used as an evaluation of the success or the failure of the implemented solution.

1.6 Scope and Delimitations

Scope

The scope of the research is based only on students with hearing impairments. There are 02 main methods to carry out studies on people with hearing impairments as:

1. Natural language to sign language conversion
2. Sign language to natural language conversion

This study focuses on the first method out of these where natural language is converted to sign language. Furthermore, there are two methods by which studies can be conducted for conversion of natural language to sign language as focussing on the conversion of audio (spoken language) or text (written language). This study restricts only for the conversion of Text to Sign Language. Conversion of spoken language is a different research area.

Out of these four areas this research focuses only on the conversion of Sinhala language. Hence, the research focuses only on conversion of Sinhala text to Sinhala sign language. For the carrying out of the study, the students from MR/ Rohana Special School was taken where the school is located in Matara, Sri Lanka. Furthermore, for the purpose of the study, the results comparison of only written examinations of one selected subject was done. Also, since there are slight variations in signs used in different regions and schools, we only consider the signs used by the teacher of the selected subject at MR/Rohana Special School.

Delimitations

The following environment is controlled to carry out the study within the time constraints.

- In the carrying out of the research, since the methodology focuses on written examinations, the subject knowledge is not considered. The student's ability to grasp the effect of the method that was introduced is considered.
- Since the written examinations of one subject are considered, the result may sometimes vary based on the type of the subject and the examination questions.
- The study does not focus on giving interpretations to the user through facial expressions.
- The signs interpreted by the movements from the uppermost finger joint are ignored.

- Since there can be regional and institutional differences in signs used by the teachers, the signs that are stored in the implemented system may vary from region to region, institute to institute and from teacher to teacher.

1.7 Significance of the Study

As discussed in the background section, there are only a limited number of researches carried out on this specific domain and especially to conversion of Sinhala text to Sinhala Sign language. With the time constraints and the scope to be addressed, this study focus on improving a previously created model for the conversion of Sinhala text to Sinhala sign language. The model that was improved is the Sign Language Translator which is a desktop application developed using Java which allows user to enter any simple sentence as an input text. Then the application parses the text, process it and present the signs via a 3D animator which is developed using Java 3D. This model was applied to the examinations context of the students with hearing impairments in MR/Rohana Special School.

This model is a language independent application. However, data has been fed only for the Sinhala Sign Language and British Sign Language. Therefore, we have improved this model to suit the Sinhala examinations context by taking the necessary steps to match the requirements. Finally an evaluation test was conducted to identify whether such an animation based interpretation is suitable to increase the text based understandability of students with hearing impairments.

The most significant reason about this research is that this is the first ever research to be conducted related to the hearing impaired students connecting with their examinations using Sinhala text to Sinhala sign language translation.

1.8 Overview of the Dissertation

The Introduction chapter of the dissertation focuses on explaining the problem identified and the probable solutions to it while explaining the domain it is implemented to. It also gives a deep description on the goals, objectives, scope and the delimitations of the study. This chapter also give a brief explanation on the significance of the study and the methodology that is to be adopted in carrying out the study.

The second chapter gives a deep explanation on the concepts used in the study according to the existing literature. This chapter also focus on explaining the previously carried out researches on this domain and the points that can be adopted to this study from those researches. Furthermore, it includes the systematic literature review carried out on the research questions.

The third chapter includes the methodology carried out in the study and the processing of the Sign Language Translator tool used.

The fourth chapter includes the primary and secondary results obtained of the study from the carrying out of the study.

The fifth chapter includes the discussion of the results obtained with relevance to the study context and the sixth chapter includes the conclusion of the study. The final chapter discusses the future research options along the pathway of continuing this research.

1.9 Summary of Introduction Chapter

The introduction chapter first gives an introduction to the problem identified for the study and the probable solutions to it when the domain of application is considered. It also explains the motivation of the study so as to why this study should be carried out. Then it explains the objectives of the study so as to explain what is targeted to be done through this study. The scope of the study is included as the next component and it explains the boundaries for the study. The delimitations of the study are included here so as to explain what the study has controlled to achieve the targeted time frame and the complexity. Then the significance of the study is explained to ensure the value of the study when compared to other studies carried out on the domain. A brief explanation on the methodology to be adopted in the study is explained on an abstract level as the next component of the introduction chapter.

Chapter 2 - Background and Literature Review

2.1 Chapter Overview

The study area of the research is described in detail in this section with the literature review. It includes the background information and the terminology that have been reviewed to spread the knowledge in the problem domain. This focuses on many areas which are related to the study and identifies the previous researches that were carried out with references. The topics discussed are the importance of communication, hearing impairment, communication modes of hearing impaired, Sign language, Speech reading, Sri Lankan Sign Language (SLSL), current procedures in teaching text based content, difficulties faced with the current procedure of teaching, Dyslexia in deaf, Natural Language Processing, Computer animation and previous researches and similar works carried out.

2.2 Significance of Communication

Communication between people is the most important thing which helps to understand each other and respect to their values. In order to ensure an effective communication between people, a common platform or a protocol should be available. Normal people (without hearing / speaking disability) use natural languages to communicate and interact with each other [4].

2.3 Dyslexia in Deaf

Developmental Dyslexia is a primary component of about 80% of all cases of learning disabilities in the hearing population [5] Current evidence suggests that it is generally caused by an underlying neural misorganization during prenatal development due to both genetic and environmental etiologies. Developmental Dyslexia and other forms of learning difficulties might occur with at least the same frequency in deaf individuals as in hearing individuals[6] Deafness and developmental Dyslexia in the same individual may jointly limit the acquisition of reading skills for different underlying reasons [7]. It seems to be the reason identified for the difficulty in people with hearing impairments for understanding a written text, which is why it is of vital importance to address this problem to develop a solution.

2.4 Communication modes of Hearing Impaired

In this communication context deaf has been ignored for many years while only the closest could communicate with them which is why the importance of a gesture based sign language arose. However, it is an unfortunate fact that there is no universal sign language, but each country has its own sign language [8]

2.4.1. Sign Language

Linguistics could be identified as the scientific study of language. According to the Ethnologue catalogue of world languages, which is one of the best linguistic resources, there are around 6909 living languages around the world. Among all, sign language plays a major role in the communication system of hearing impaired community since it facilitates the hearing impaired community to communicate using gestures, and facial expressions instead of acoustically conveyed sound patterns. Not only the hearing impaired community but also others could use this language to communicate with hearing impaired people. However the person who communicates using sign language is called the signer. The three types of gestures in human body are called mimetic, deictic and arbitrary. While the mimetic gestures complete figure movements, Deictic occurs by pointing to a specific object. And the arbitrary gestures are not recognizable. Unfortunately the sign language falls under this arbitrary gestures. So that it acts as an intelligent way of communicating. When it comes to the different types of sign languages using around the world, there are many sign language categories in each continent [9]. For example, In Europe countries there are around sixty sign language categories which goes with different ethnic groups of the continent.

2.4.2 Speech Reading / Lip Reading

Speech reading allows people with profoundly impaired hearing access to spoken language. However, such access may be very limited, since not all of the segmental speech contrasts, available by ear are also available by eye alone. In addition, spoken language development is delayed in people who are deaf from an early age [10]. Lip reading could be recognized as an alternative for sign language. But it could not help all the time as the limitations in lip gestures occur due to the different pronunciations coming from different countries, different ethnic groups, sometimes in the same society. Always not all the people move their lips in the same manner to make it easy to grab lip gestures [9].

A study carried out on speech reading and its association with reading among deaf, hearing and dyslexic individuals has suggested that prelingually deaf adults outperformed matched hearing people at speech reading proving that long experience with seen speech improves its perception even when audio visual experience is minimal. It indicates that good speech reading is associated with a developmental history of reliance on visible speech [10] which is why another solution to the above stated problem should be sorted out. It is a known fact that speech reading and sign language are the methods used by people with hearing impairments to communicate with each other. But, as explained above, speech reading is not a good method for interpreting text to deaf people since prelingually deaf people fall into difficulties at grabbing the words through speech reading.

2.5 Sri Lankan Sign Language

Sri Lankan Sign Language (SLSL) is the common sign language that all Sri Lankan deaf community use in communication. Since Sri Lanka is comprised with a multicultural and multilingual society, people use various languages like Sinhala, Tamil and English as their preferred method in speaking, reading and writing. As normal hearing people, deaf people use their preferred language Sinhala, Tamil or English in reading and writing while all of them use the Sri Lankan sign language which is common to all of them in speaking. 25 deaf schools located around the country distribute the knowledge to deaf people and each of these schools use Sri Lankan sign language while there are very little regional variations [11]. These regional variations can be mostly seen in Nuwara Eliya area, Southern Province and North Eastern provinces [12]. Scope of this study specifies that the regional differences will not be considered in this study.

Sri Lankan Sign Language is taught to the students by the teachers who are well trained about the Sri Lankan Sign Language at schools and according to Shamila Kurukulasooriya, parents are the key for the success of education of deaf students [13]. There are some text books published by Shamila Kurukulasooriya that address all Sinhala, Tamil and English preschool deaf students to enhance their knowledge about Sri Lankan Sign Language but there is no standardized and approved text book for Sri Lankan Sign Language, announced by the Sri Lankan government as the basic text book for school children.

Sri Lankan Sign Language has got about more than 2000 sign words currently [14] and there are two ways of interpreting Sign Language as;

1. Discrete Approach
2. Continuous Approach

In discrete format of sign language gestures, there will be a pause between interpreting two words while in continuous format, there will be no pauses between words. The way of interpreting will be decided by the interpreter according to the situation and most often continuous format is being used in common such as in news broadcasting. In sign language, there are some signs that describes a whole sentence at once while there are complex sentences which uses more than one sign per one word. The following figures taken from ”An Introduction to Sri Lankan Sign Language“ which is the first ever conversational sign language dictionary gives a clear idea about how these signs are used in interpreting Sinhala words with sign language. Figure 3 shows the interpretation of “I Love You” in Sri Lankan sign language and *Figure 4* shows the Sri Lankan sign language interpretation of “You and I are the same.”

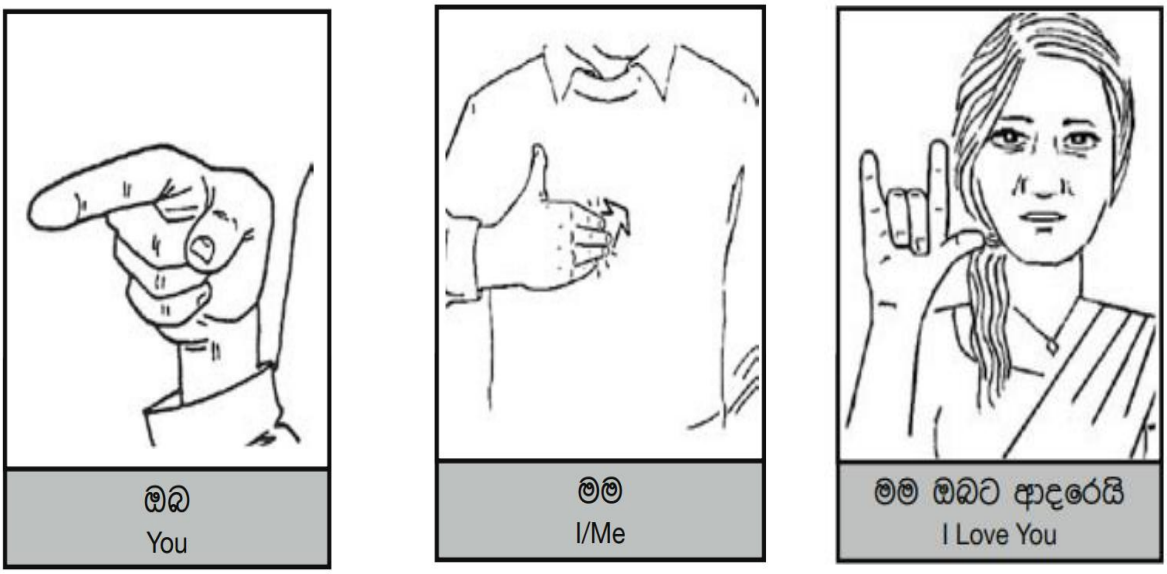


Figure 3 - Sign Language Interpretation of "I Love You"

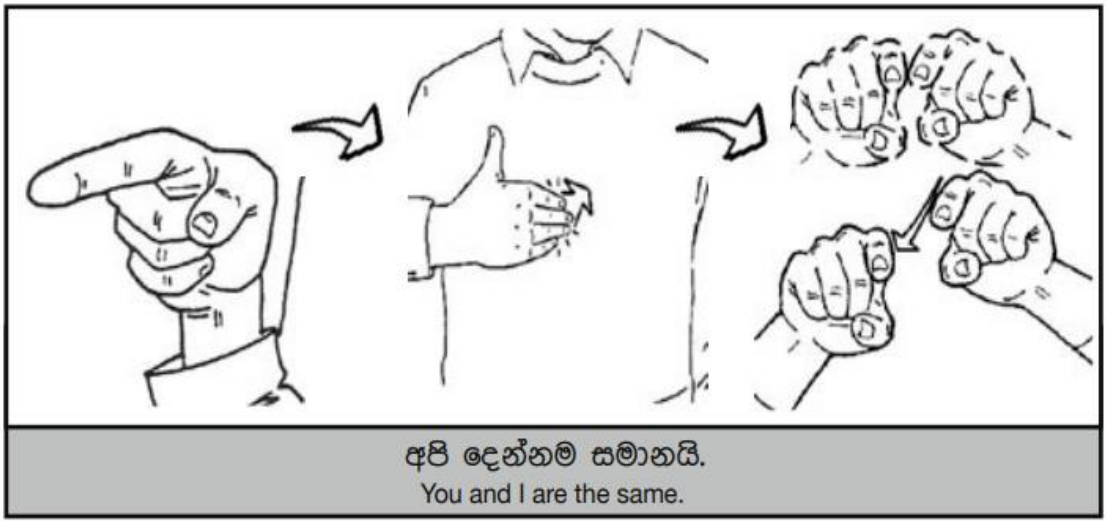


Figure 4 - Sign Language Interpretation of "You and I are the same"

2.6 Current procedure in teaching text based content

2.6.1 Home School Environment

This technique is mostly used in the preliminary education system. It allows to develop appropriate learning techniques and materials, language rich environment and specially a well maintained education set up for children. But here in the deaf education system, that technique is suitable for any age group. When it comes to its applicability in GCE (General Certificate of Education) Ordinary Level grades, it is more suitable for subjects like history, science and technology, mathematics, geography and all other fact and theory based subjects.

