

Educational Assistive Technology for Students with Communication Disorders

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Received date: March 27, 2017; Accepted date: April 5, 2017; Published date: April 12, 2017

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Abstract

Assistive technology has a significant impact on helping students with communication disorders achieve their academic goals. Selecting an appropriate assistive technology for a student requires parents, educators, and other professionals take a comprehensive view, carefully analyzing the interaction between the student, the technology, the tasks to be performed, and the settings where it will be used. It is important for the researchers to have better understanding of this disability issues and develop their own tool. Foreign assistive technologies are expensive and not readily available for the student with communication disorders in Thailand. It is therefore desirable to design and develop such tools for the student in Thailand and determine its effectiveness on performance of the student. Consequently, this paper obviously is considered on a study to integrate usability testing into the design and development of two assistive technology tools called Thai Word Search program and Thai word prediction program. Thai Word Search program assists student with communication disorders to write any vocabulary that he/she cannot spell it correctly. However, Thai word prediction has its advantages for students with communication disorders as the function of word completion and word prediction. Finally, the study indicated that student with communication disorders in this study increase his ability in writing when using assistive technology more than without using assistive technology. The result for the first tool shows the value of p is 0.00001. Additionally, result for the second tool shows the value of p is 0.00027. Therefore both results are significant at $p \leq 0.05$.

Keywords: Assistive technology; Communication disorders; Computer applications; Dyslexia; Learning disabilities; Research and development; Student experiments

Introduction

Children with communication disorders have difficulties in their ability to exchange information with others. A communication disorder may occur in the realm of language, speech and/or hearing. Language difficulties include spoken language, reading and/or writing difficulties. Communication disorders may result from many different conditions such as language-based learning disabilities. Language-based learning disabilities are the result of a difference in brain structure occur at birth and may be genetically based [1]. Therefore these studies will emphasis on assistive technology for students with communication disorders which related to "Learning Disabilities".

Learning disabilities involve many different intellectual disabilities. It means that a person's capacity to learn is affected and that they may not learn things as quickly as other people. Sometimes a learning disability is called a learning difficulty, intellectual impairment or intellectual disability [2].

However, learning disability is not an illness. Some of them may experience mental health problem from their depression. Students with learning disabilities are not able to meet learning achievement; some have high potential as they experience difficulty in reading, writing, calculating, talking, communicating, language using and muscle moving.

Most physicians state that people usually have a learning disability from birth or sometimes from early childhood. Although it is a permanent condition, people with a learning disability can and do learn and develop with the right sorts of support from other people [3].

In addition, the National Center for Learning Disabilities informs that people with learning disabilities fall into one of two categories which are verbal and nonverbal [4].

People with verbal learning disabilities have difficulty with words, both spoken and written. People with nonverbal learning disabilities may have difficulty processing what they see. They cannot understand the visual details like numbers on a book or blackboard. Nonverbal learning disability may confuse the plus sign with the sign for division. They also have problem with abstract concepts like fractions which may be difficult to master for them.

Although some learning disabilities students can learn in the same class with normal student but they need certain learning procedure that can elicit their proficiency and talent to offset or cover their disadvantage in order to allow them to live their life normally.

Training may help improving reading and calculation skills to some extent but the nature of how such learning disabilities students learn may differ from other student and so technique will be different including technological learning aids e.g. cassette, video, computer, computer program etc. Presently, most of students with learning disabilities still have to learn under the same methods as those of normal student as there are shortage in Assistive Technology or AT suitable for learning.

In this article the authors will present the design and development of two writing software tools for students with learning disabilities. The first program called Thai Word Search Program and the second program called Thai word prediction Program. Both tools are assistive technology to help students with learning disabilities in Thailand who have problem in their writing.

Design and Development of Assistive Technology

Thai word search program

Thai Word Search program is an assistive technology tool for student with learning disabilities in writing by providing help in searching for vocabulary either in the mode of Homophony or Soundex (word that is pronounced the same but has different grapheme) or Word Approximation (words with a similar depiction; probably be misspelled or wrong tone) [5,6]. With respect to Thai Word Search program, when the student wants to write any vocabulary that he/she cannot spell it correctly, the student will just type part of word according to pronunciation or as guessed, the program will then check and demonstrate the words for selection that most likely matches the one desired by the child including their pronunciation. Figure 1 demonstrates the system architectural design of Thai Word Search program.