Hearing impaired students need a modified classroom, which should incorporate well-designed acoustics (for maximum sound production), little distractive noise, and proper lighting for visuals. Each student should have a clear view of all visuals as well as the instructor [15]. Furthermore the years of research and development have provided educators with wonderful tools for maximizing auditory abilities for those students with some degree of hearing including FM Systems which can project sound from an instructor's microphone, C- Print which is a speech-to-text computer system, speech synthesizer which converts a typed word into speech format, Personal amplification systems. Since the Sri Lankan education system is upgrading with multimedia support and virtual learning environment, it will be easy to adopt hearing impaired education system to a technology based learning platform.

2.7 Natural Language Processing and Text to Sign Language Processing

Natural Language Processing (NLP) is a medium that acts as a bridge between human language and computers. NLP allows computers to analyze human language through text or voice in order to convert them into machine usable data and to be used in performing tasks such as translation and relationship extraction [16]. NLP is considered as really hard because the human language is more complex and human language expands from single words to paragraphs which connects several sentences with their grammatical exposure.

NLP becomes a major component in this study since this study concerns about finding the text based understandability of students using translation of human language in text to sign language. Here, it becomes more difficult because the human language used in this study is Sinhala language which contains a mass amount of variations and grammar inside the language and also which is considered as one of the most difficult languages in the world.

Since the study mainly focuses on text based understandability of students and the translation of examination papers is taking place, we have to use an application or a translator which consists of a summarizer because the questions need to be summarized in interpreting, considering the time duration of the examination. Also, a language parser is useful because the text should be analyzed according to grammar and the linkage between words.

Furthermore, when discussing about the connection between NLP and text to sign translation, we are needing an application or a translator with Part Of Speech (POS) tagging tool due to the combination between the word dictionary and the text where we are going to map the relevant word with a predefined sign in the sign word dictionary. Tagging becomes more relevant in finding those relevant signs.

2.8 Related Work and Literature Review

2.8.1 Previous Researches / Similar Work

Many researches have been carried out to address the problem of conversions between natural spoken language and sign language. But there are only very few researches carried on the conversion of text to sign language. Furthermore, this becomes fewer when it comes to Sri Lankan context since researches on converting Sinhala text to Sinhala Sign language is minimal.

From the 80’s, researchers began to analyze and process sign language. Next, they

designed and developed routines for communication of intra-deaf and between hearing and deaf people. Starting from the design of automatic annotation system of the various components of sign language and coming to the 3D synthesis of signs through virtual avatars. In recent years, there was the appearance of a new line of research said automatic Sign Language Processing noted SLP. SLP is how to design, represent and process sign language incompletely described [17].

2.8.1.1 Statistical Sign Language Machine Translation from English Written text to American Sign Language

A study carried out in University of Tunis on Statistical Sign Language Machine Translation from English Written text to American Sign Language has used a Moses tool with some modifications and the results were synthesized through some 3D avatar for interpretation. As stated in this study, words in American Sign Language are very similar to English written text. So, this research has used others techniques to learn data quickly and efficiently, for example, string-matching. String-matching is a very important subject in the wider domain of text processing. String-matching algorithms are basic components used in implementations of practical software existing under most operating systems. Moreover, they emphasize programming methods that serve as paradigms in other fields of computer science. They also play an important role in theoretical computer science by providing challenging problems. String-matching consists in finding one or all the occurrences of a string in a text or with another string. After String matching techniques, this study has used phrase based model and decoding. The aim of it was to reduce the restrictions of word-based translation by translating whole sequences of words, where the lengths may differ. There they have used the MOSES tool to learn phrase alignment. After that, they have exploited the decoding tool. This step is the main function in this system. The input is an English sentence. The role of the decoder is to find the best translation. Finally the translation is mapped to a 3D avatar using this technique. The results of this study has found out that employing a technique of string matching is crucial in this context. In concluding the results, phrase based statistical machine translation for sign language from English to American Sign Language has identified to be performing well despite the expectations arising from linguistic knowledge [8].

2.8.1.2 Text to Sign Language Interpreter

A study carried out in University of Colombo School of Computing has implemented an application named as Text to sign language interpreter. When a certain sentence is input to the

system they are tokenized and individual words are extracted. Then morphological analysis is carried out to find the basic components of individual words. Then these words are mapped with the corresponding prerecorded sign videos in the library and the final translation is done by concatenating single video clips as a video stream. The accuracy of this system has been lower since only 47% of the signs were correctly identified [18].

2.8.1.3 Sign Language Translator

Another research carried out in the University Of Colombo School Of Computing has implemented the Sign Language Translator which is a desktop application developed using Java which allows user to enter any simple sentence as an input text. Then the application parses the text, process it and present the signs via a 3D animator which is developed using Java 3D. The significance of this project is that it is language independent. But the drawback of this system is that it cannot handle grammatical structures [12]. This study's application is used as the baseline tool for this current research. Further information on this study will be provided in the Chapter 03.

2.8.2 Literature Review

In this chapter we present our findings from our systematic literature review on the text based understandability of students with hearing impairments. By updating the knowledge on the previous studies in this area we help the parties interested in finding an approach to improve the text based understandability of students with hearing impairments through shared knowledge on the current state of research in this area. Our systematic approach in analyzing the published studies provided us with knowledge on the studies carried out on this area previously, the conflicting views that has arose and the gaps that are available among the previously carried out studies.

Communication between people is identified as to become the most important thing which helps to understand each other and respect with their values. It is also stated that, in order to ensure an effective communication between people, a common platform or a protocol should be available. Normal people (without hearing / speaking disability) use natural languages to communicate and interact with each other [10]. In the hearing impaired people or people who are commonly referred as "Deaf" [5], it is reported that hearing impairment is a symptom of many injuries and diseases. It is found that individuals with at least an 80 dB loss in both ears are profoundly deaf unless ameliorated by a hearing aid or surgery, this loss is so severe as to preclude successful processing of auditory information. Untreated prelingual deafness has

identified to be interfering with speech as well as hearing, leading in its extreme form to the condition formerly known as deaf mutism [5]. While the background is explained as above, it is identified that in this communication context deaf has been ignored for many years while only the closest could communicate with them which is why the importance of a gesture based sign language arose. But it is an unfortunate fact that there is no universal sign language where each country has its own sign language [9]. As reported in previous studies, Speech reading allows people with profoundly impaired hearing access to spoken language.

However, such access may be very limited, since not all of the segmental speech contrasts, available by ear are also available by eye alone. In addition, spoken language development is delayed in people who are deaf from an early age [18]. Lip reading could be recognized as an alternative for sign language. But it could not help all the time as the limitations in lip gestures occur due to the different pronunciations coming from different countries, different ethnic groups, sometimes in the same society. Always snot all the people move their lips in the same manner to make it easy to grab lip gestures [7]. It is reported that Developmental Dyslexia is a primary component of about 80% of all cases of learning disabilities in the hearing population [19] and Deafness and developmental Dyslexia in the same individual may jointly limit the acquisition of reading skills for different underlying reasons [20]. Although, with all these factual information on the need that a solution to this problem has to be sought out is identified, no systematic literature review is undertaken to bring together the knowledge from the previously carried out studies on finding a solution to improve the text based understandability of the students with hearing impairments.

Given the importance of identifying a solution to improve the text based understandability of students with hearing impairments, we conducted a systematic literature review of the current procedures of teaching the text based content to students with hearing impairments, difficulties faced by these students in learning text based content and the solutions proposed to improve the text based understandability of these students. A systematic literature review evaluates and interprets all available research relevant to a particular research question or topic area. It aims to present an evaluation of the literature relative to a research topic by using a rigorous and auditable methodology [21]. We summarized the findings on what solutions are currently used and proposed to improve the text based understandability of students with hearing impairments. We analyzed the literature to find answers to three research questions:

- RQ1: What are the current procedures in teaching text based content to students with hearing impairments?
- RQ2: What are the difficulties faced by students with hearing impairments in understanding text based content?
- RQ3: What are the solutions proposed for the conversion of text based content to sign language?

RQ1 refers to the current processes of teaching text based content to hearing impaired student. There is an understandable difference between hearing impaired students and non-hearing impaired students in understanding text based content and keep them in memory. Especially this matter occurs when the learning materials are in printed form [22]. Since the hearing impaired students have to follow the general local syllabus, there should be special techniques in order to support them to grab the knowledge. The teaching methods, observation techniques and writing methods should differ to facilitate hearing impaired students. When it comes to the memory skills, it could be divided into two areas called working memory and short term memory [23]. Since the memory and text based education are two concepts which goes in parallel and sometimes one on another to keep the text based processes in a successful status, memory skills of the students also should be considered. To get a better output from hearing impaired students in learning environment, there is a need of taking actions to address the deficiencies of deaf including sequential memory, processing speed, attention and memory load. The processes of teaching should consider those practices when deciding a manner to educate this community. If there occurs any defects in teaching methods in hearing impaired community, it would make harm more than it does to the non- hearing impaired community. So the attention to teaching processes is so important.

When considering this research question, mainly three research journals provided details to understand the current techniques used in teaching text based content to hearing impaired students. The following approaches were mainly tested and examined throughout the research studies identified. The approach uses metacognitive strategies to improve deaf and hard of hearing students could be useful in many ways to the study. It was highlighted in most of the researches as a technique of enhancing hearing impaired education system. But some of the studies cannot be taken as a whole to our research study as it has underestimated the difficulty of content area text. It highlights the need of using multiple readability formulas to select most readable text for individuals [24].

The research studies examined the interactive writing with the observation of trained

teachers is another method of teaching text based content to hearing impaired students. The approach was called team teaching in an integrated classroom [25]. Identifying the groups of students who have similar writing skills and goals were identified through the research study in order to improve the student morality while guiding through the pathway. But the research itself explained that there is an uncertainty in giving attention span for students and correlate with the length of students. It disinters the need to analyze within the local community for the guiders or the teachers with the capability of supervising hearing impaired students through protracted local syllabus within a specific time period while observing all the students.

Use of embedded reading instructions and writing-to-learn activities could be asserted as another technique of teaching text based content [25]. The interactive-constructive model of science reading including prior domain and topic knowledge, metacognitive awareness and executive control, science reading strategies was highlighted under the study area. The research study specifies the need of keeping science content central in the writing process, helping students structure and synthesize the knowledge, providing real audience for student writers who values, keep questioning and provide supportive criticism, spending time for pre writing, collecting information from other sources such as concrete experiences, printed materials, experts and so on. Further it explains the need of providing ongoing teacher support, guidance, explicit instructions, encouraging revisions and redrafting supportive criticism in order to address conceptual questions and clarify understanding [25].

As a whole 98% of the research studies specify the teacher-student interaction and close observation could make a change of hearing impaired learning behavior. Further the research studies conducted on current methods and techniques used in teaching text based content to hearing impaired students give forth to the need of using useful algorithms to develop comprehensions of learning and doing in class experiments to improve the effectiveness of learning.

As an introduction to the RQ2, the difficulties faced by hearing impaired students in understanding text, researchers has found that hearing impaired children has performed far more level below than hearing children in understanding printed English words[22]. This gap between hearing and hearing impaired children can be caused by many reasons because hearing impaired children face many difficulties comparing to the hearing children. In understanding the text, making notes and understanding the text is very important. But, in order to understand the text,

learner needs to have built an adequate vocabulary, to have a good grasp of literature and oral literature aspects and a good knowledge of the grammar of English language. This is not relevant to only English language but for all other languages as well. The problem here is the hearing impaired children who use sign language as a main communication mode have got a very limited vocabulary in their day today life. So, learning the needed complex vocabulary in written language without the hearing ability will be a challenge for the hearing impaired children. As such, hearing impaired children face lots of difficulties in understanding the text based content compared with hearing children and in this review we discuss about the various findings of the previous studies regarding the difficulties that hearing impaired children face in understanding text. 5 papers answered the research question 2, what are the difficulties faced by the students in understanding text based content.

95% of the considered research papers have found the similar difficulties that are faced by hearing impaired students and regarding reading and metacognitive strategies, the main problem found was that the hearing impaired students face difficulties in understanding the meaning of texts since they don't use connections between elements through the text.

Another issue that was found by the previous researches was that hearing impaired people do not have a prior knowledge about the issues in the text. According to the found results from the above mentioned research, people did not have any idea about the irrelevant sentences that were included in the text and spelling mistakes and grammar mistakes.

Similar studies have found that students who use sign languages that are not very common may have difficulties with grammatical and syntactical structure of common languages. All most all the researches considered in this review discussed about the limited vocabulary of hearing impaired students that in turn may affect their reading ability.

Two studies have mentioned directly that, time has become a major factor that hinder the understandability of the text for hearing impaired students and as an example they have mentioned that students who need information transcribed from a tape must sometimes wait for a significant period of time to obtain the information while giving extra time and the chance to reread the sentences will be a good solution to avoid this difficulty with response to time. Emotional baggage that these students will carry as a result of past learning failures will decrease their confidence and motivation in understanding text and this will be a challenge for any student in achieving successful understandability regarding the given text. Poor memory skills, poor

comprehension skills, poor inference skills together with the so called limited vocabulary skills have been identified as the difficulties or challenges that hearing impaired students have to face when understanding text by William and Anne in their study that has been conducted to study challenges faced by hearing impaired learners in composition writing and in answering comprehension questions in English language lessons. Some other similar studies have been carried out and they have found that development of phonological skills, cognitive skills and strength of primary knowledge will reduce the difficulties that hearing impaired students in understanding text based context RQ3 refers to the solutions proposed for the conversion of text to sign language. All of the approaches which has been reported in the previous studies base on a machine translation of text to sign language. Sign language machine translation follow two approaches: Rule based and Data driven approach. The Data driven approach, also known as corpus-based approach, can be divided into Statistical Machine Translation (SMT) and Example–Based Machine Translation (EBMT) methodologies. The Data driven approach requires a prerequisite corpus to work on it and the accuracy and quality of the transition depend on the corpus size.

On the other hand, Rule-based approach, the second approach, is based on linguistic rules. It has two paths: direct path and indirect path. Direct path approach is used in bilingual dictionaries that require translating a word to corresponding word only without any detailed analysis of the syntactic structures of the inputted text or any relation to the meaning of the words or relationship between them. Indirect path approach is the most sophisticated and widely used approach in machine translation. This approach is used to analyse the syntactic structure of the inputted text and create an intermediate or abstract representation of it and then generate a target language text from it, this means that we need to specify the word structure, sentence structure and semantic structure in successive processes. As a means of collecting the knowledge of previous studies conducted with the idea of improving the text based understandability of students with hearing impairments, we conduct this literature survey to find answers to this review research question.

15 papers answered the research question 3 on the proposed solutions for the conversion of text into sign language. Out of the 15 papers, 86% of the studies' approach was based on the technique of parsing text using natural language processing and presenting them via 3D avatar based models. Other studies' approaches were robotics and web technologies. Summary of the findings is as shown in *Table 1* as follows.

Technique for Translation	Context
Text parsing using natural language processing and presenting via 3D avatar based models	American Sign Language, Sinhala Sign Language, Polish Sign Language, British Sign Language, Greek Sign Language, Web Content
Robotics	Polish Sign Language
Web Based Solutions	Web Content

Table 1 - Sign Language Machine Translation Techniques

A brief description of these types of technologies is stated as follows.

Text parsing using natural language processing and presenting via 3D avatar based models

A desktop application or any other user interface based application is developed which facilitates the user to enter sentences, phrases or words in the required language. Then the validation of this sentence is done by a language parser. For this step most of the applications have used a Natural Language Processing tool. After the validation, the entered sentence is tokenized into Sign Language translatable primitives. These primitives are matched with pre-stored signs from a database. Out of the 86% of the studies that used this method, all of the studies had not employed a database. Only some studies had used a database inbuilt to the application. Finally the matched signs will be presented using a 3D animation, which is called as a 3D Avatar (a 3D human model) through the application's user interface.

Robotics based models

Robotics has become a major area of interest in the era as it has provided solutions to most of the critical problems that were there in the society. When it comes to the projects applicable to sign language transliteration, robots play a major role. In one of the studies was a robotic hand which was capable of spelling words using the manual alphabet. It was able to direct deaf/blind individuals through duplicating the hand-on-hand interpretation of manual alphabet developed by human beings. Since the failures occurred in the original model of fingerspelling hand 'Dexter II' was invented in 1992. That was able to produce letters received from Text telephone (TTY) in fluid movements. As the major contribution from robotics to sign language translation, Ralph (Robotic ALPHabet) was invented which is a fourth generation

computer-controlled electromechanical fingerspelling hand with a menu- driven user interface. Ralph is capable of accepting inputs from various sources including modified caption system.

Web based Models

Two out of the O studies has employed a web based solution. This solution is named as SLIM which stands for Sign Language Interpreter Module which uses a multimodal approach for combining media elements such as video, audio, subtitles and media navigation controls into a new layer. Here these modalities manifest as transparent videos, which are exposed over the existing web pages instead of usual statically positioned videos. With this method, the structure of the website remains unaltered, and provides a simplified addition to deaf and hard of hearing end-users. From a developer's point of view, the integration process of one SLIM module consists of an icon button, video and video linkage. These three elements are handled with JavaScript or any similar code.

Out of the 15 studies, only a few studies address the grammatical structure of the sentences during conversion of text to sign language. One study has directly mentioned that employing a string matching technique is crucial the machine translation of text to sign language. It also states that its approach can be applied to the American context even without prelinguistic knowledge on American Sign Language.

Another study directly mentions that having an inbuilt database of sign words for the application improves the accuracy of the model and with the increase of the number of terms in the database, the accuracy level of the translation moves to high level.

We have conducted the literature review using 49 acceptable papers which belongs to different contexts. But it cannot be guaranteed that the whole global arena is covered by this study. The studies covered languages like English, Polish. Greek, Arabic and Sinhala. But there are other languages that employ sign language as well. We could have missed these studies in this review.

Since the deaf community is limited in a population, the researchers in these studies have undergone many biases in conducting this research. Furthermore, any of the studies has not employed an approach to evaluate the effect to all the categories of hearing impairments.
Therefore, this issue is not addressed in this review. Another limitation of this review is the

usage of the studies which are based on technology literacy of human beings. Therefore, there is a dependency on the skill level for the technology literacy.

Chapter 3 - Design and Methodology

The methodology of this study consists of the following components.

1. Setting up the environment to input Sinhala text and get the output.
2. Selecting the subjects for the study.
3. Selecting the words for the study.
4. Carrying out the test.
5. Analyzing the text based understandability differences.

3.1 Setting up the environment to input Sinhala text and get the output

The Sinhala text that is input is decided to be converted to an output presented in the avatar mode. So a framework for this requirement was used. The framework was introduced by a previous research carried out in University of Colombo School of Computing [12]. This application named as Sign Language Translator is a desktop application developed using Java which allows a user to enter any simple sentence as an input text that needs to be translated to Sign Language. The application processes it and presents the signs via a 3D animation which is developed using Java3D.

The 3D animation is a human model which can display basic signs using its hands and fingers. This output is shown in *Figure 5.*

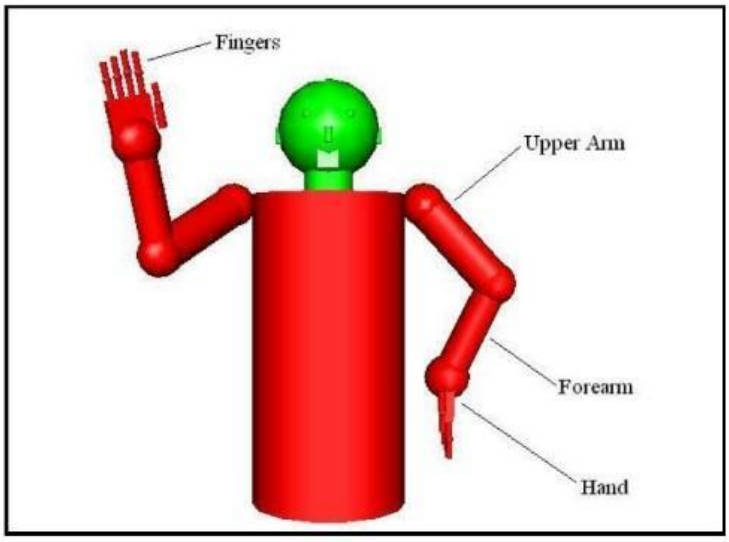


Figure 5 - 3D Avatar Output

The following *Figure 6* shows the user interface provided to the students for getting the interpretation of the questions. The buttons on the left side provides the instructions to the questions while the numbered buttons give the interpretation of the questions. Buttons 1 to 15 give the interpretation of the multiple choice questions.

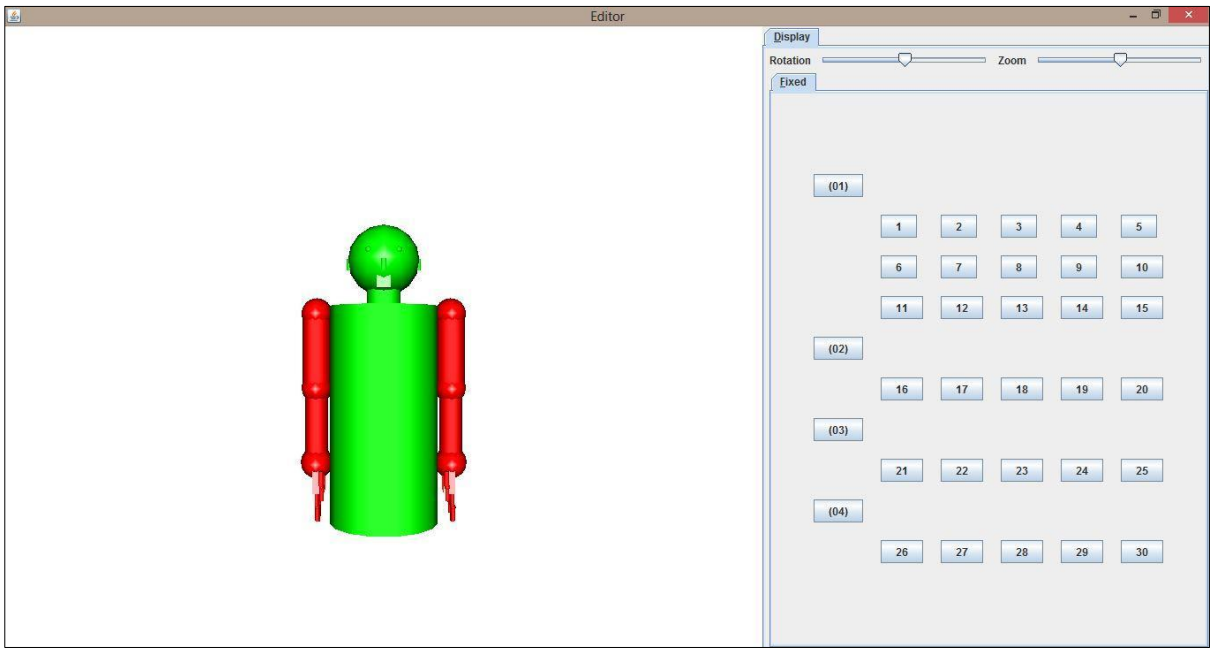


Figure 6 - User Interface for the question paper

The *Figure 7* shows the Editor interface of the Sign Language Translator. The menu buttons are named as 'Main' and the 'Setup'.

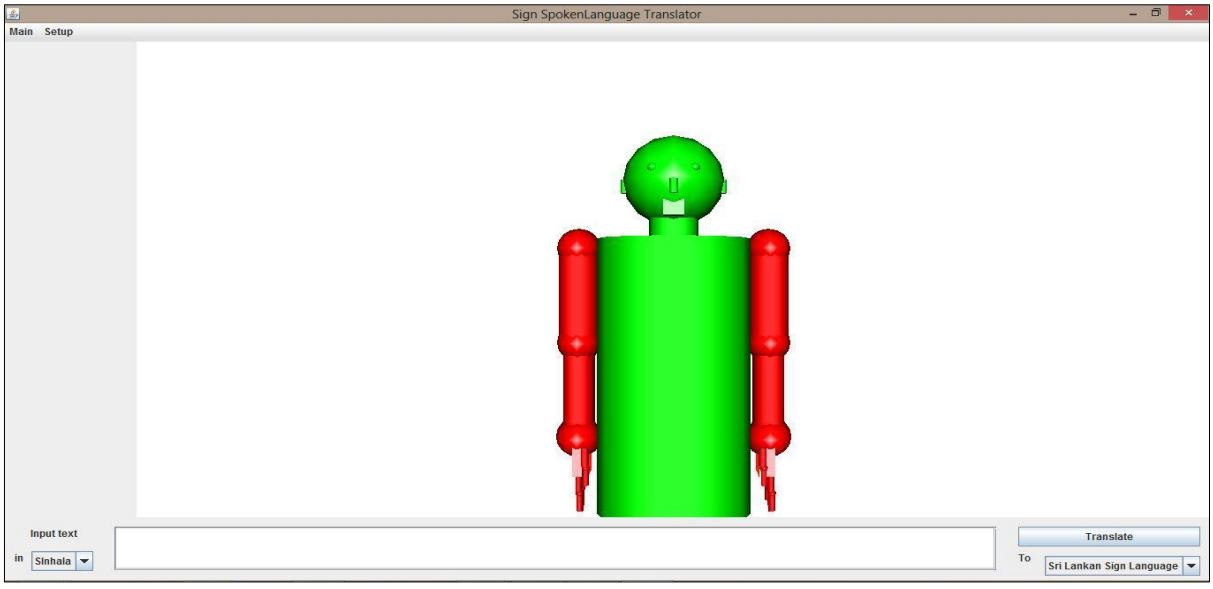


Figure 7 - Editor Interface

The *Figure 8* shows the window that pops when the first option of the ‘Setup’ is clicked. It allows to input the different countries using a country code. This option is used for the language independent feature of the tool.