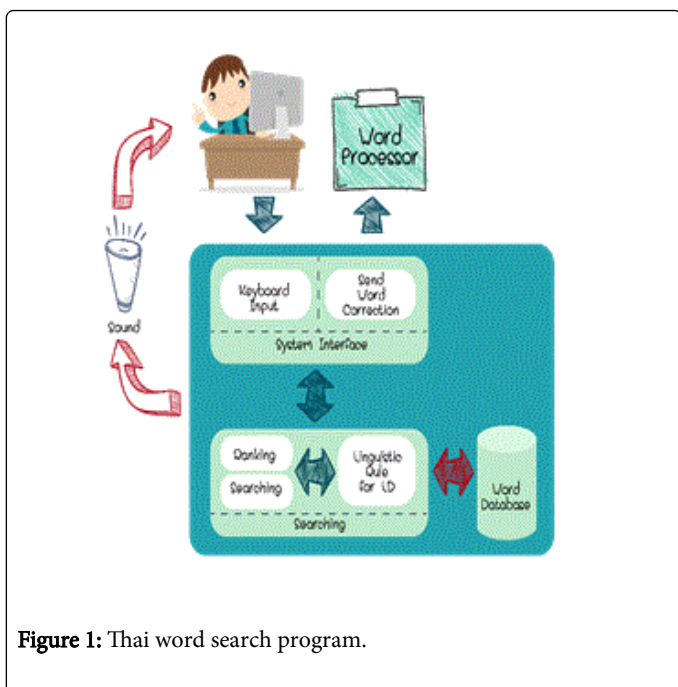


Figure 1: Thai word search program.

Interface design and the component of Thai Word Search Program will demonstrate below. Figure 2 shows the interface design and the components of Thai Word Search Program. The Component of Thai Word Search Program consists of 4 parts (1) Setting Menu, (2) Keyboard Parameter Display, (3) Vocabulary Lists, and (4) Page Selection.

Program design

Program design consists of searching function. The function can search for Homophony or Soundex and Word Approximation.

Homophony or soundex search

Homophony or Soundex search will take searching word from the user and then apply W2P (Word-to-Phoneme; the phoneme is the basic building block for spoken words) tool to convert searching word into voice through the converting process which will discard ror-reua, lor-ling (two Thai letters having close pronunciation) before searching into hash database of voice code, to gain the result in writing pattern

and return it to the user. Homophony or Soundex search will pay attention to only pronunciation of such word. When the users have got a word in writing pattern (Grapheme) they will then find its pronunciation and it is called Phoneme. Normal grapheme will be definite while Phoneme may be Phonetic or code or other kind of voice.

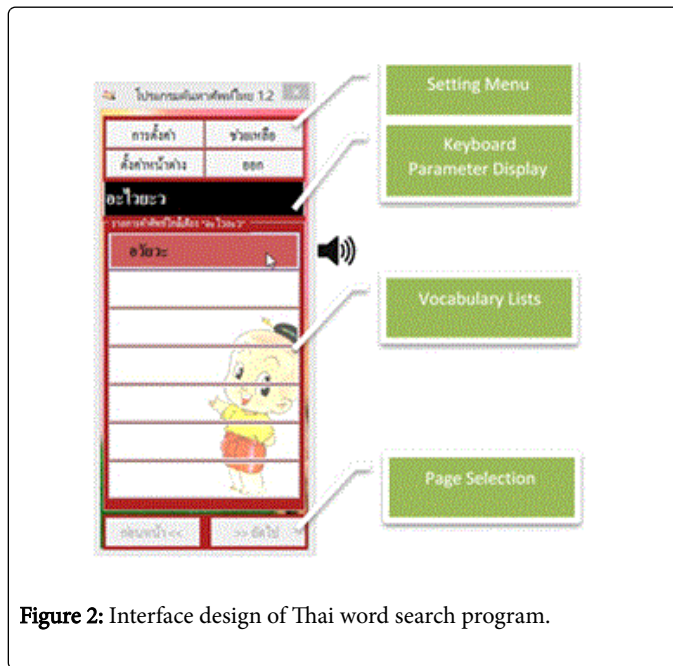


Figure 2: Interface design of Thai word search program.