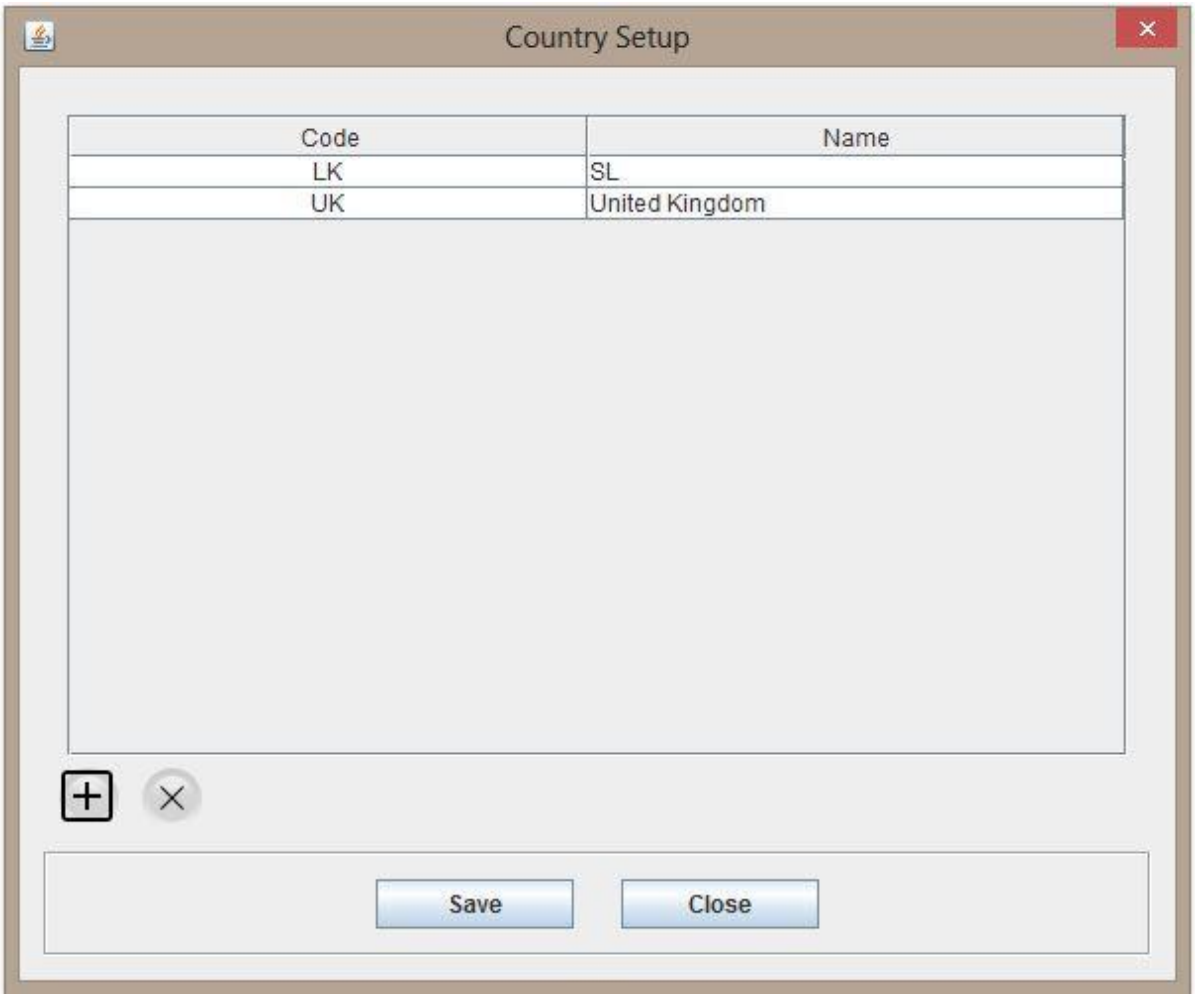


Figure 8 - Country Setup

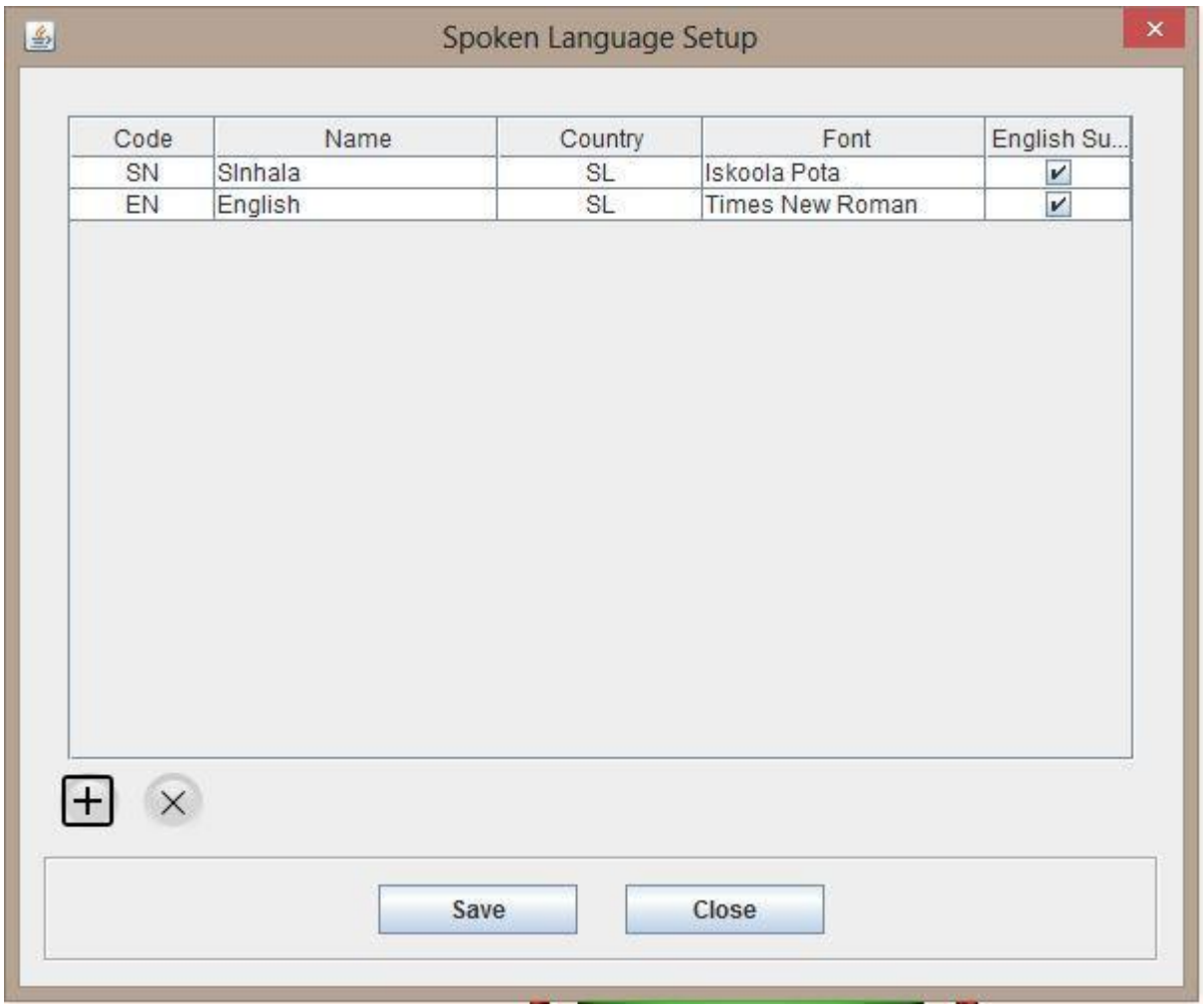


Figure 9 - Spoken Language Setup

Figure 9 shows the second option of the Setup Menu where the Spoken language can be introduced to the tool.

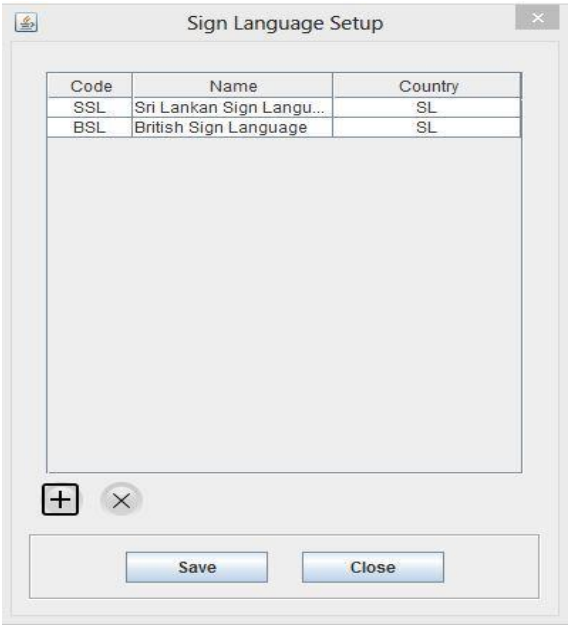


Figure 10 - Sign Language Setup

Figure 10 shows the third option of the Setup where Sign Language can be setup as the third menu option of the setup.

Figure 11 shows the process of inputting the Part of the Speech tag of the words. Since the tool was customized to suit the purpose of this study and due to the unavailability of a Sinhala language parser only the 'Noun' and 'Verb' tags were used here.

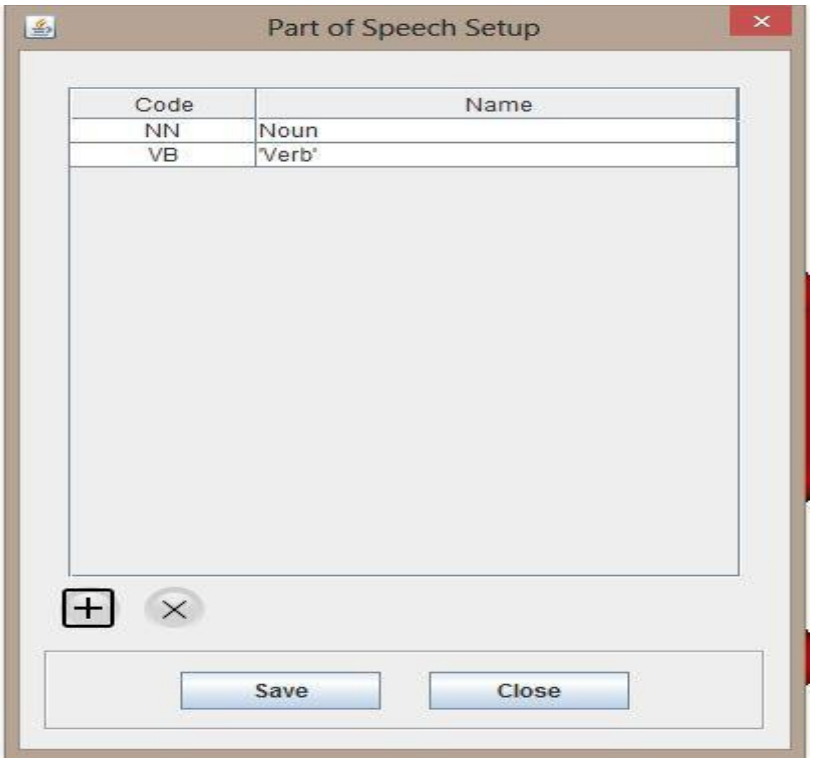


Figure 11 - Part of Speech Tagging

Figure 12 shows the interface provided upon creating signs. It has different components for two hands and two main components for rotation of arm angle and forearm angle.

Figure 13 shows the interface provided upon creating specific signs using finger movements. It has two components for rotation of fingers and palm angle.

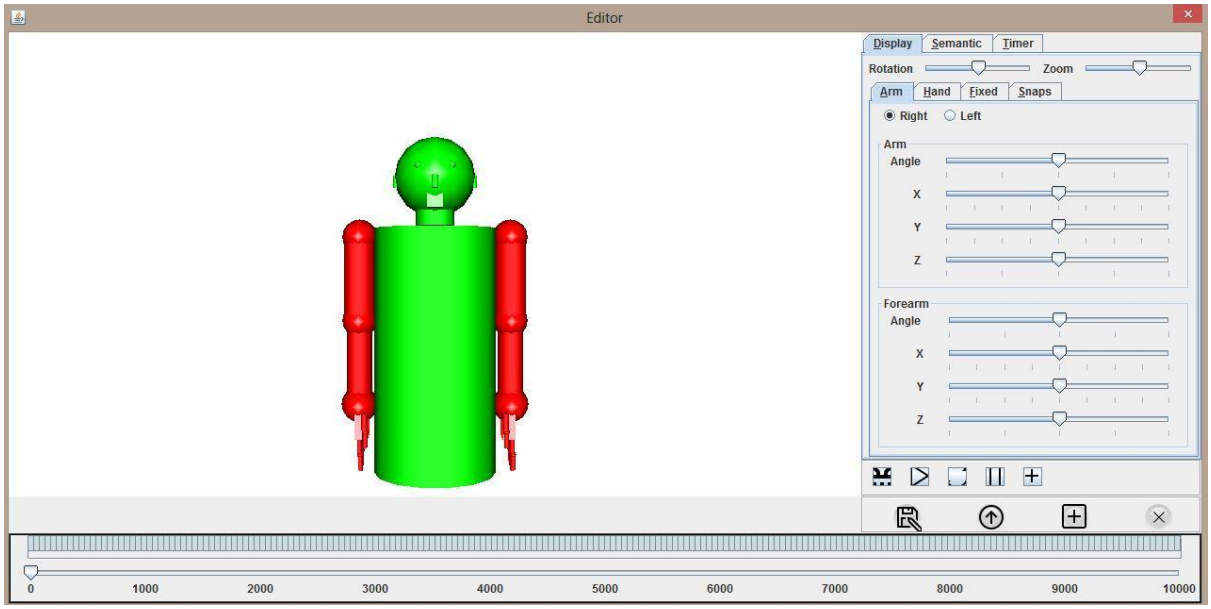


Figure 12 - Arm and forearm angle editing

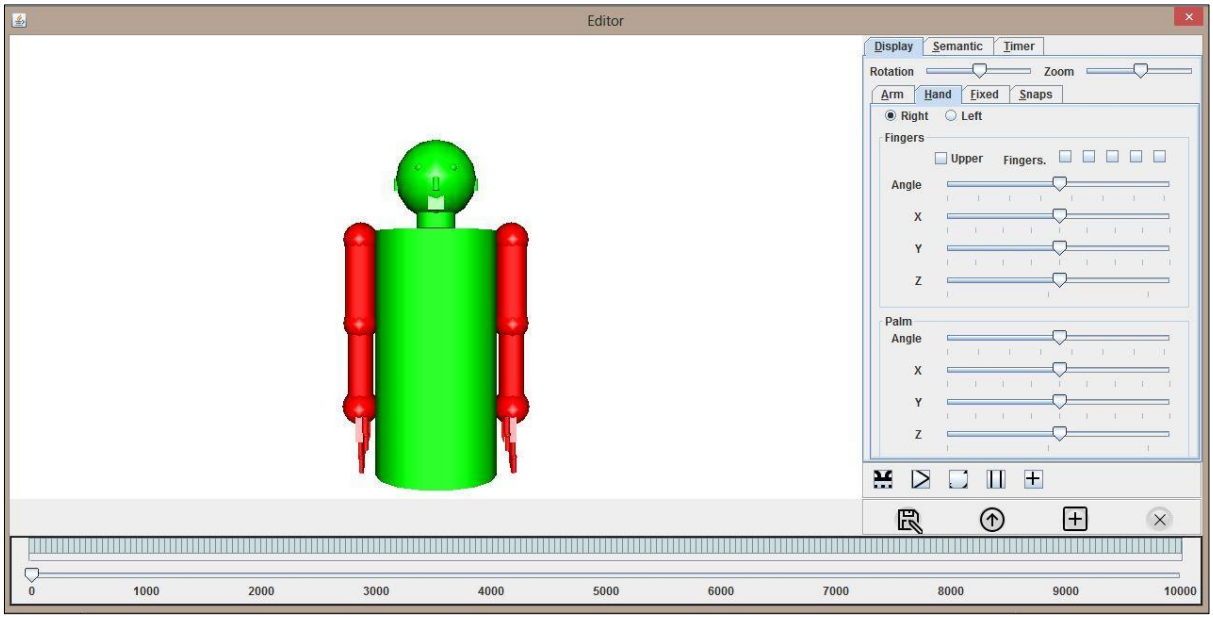


Figure 13 - Fingers and Palm angle editing

Figure 14 to *Figure 18* show the order of hand movements done to create the sign for the Number 01.