Procedures for homophony or soundex search

It is able to convert Grapheme into Phoneme more easily. This will start from dividing word into syllables via the process of Lexeme Tokenizer applying a mark “|” to define syllable [7]. Intonation mark of such individual syllable will be then deleted by Tone Remover process to avoid being confused by the system. Cancelled Letter Remover will be applied to delete the mark from syllable before the last process of converting Grapheme into Phoneme (G2P) [8].

Data storage in Homophony or Soundex search system is done by hash database the advantage of which is the focus on swift searching and adding/deleting member until static time O (1) but such data has to have no priority and duplicity [9,10]. This first step is to take word aimed to search for into the searching system G2P by following the process mentioned above and voice code from these words will be converted where ror-reua, lor-ling will be discarded by the system.

When these phonemes are identified, searching process will continue under the following steps:

- All correct words search
- 1 wrong word search which will occur when the wrong word entered by the user has more than 2 syllables, and
- All words in the vocabulary search pattern

These 3 processes will be followed respectively and if result is gained at any step, it will be presented immediately.

Approximation search

Search for approximation means searching for words having close Grapheme to designated word and may contain slightly different letter

e.g. “ka-la-the-sa, mistaken with Thai alphabet number 40”-“ka-la-the-sa” or “wi-cha-ra-na-jan, mistaken with Thai alphabet number 25”-“wi-cha-ra-na-jan” etc. These samples are set of homophony which can be search by homophony or Soundex search system if desire but from the other perspective, these words contain only few different letters e.g. “wi-cha-ra-na-jan”- “wi-cha-ra-na-jan” differ from each other by using “nor-noo, Thai alphabet number 25” or “nor-nen, Thai alphabet number 19”. This approximation search will ignore pronunciation but close grapheme. By the use of approximation search, the key attention is mistyping e.g. “pha-con-phaj, mistaken with Thai alphabet number 34”-“pha-con-phaj”, “krun-si-a-yut-tha-ba, mistaken with Thai alphabet number 26”-“krun-si-a-yut-tha-ya” or “kon-luan”-“ kon-lor-ngor-wor” etc. It can be noticed that some word cannot be even spelled out or can be spelled without meaning. In case of “pha-con-phaj”-“pha-con-phaj”, it may be the result of mistyping as letter “yor-ying, Thai alphabet number 13” and “yor-yak, Thai alphabet number 13” are on the same key but the shift key has not been pressed properly to change from “yor-yak” to “yor-ying”.

Procedures for approximation search

Data storage in approximation search system is done by hash database. The advantage of which is the focus on swift searching and adding/deleting member until static time $O(1)$ but such data has to have no priority and duplicity.

First step is to take designated word to be processed under 3 steps as follows:

- Search for all correct words, search by LD's Rule 1st round by the method shown below [11].
- Deletion: refer to the step that word typed by the user will be deleted letter by letter, the result is n .
- Transposition: refer to the step that word typed by the user will be switched letter by letter, the result is $n-1$.
- Substitution: refer to the step that word typed by the user will be changed letter by letter under Rule of LD e.g. letter “koh-kai” can be changed to “ko-kai” “poh-sam-phao” “toh-tung” “rue” “dor-dek” “bor-bai-mai” “mor-mah” or “yor-yak”.
- Insertion: refer to the step that the word typed by the user will be added letter by letter, the result is $(n+1) \times 66$ results.
- Search again by LD's Rule, 2nd round.

The above processes will be followed step by step and if result is gained at any step, it will be presented immediately. However, this method has some limitation, that is, it cannot correct the word containing fault for more than 2 letters and thus API Appoxy, Edit distance has been introduced to increase the efficiency for search.

User interface engineering

Graphic user interface design consists of the following: The database: Vocabulary database used in Thai Word Search program consists of 2 databases for the user, which are general word database (corpus) and Thai textbook vocabulary database (corpus). The former comprise words from 2 sources; Bureau of Academic Affairs and Education Standards, Office of the Basic Education Commission and database from BEST corpus (Benchmark for Enhancing the Standard of Thai Language Processing).