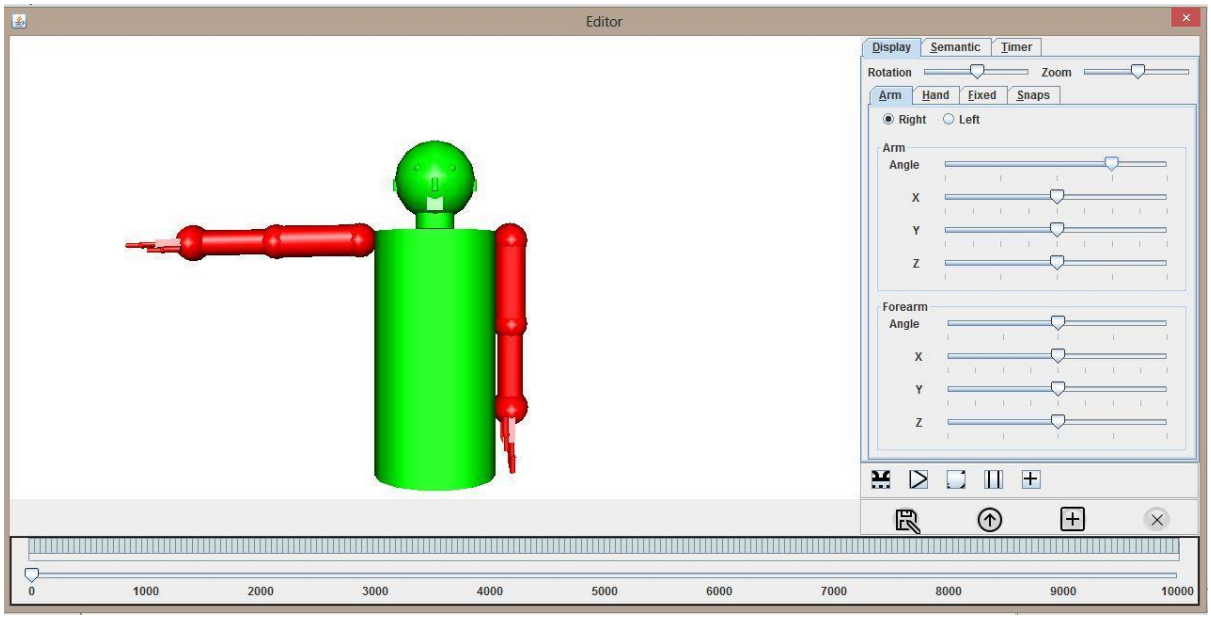


Figure 14 - Arm angle movement 1

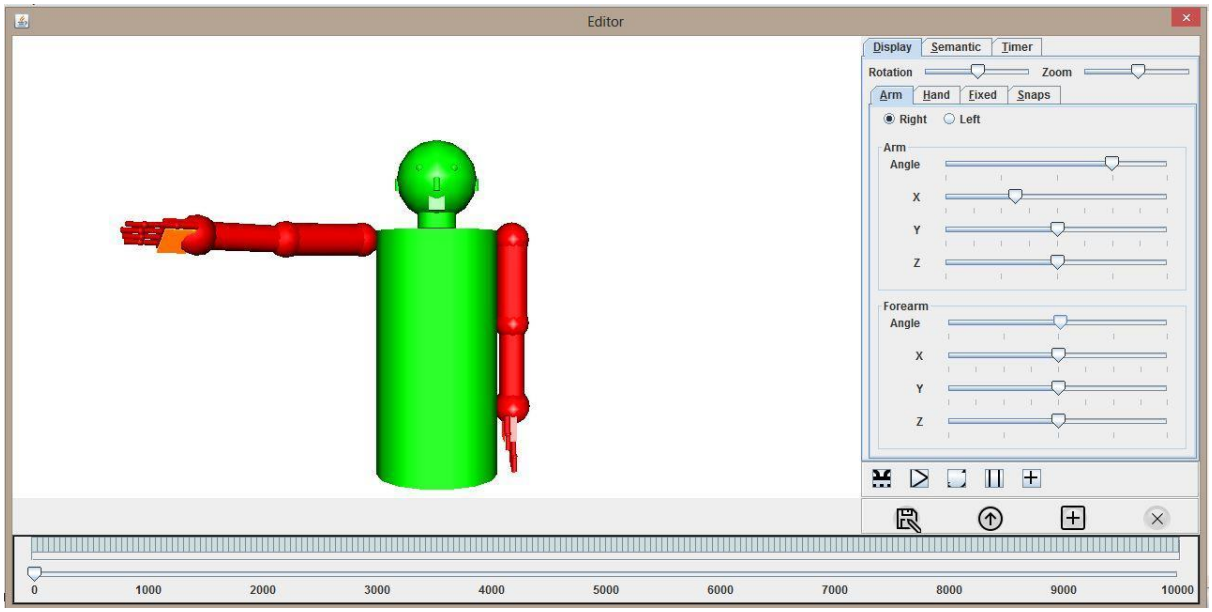


Figure 15 - Arm angle movement 2

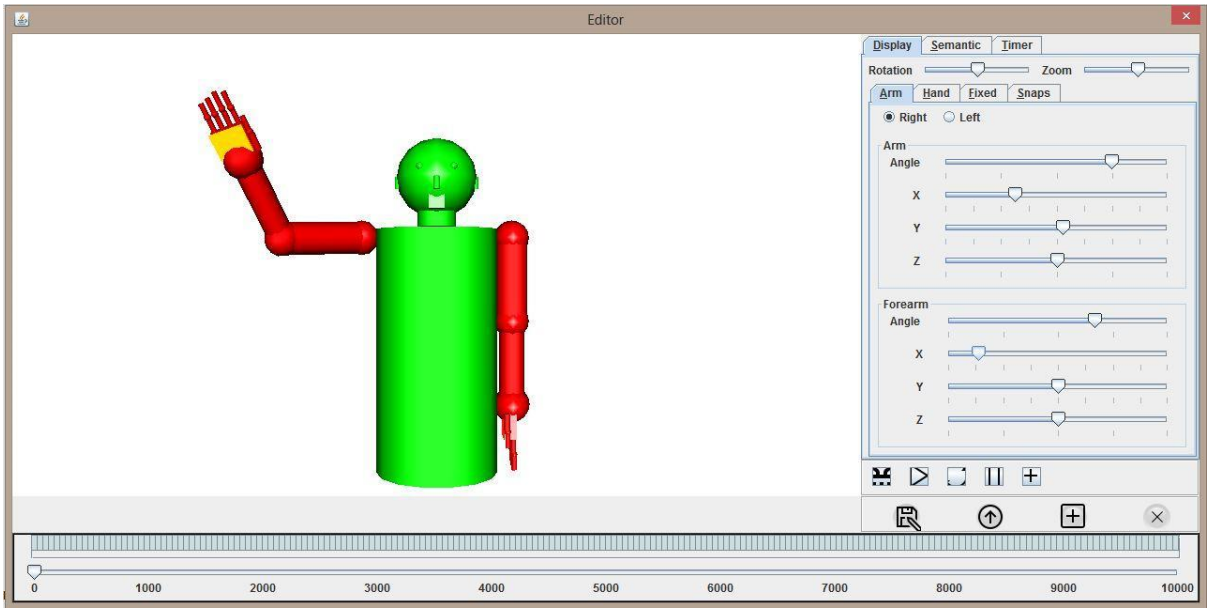


Figure 16 - Forearm angle movement

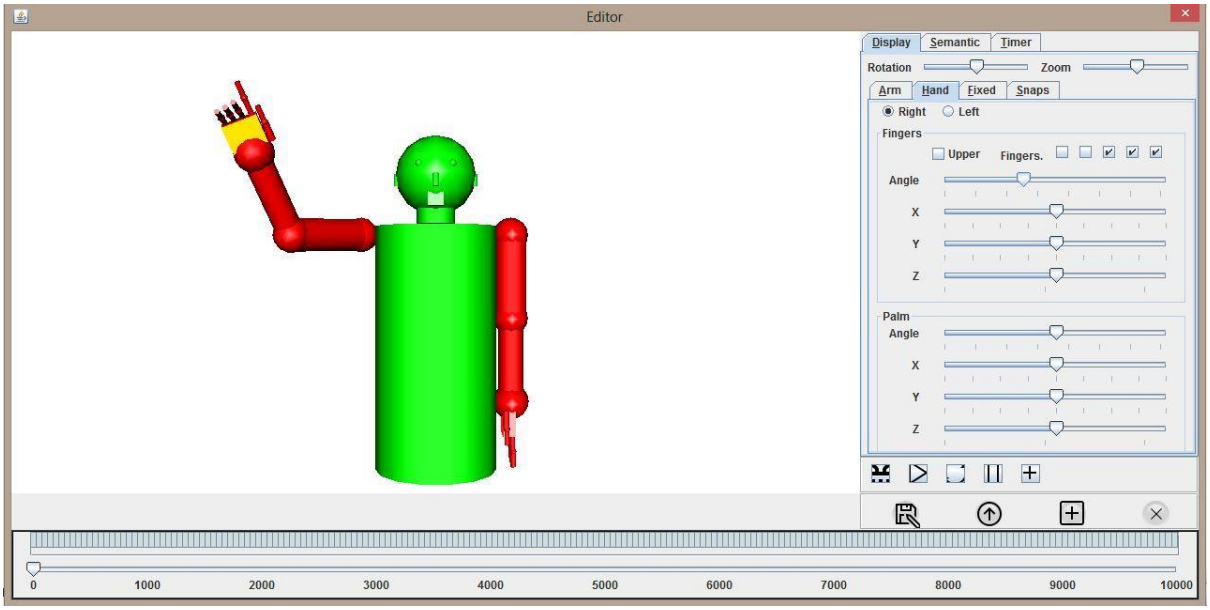


Figure 17 - Third joint movement of fingers

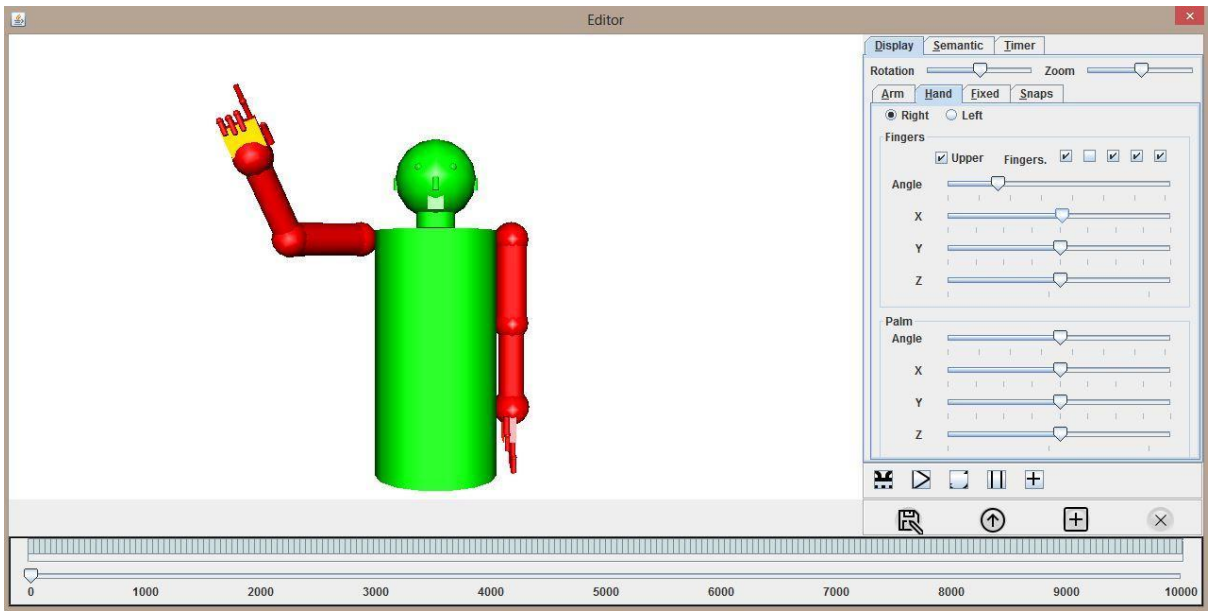


Figure 18 - Second joint movement of the fingers

After the creation of the sign a timestamp should be given for the created sign as in *Figure 19* at the bottom.

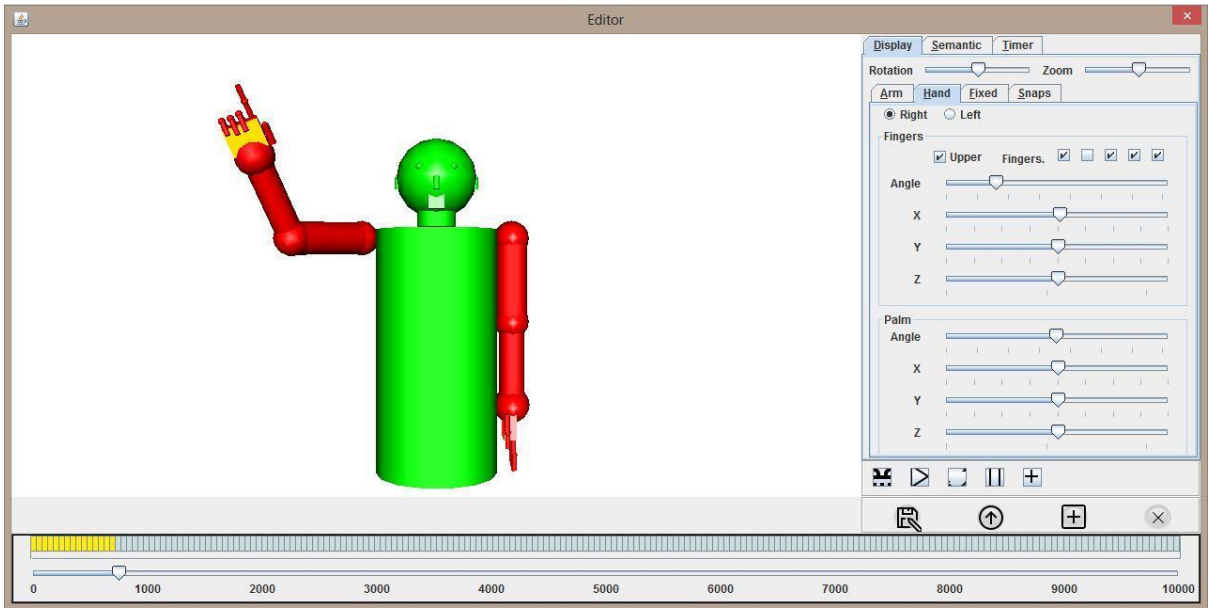


Figure 19 - Time stamping

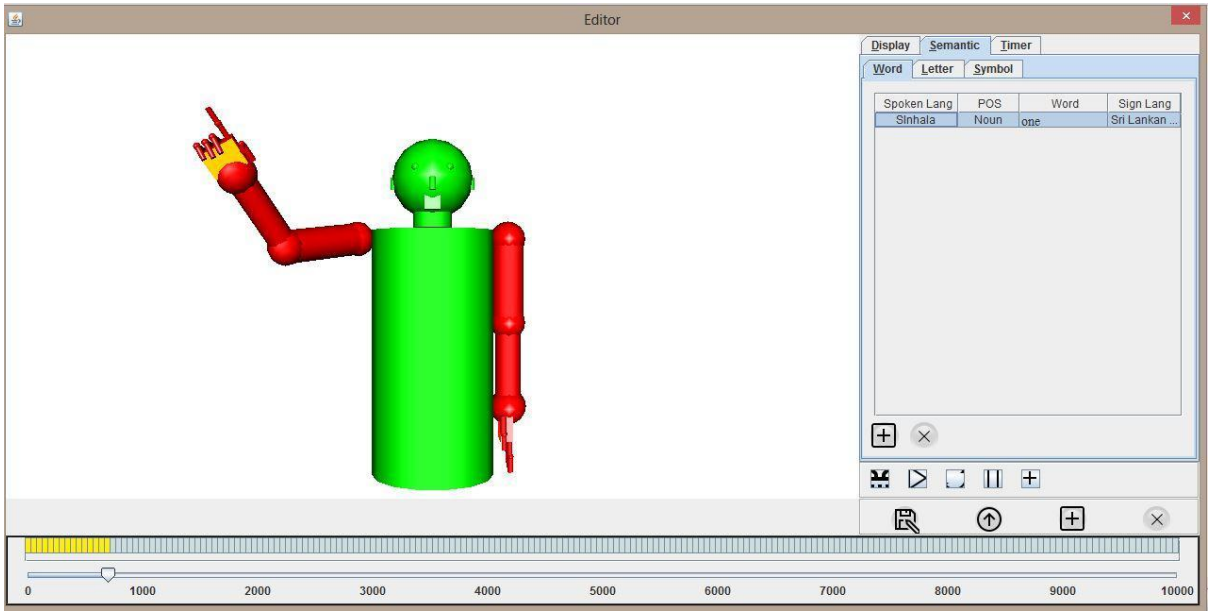


Figure 20 - Semantics Setup

After the timestamp is given the Semantics setup of the sign should be created as shown in *Figure 20* and finally the sign should be saved.

MySql is the database which is used to store data. The main advantage of it is that it grows with its usage, as the user can add animated signs with their corresponding words or phrases continuously. The inbuilt dictionary can be used as a global repository for Sign Languages. Prior to the translation process the system should have the necessary signs added to it. In other words the user should have entered the signs and their corresponding words to the system before the translation process begins. We have added signs to the system to represent the words. The encoding process used in the application's study was adopted to create the signs for the words.

3.2 Selecting of students

After a discussion with a Sinhala to Sign language interpreter, the positives and negatives of selecting the population and sample of the study were analyzed. Based on the goal to introduce the application to the hearing impaired school students of Sri Lanka, the subjects were selected from the Matara Rohana Special School. Based on the requirement to use a verifiable sample size and the student's ability to handle computers, the subjects were selected to be students of grade 7 of the school.

3.3 Selecting of words

After the subjects were selected, the study materials of them were thoroughly analyzed to identify the areas suitable for conducting the test. Eventually a standard examination paper was prepared for the subject Buddhism with the help of a teacher appointed for the subject. The prepared paper is annexed in the *Attachment 1*. The level of standard of the paper was verified by the relevant school and a list of words included in the paper was created. Finally the words were inserted to the Sign Language Translator by creating the signs for it. Here, the questions in the paper were inserted as words and the user interface contained buttons for each question in the paper where the question is interpreted by the avatar upon clicking the button. The signs were gathered from the Buddhism teacher of the school. Since the subject is Buddhism, there were no pre - built signs to represent some of the specific terms of the subject. Hence, the signs used in the school by the teacher were gathered and created.

3.4 Testing

A classroom of the school was selected with minimum external interference to conduct the test and the subjects were provided with the paper prepared. The sample contained 08 students and these 08 students were grouped into two groups of four students each. Out of them one group was allowed to use the inbuilt Signs input in Sign Language Translator to interpret the paper and the other group was allowed to answer the paper in the method that was previously used. One of the teachers of the school was selected as the interpreter of the paper for this group and the teacher explained the paper to the subjects in the currently used procedure for interpreting examination papers to the hearing impaired students in a one-time method. The student group who used the Sign Language Translator could repeatedly get the interpretation of the questions by clicking on the questions and the other group did not have such a method. The students were allowed to answer the examination paper on their own. The answers were evaluated after the test.

In the research approach, it was identified that a Pretest - Post test methodology is not suitable for carrying out this study as there is no method to cover up for the effect caused by the knowledge gap between the pretest and the post test. Therefore, it was decided to use this approach where a control group and experimental group is employed and the test for the both groups is conducted at the same time so that the external influences to the final result are minimal.

3.5 Analyzing

Since all the conditions of the two student groups were similar to each other except for the fact that the Sign Language Translator Application was used for one group instead of the current procedure of interpreting the paper to the students, the marks difference of the students was thoroughly analyzed. This analyzed results were considered as associative to the text based understandability of students with hearing impairments. Then the student marks of the two groups were compared with their previous term test marks to identify whether any improvement of the text based understandability of the students has been made by the use of the sign language interpretation tool.

Chapter 4 - Analysis and Results

The methodology of the study consisted of setting up the environment to input Sinhala text and get the output, selecting the subjects for the study, selecting the words for the study, carrying out the test and analyzing the text based understandability differences. The Sign Language Translator application was modified by inputting Sinhala words and creating their relevant signs using animations. A sample of 08 students from the Grade 07 class of Matara Rohana Special School was selected for the study and a test paper was given to these students. The test paper was created to match the standard of the Grade 07 curriculum of Buddhism subject. Individual words relevant to the Sinhala sign language context and Buddhism subject included in the paper were input to the tool and their relevant signs were created. Finally the test was conducted by dividing the students into two groups as experimental group and control group. The students of the control group were assigned to answer the test paper using their normal method of answering where an interpreter interpreted the whole paper at the start of the paper and the experimental group was asked to answer the paper using the Sign Language Translator where the words in the paper were fed. They could get an interpretation to any question which they could not read and understand during the whole duration of the paper at any time. Finally the marks of the two student groups were compared with each other. Furthermore the marks of the test were also compared with the marks of the previous term test.

The marks of the students obtained from the test are shown in *Table 2* as follows. These marks were arranged in descending order of each group and the marks of each student from the control group was considered with the marks of each student in the experimental group with accordance to their matching positional value when arranged in descending order.

Students who used Sign Language Translator (%)	Students who used normal method of answering (%)
60	61
29	32
24	30
22	28
Average Marks = 33.75	Average Marks = 37.75

Table 2 - Marks of Students

In the case of students who used normal method of answering, there was an outlier who obtained 61% marks while the other students' marks ranged from 20% to 32%. At the same time, there was an outlier who obtained 60% marks where they used the Sign Language Translator application for answering and the others marks were in the range of 20% and 30%.

The marks of the students for the previous term test conducted by the school were obtained. They are depicted in the *Table 3*. The highest marks were obtained by two outliers as 76% and 83%. Other students' marks were ranging from 30% to 40%. The students' marks were compared with the previous term test marks and the relevant graphs were drawn as in *Figure 21 and Figure 22*.

Student	Test Marks (%)	Previous Test Marks (%)	Change in marks	Percentage Change
Student 1	61	83	22	26.51%
Student 2	32	43	11	25.58%%
Student 3	30	41	11	26.83%
Student 4	28	48	20	41.67%

Student 5	60	76	16	21.05%
Student 6	29	33	04	12.12%
Student 7	24	31	07	22.58%
Student 8	22	28	06	21.43%

Table 3 - Previous Term Test Marks

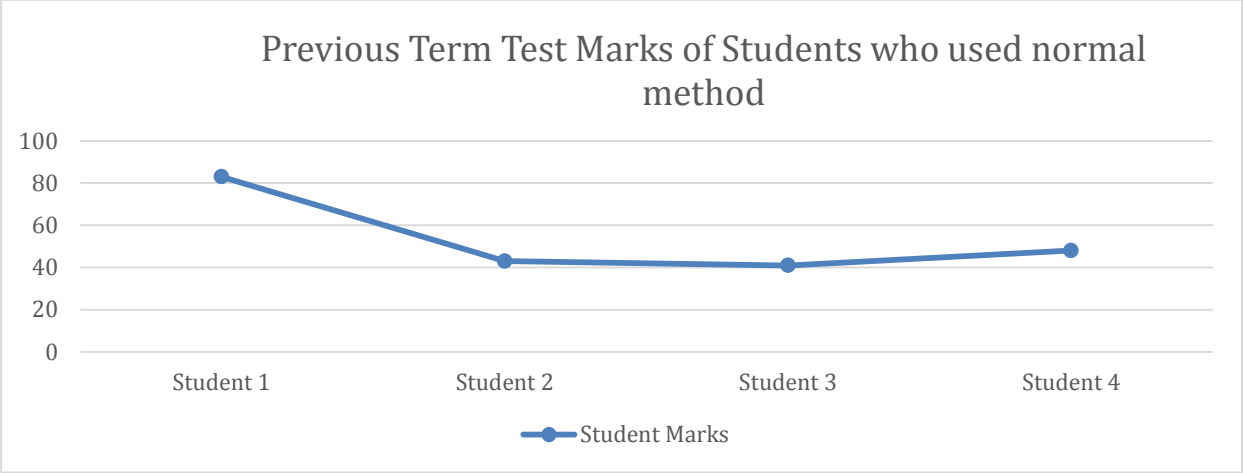


Figure 21- Previous test marks of students who used normal method

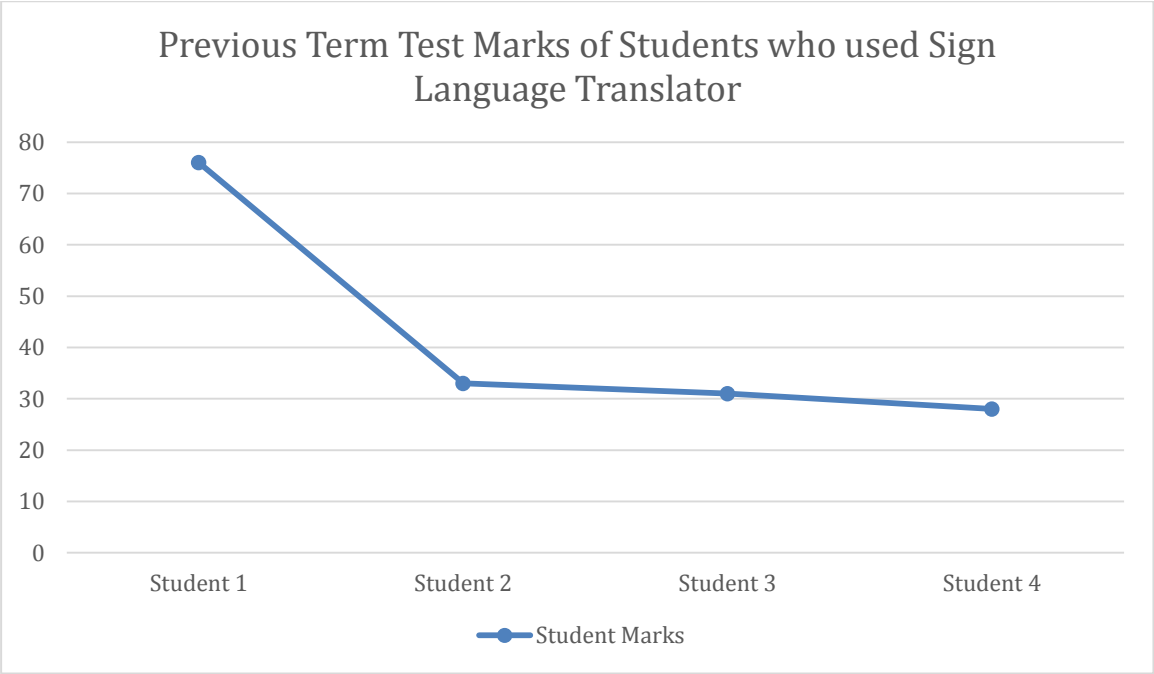


Figure 22 - Previous Term Test Marks of Students who used Sign Language Translator

As shown in the table itself, all the students' marks has decreased when coming from previous term test which is a mid-term test in the school to this particular test conducted in the final term of the school. The marks of the students who have used the Sign Language Translator for answering the questions is shown as highlighted in dark color. The average decrease of marks of the student group who used the normal method for answering is 16 while the average decrease of the marks of the group that used the Sign Language Translator is 8.25 showing that the decrease has reduced by around half in the experimental group. The following graph at *Figure 23* represents the percentage change in the marks of the two student groups in comparison with the previous term test.

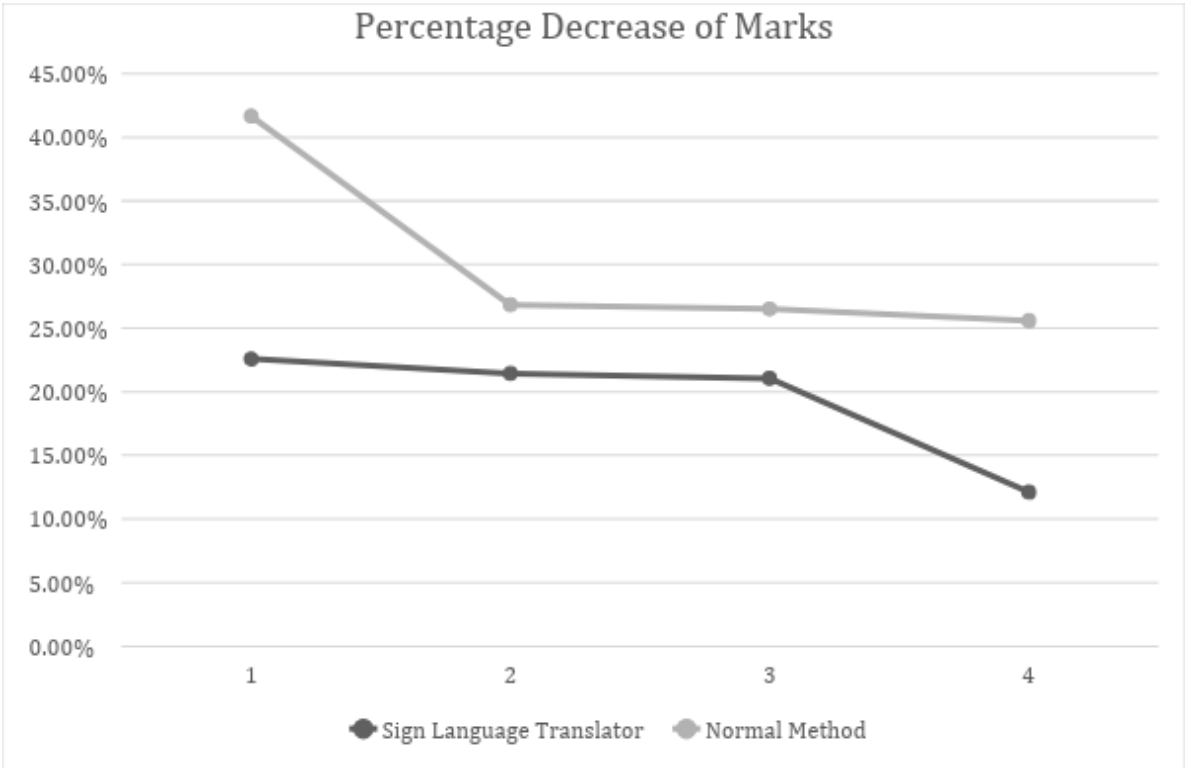


Figure 23 - Percentage decrease in marks

To get a further analysis of the results the statistical significance of the results were calculated as follows using the Mann - Whitney test.

Let,

M_W = Median difference in marks of the students who faced the test using the normal method.

M_T = Median difference in marks of the students who faced the test using the Sign Language Translator

Hypothesis:

H_0 : MW = MT

H_1 : MW > MT

n_W (n1) = 4

n_T (n2) = 4

Here the marks of both samples of normal method of answering and Sign Language Translator used answering method get a sample size of 4 which is very low the critical values of the Mann - Whitney test gives the value of 1 for one tailed testing saying that these two groups of results are not statistically significant.

The feedback of the teacher and the students about the usage of a computational tool were obtained. The feedback included,

- The method is a good tool to improve the teaching – learning process of the teachers and students.
- The tool was successful to a certain extent.
- The tool should be developed further.
- The tool should represent the facial expressions for a better understanding.
- The avatar should be more active when it comes to the upper body movements

Chapter 5 - Discussion

The subject selection step was a crucial step in the research since this tool was used as a proof of concept it should be easier to be used by the students as well as the research team. First the grade to which the test should be carried out was decided considering the number of students. According to the student populations of MR/Rohana Special School, grade 11 had only 2 students, grade 10 had only 1 student while grade 8 and grade 9 had 5 students each. Since the accuracy of the research can be improved by using a better sample size, grade 7 was selected as the most suitable grade for the research which consisted of 8 students.

Selection of the subject was done based on many criteria such as the marks of the students for each subject, the extent to which the usage of sign language is involved in each subject, capability of the students in memorizing the subject matters etc. When considering Sinhala, students were not very much familiar with the words and the signs related to Sinhala literature and the words were difficult to memorize because of the difficult pronunciations. If these problems were not there, Sinhala would have been the best subject to evaluate these students since it is their mother tongue and this tool is mainly introduced for Sinhala to sign language translation. English is one of the other main subjects but, it is not useful for this research since this is mainly focused on Sinhala to sign language translations. Considering Mathematics, where many people argue it is easy to carry on, students have scored well in mathematics in their past examinations since there are very less amount of text included in mathematics subject. For this research, where the text based understandability is to be tested, a subject with less text materials would not work. Also, since this research is aiming at the difference of scores students achieve with the usage of the tool, a subject which already has considerable marks will do nothing different. History was not chosen for this research because of the number of terminologies that are used throughout the subject and giving consideration to the convenience of students as well as the research team. Buddhism was ideal because students learn this subject with much enthusiasm and they have got moderate marks for their examinations for this subject.

Examination paper that was used for conducting the evaluation test was an approved test paper by the Buddhism teacher of the school and made by the research team. The paper was tougher than the previous term test paper since this test was conducted at the end of the third term and the content was from all the lessons covered until the third term. With comparison to the results of the students it was clear that the paper was tough and was up to the related standard

due to the decrement of results of all the students of the class including both the students who used the tool for completing the paper and the control group students who followed the normal method of examinations. It is predictable that the results of the students may be increased if the evaluation paper was much easier than the previous term test paper and also if it was not made under the given standards. Since that will reduce the accuracy of the study we believe that method is not suitable and that will be a good method just to obtain a satisfactory and a successful output. Also, the paper used for this study was a similar paper that is given for the term tests of MR / Rohana Special School. However, the results can vary for the study if a government papers that are tougher than these papers was used.

When the marks of the study test are considered, it is depicted that the student group who used the Sign Language Translator has scored relatively low when compared with the student group who used the normal method. But, the two students who have scored the highest marks of each group has been identified to be students who are capable of understanding using lip reading or speech reading. Hence, it clearly shows that students who possess this ability are more capable of understanding text with relation to other students who do not possess this ability. At the same time these two students of each group are identified to be outliers deviating from other students' marks. Although the marks obtained by the student group who used the normal method of answering is relatively high, this increase cannot be specified as causing any effect to the research conclusion since the marks difference is very low when the two groups are considered.

When the previous term test marks are considered, the same two students who scored outlying deviating marks for study test have scored in the same way for the previous term test. This concludes the fact that lip reading is an enabling capability for understanding text based content for hearing impaired students in examinations. At the same time, the same 06 students who have scored less in the study test have scored the lesser in the previous term test. This depicts that these 06 students' knowledge is at a low level when they are considered. Somehow all the 08 students have scored lower than the previous term test, in the study test. The reason for this might be the paper prepared for the study test being relatively difficult to answer or the number of lessons included in the study test being higher.

When the percentage decrease of marks of the two student groups in comparison to the previous term test is considered, the percentage decrease is higher in the student group who used the normal method for answering the paper. At the same time the percentage decrease is lower in the student group who has used the Sign Language Translator for answering. This clearly shows

that the text based understandability of the student group who has used the Sign Language Translator for answering has increased. It suggests that a computational tool that translates text into Sign Language might be a good and helpful tool to increase the text based understandability of students with hearing impairments.

When the feedback of the teacher and the students about using such a computational tool to translate text into sign language for improving the text based understandability of hearing impaired students is considered, it says that the tool is successful only to a certain extent due to its inability to show facial expressions. This gives away a very important consideration for building a tool for text to sign language conversion since facial expressions play a vital role in the understandability of hearing impaired students since it is the only way they grab information for communication out of all the five sensory organs. Hence, future researchers should focus on building tools that include facial expressions as well in the conversion of text to sign language. The feedback also suggests that this type of method is really helpful in the teaching and learning process of hearing impaired students when it comes to conversion of text into sign language. This is also proved by the percentage decrease of marks difference in the two groups of students used for the study.

The results of the study is derived considering the limitations discussed below. The study does not focus on facial expressions or lip reading and hence certain signs using these features of the face will not be concerned in this study. The study will not focus on the fact whether the student is prelingually deaf or has been deaf after the birth. All these two types will be treated equally in this study. Hence the effect of this hearing impairment variation will not be considered in this study. The study focus only on written examination answers accuracy differences during the test. In the study, the level of subject knowledge of the student will be ignored. Hence the study's results may vary on the fact that a certain student has more knowledge on the subject and another student may have less knowledge on it. Furthermore, since the study is carried out only for one subject, the results of the study may vary if the same study was repeated for another subject with the presence of more subject dependent signs. The Sinhala Sign language is identified as having a less vocabulary. As well, the number of signs and the number of methods to communicate a certain sentence using signs increase with the scope of the subject being localized. Hence the study depends on the knowledge of the students on Sign language. Furthermore, since all the signs for the subject are not prevalent and the teachers have created signs to convey the meaning, if this same test is conducted to another school, there is a possibility for the results to be varying.

Finally when considering the reuse of this tool, this can be considered in different possible ways of usage. Some of these ways are, we can use this tool for the same subject Buddhism and also for various grades such as 8,9,10 and 11 grades for this subject. If grade 7 Buddhism is considered, we have already used about 300 words in the dictionary of this tool and if we look at 4 or 5 other papers of the same grade and subject we will be able to input most of the signs that are used throughout this subject and that will make the use of the tool easier for new users because, most of the words are available and they only have to input a very less number of words to the tool to use it again for the same subject. But if we look at the Buddhism subject for other grades, the wordings that they use in these grades will be much more advanced and high in number due to the expansion of the subject area and the number of words that new users should input to the system or tool will increase. Similarly we can predict that the number of words and the effort that a new user have to input to the tool will get much higher if we are using this tool for a completely different subject. Among that also subjects like Sinhala and history will require relatively less number of word additions because these subjects use more likely words as in Buddhism rather than the wordings in distractive subjects like mathematics, dancing and home science. This can be considered as a recommendation for the future students to study about and that will be very useful to carry out a study to identify the effort that new users have to put on in using this tool and improving this furthermore.

When the Mann - Whitney test for identifying the statistical significance was conducted, it showed that the two groups had no statistical significance. The reason for this is that the sample contained only 04 students and the difference in marks in the two groups was very low. But the percentage decrease of marks of the two groups show that the students who used the Sign Language Translator has got a better understanding of the text based content which is why their percentage decrease of marks in comparison with the previous term test is relatively low.

Chapter 6 - Conclusion

Given the area of concern at hand, it is important to identify a solution to this problem, considering the importance of communication to each and every one. A framework to convert Sinhala text to Sinhala Sign language is of immense importance when this problem is considered. But, still there are no studies carried out to identify the change of text based understandability of the students with hearing impairments, when such a computational framework is used. Therefore, this study will be able to verify the usability of such a computational framework depending on its limitations. Facial expressions play a vital role in the text based understandability of students with hearing impairments.

Chapter 7 - Future Works

Further studies may include studying whether the type of the subject affects the change of text based understandability when a computational framework for text to sign language conversion is used. At the same time, effect of text based understandability when facial expressions are introduced should also be researched further.

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Appendix 1 – Buddhism Paper for the School

7 ශ්‍රේණිය - බුද්ධ ධර්මය

01)නිවැරදි පිළිතුර යටින් ඉරක් අඳින්න.

1. සම්මා සම්බුද්ධත්වයට පත්වීමෙන් පසු බුදුරජාණන් වහන්සේ ජය ශ්‍රී මහා බෝධීන් වහන්සේ ඇසුරු කරමින් ගත කළ දින ගණන වනුයේ,

   1. දින 3 කි
   2. දින 5 කි
   3. දින 7 කි
   4. දින 9 කි

2. බුදුන් සරණ ගිය පළමු උපාසකවරුන් ලෙස හැඳින්වෙන්නේ,

   1. ආලාරකාලාම සහ උද්දකරාමපුත්ත
   2. තපස්සු හල්ලුක
   3. උරුවේල කාශ්‍යප සහ නදී කාශ්‍යප
   4. කෝලිත සහ උපතිස්ස

3. සෝවාන් වූ පළමු රජතුමා ලෙස හැඳින්විය හැක්කේ,

   1. ධාතුසේන රජතුමා
   2. ධර්මාශෝක රජතුමා
   3. බිම්බිසාර රජතුමා
   4. දේවානම්පියතිස්ස රජතුමා

4. බුදුරජාණන් වහන්සේ ගිලානෝපස්ථානයේ වටිනාකම පෙන්නුම් කළ අවස්ථාවක් වනුයේ,

   1. සෝපාකට පිහිට වීම
   2. පූතිගත්ත තිස්ස ස්වාමීන්වහන්සේට පිහිට වීම
   3. සුනීතට පිහිට වීම
   4. පටාචාරාවට පිහිට වීම

5. උපස්ථායකයකු සතුව තිබිය යුතු ගුණාංගයක් නොවන්නේ,

   1. රෝගියාට අවශ්‍ය බෙහෙත් පිළියෙල කර දීම
   2. රෝගියාගේ සිත සැනසෙන කථා පැවසීම
   3. මල මුත්‍ර ආදිය කෙරෙහි පිළිකුල් උපදවා ගැනීම
   4. රෝගියාට හිතකර හා අහිතකර ආහාර පාන දැන ඒ අනුව කටයුතු කිරීම

6. නිවසේදී අනුගමනය කළ යුතු සිරිත් විරිත් වලින් එකක් නොවන්නේ,

1. පිරිසිදු නිල ඇඳුමෙන් සැරසී සිටීම
2. වාතාශ්‍රය එන පරිදි ජනෙල් පියන්පත් ඇර තැබීම
3. දිනකට දෙවරක්වත් ගෙදර හා ගෙදර අවට අතුපතු ගෑම
4. කැලි කසල ආදී අපද්‍රව්‍ය නිසි පරිදි බැහැර කිරීම

7. බුදු සසුනේ අග්‍ර දායකයා වනුයේ,

1. අනේපිඬු සිටුතුමා
2. අසිත තාපසතුමා
3. මෙණ්ඩක සිටුතුමා
4. මිගාර සිටුතුමා

8. පංචශීලයට අයත් නොවන ආජීව අෂ්ටමක ශීලයට අයත් වන සිල් පදයක් වනුයේ,

1. මුසාවාදා වේරමණී සික්ඛාපදං සමාදියාමි
2. පිසුණාවාචා වේරමණී සික්ඛාපදං සමාදියාමි
3. අදින්නාදානා වේරමණී සික්ඛාපදං සමාදියාමි
4. පාණාතිපාතා වේරමණී සික්ඛාපදං සමාදියාමි

9. සිඟාලෝවාද සූත්‍රයට අනුව ගුරුවරුන් උපමා කර ඇත්තේ කුමන දිශාවටද?

1. දකුණු දිශාවෙනි
2. උතුරු දිශාවෙනි
3. බටහිර දිශාවෙනි
4. නැගෙනහිර දිශාවෙනි

10. පන්සිය පනස් ජාතකයෙහි දැක්වෙන අපණ්ණක ජාතකයෙන් අපට ලබාගත හැකි වැදගත් ආදර්ශයක් වනුයේ

1. හදිසි තීරණ ගැනීම
2. ඉවසිලිමත් බව
3. වගකීම් දැරීමට අකමැති වීම
4. ගැටළුවක් හමුවේ තම ආරක්ෂාව පමණක් සැළකීම

11. ඉවසීමේ ගුණය මැනවින් පෙන්නුම් කරන ස්වාමීන් වහන්සේ නමකට උදාහරණයක් වනුයේ

1. සුදත්ත ස්වාමීන් වහන්සේ
2. අසිත ස්වාමීන් වහන්සේ
3. පුණ්ණ ස්වාමීන් වහන්සේ
4. කාලදේවල ස්වාමීන් වහන්සේ

12. දස පාරමිතා අතරින් ඉවසීමේ ගුණයට අදාළ පාරමිතාව වනුයේ

1. ඛන්තී පාරමිතාව
2. දාන පාරමිතාව
3. සීල පාරමිතාව
4. භාවනා පාරමිතාව

13. හෙළ බොදු ජනතාවගේ හොඳ සිරිත් අතරට අයත් නොවනුයේ

1. මත්පැන් පානය කිරීම
2. වැඩිහිටියන්ට සැලකීම
3. ආගන්තුක සත්කාරය
4. කළගුණ සැලකීම

14. බුදුරජාණන් වහන්සේ සතු කළගුණ සැලකීමේ ගුණාංගය පෙන්නුම් කරන අවස්ථාවක් නොවනුයේ

1. අනිමිස ලෝචන පූජාව
2. දරුවන් දන් දීම
3. තමා මෙලොවට ජනිත කළ මවට උපකාර කිරීමට තව්තිසා දෙව්ලොවට වැඩම කිරීම
4. ප්රජාපතී ගෝතමී මෑණියන්ට ආචාර දැක්වීම

15. සම්මා දිට්ඨි යනු

1.නිවැරදි සිහිය
2. නිවැරදි ක්රියාව
3. නිවැරදි දැකීම
4. නිවැරදි දිවිපැවැත්ම

02) පහත දී ඇති ප්රකාශ නිවැරදි නම් හරි ලකුණද, වැරදි නම් x ලකුණද වරහන තුළ යොදන්න.

16. ‘පිටත ගිනි ඇතුළට නොගත යුතුය‘ යන උපදේශය ධනංජය සිටුතුමා විසින් විශාඛා මහා උපාසිකාවට දෙන ලද්දකි. ( )
17. පස්වග මහණුන් රහත්භාවයට පත්වූයේ දම්සක් පැවතුම් සූත්ර දේශනාව ඇසීමෙනි. ( )

18. ඉවසීමේ ගුණය දැක්වෙන පාරමිතාව දාන පාරමිතාව වේ. ( )
19. අලුත් සහල් දන් දීම හොඳ සිංහල බොදු සිරිතක් වේ. ( )
20. දුක්ඛ සමුදය ආර්ය සත්යය යනු දුකට හේතුව පොයන සත්යය වේ. ( )

03) වරහන් තුලින් නිවැරදි පිළිතුර තෝරා යටින් ඉරක් අඳින්න

21) උරුවේල් දනව්වේදී පැවිදි වී, තම ජටා ආදිය ගලවා ගඟට දැමූයේ _ _ _ _ _ _ _ _ _ _(උරුවේල් කාශ්යප/ රතී කාශ්යප) විසිනි.
22) ජේතවනාරාමය _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ (අනේපිඬු සිටුතුමා/ ජේත කුමාරයා) විසින් කරවා බුදුරජාණන් වහන්සේට පූජා කරවන ලදි.
23) පංච ඉන්ද්රිය පිනවීමට ඇති ආසාව _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ (විභව තණ්හා / කාම තණ්හා) වේ.
24) ආර්ය අෂ්ටාංගික මාර්ගයේ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ (සම්මා වාචා / සම්මා කම්මන්ත) යනු යහපත් ක්රියාවල නිරත වීම වේ.
25) දම්සක් පැවතුම් සූත්ර දේශනාව බුදුරජාණන් වහන්සේගේ _ _ _ _ _ _ _ _ _ _ _ _ (පළමු / පස්වන) ධර්ම දේශනාව වේ.

04)පිළිතුරු සපයන්න

26. පාසලේදී අනුගමනය කල යුතු සිරිත් විරිත් 03 ක් නම් කරන්න.
27. නව අරහාදී බුදුගුණ නම් කරන්න.
28. ආර්ය අෂ්ටාංගික මාර්ගයේ අඩංගු සත්ය 04 නම් කරන්න.
29. සිඟාලෝවාද සූත්රයේ දැක්වෙන පරිදි සිසුන්ගෙන් ගුරුවරුන්ට ඉටුවිය යුතු යුතුකම් නම් කරන්න.
30. ඉවසීමේ ගුණය නිසා ලැබෙන ආනිශංස නම් කරන්න.