Data Dictionary which applies to Thai Word Search Program can be classified into 2 groups:

- Vocabulary from homophony or Soundex system
- Vocabulary from approximation system

Dictionary of this approximation system is categorized into 3 types for the users; for Grade 1-3, for Grade 4-6 and general type.

Module design

Modules of Thai word search program are designed into APIs format to be easy to connect and activate for further development.

Usability testing

A study to integrate usability engineering in the design and development of Thai Word Search: Usability Testing was performed before testing the program with real user. Usability testing means a way to measure how people find it (easy, moderate or difficult) to interact with and use the system keeping its purpose in mind. It is a standard statement that Usability testing measures the usability of the system [12]. In this study the authors use heuristic evaluation [13,14] which is the most popular of the usability inspection methods [15]. Nielsen and Landauer suggested that the best results come from testing no more than 5 evaluators and running as many small tests as the researchers can afford [16].

Usability engineering for Thai word search

The researchers conducted the usability testing with 4 users who have moderate background of computer engineering and 1 user who has an expertise in computer science [17]. The following tables illustrate the results of usability testing from 5 evaluators. Thai Word Search was designed and developed to use with Operating system such as Windows XP, Windows 7 and Windows 8 on PC and Tablet. The program is able to work with various text editors: Notepad, Microsoft Office 2003, Microsoft Office 2007, Microsoft Office 2010, Microsoft Office 2013, Open Office, and Libre Office.

Thai word prediction program

Thai word prediction is a software program that aims to assist students with learning disabilities in their writing. The program works with any word editor programs. It predicts the word the students want to enter into the computer. The students type the first letter of a word and the program offers a list of words beginning with that letter. It displays words based on frequency of use and most recently used words. There are 2 types of word lists that the program offers to the students: word completion and word prediction (Figure 3).

System architectural design

System function will start from the user needs to print document by allowing word prediction program to work with any word editor programs on Windows where word prediction will run behind word editor program but program output will be displayed in the manner of Top Level, that is, program output will be displayed at the top level of Windows and able to be seen all the time. When the user hit keyboard, system interface component word prediction will detect such stroke for further processing and searching for vocabulary from database. Word searching will consider frequency of words which are put in ranking and then selected for certain number as set out earlier to be displayed to and selected by the user.

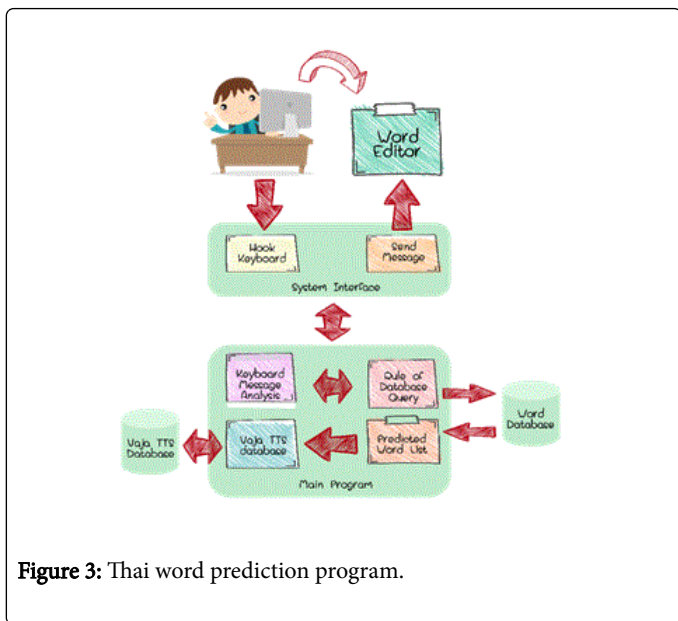


Figure 3: Thai word prediction program.

When the program has displayed list of words to the user and the user has selected certain vocabulary from such list, the system interface element will send such vocabulary to be printed in word editor program immediately and then process another searching to be displayed to the user. The word selected will be simultaneously given its accumulative frequency in the database. In the event there is no vocabulary in the database, the user can add the word by pressing function key designated for adding vocabulary. In addition, the advantage of word prediction program is that it can pronounce such words in the list by adopting VAJA (Thai Text To Speech Synthesis, developed by Human Language Technology Lab which is characterized as APIs to be used for this function [18]. Figure 4 shows system architectural design of Thai word prediction Program.

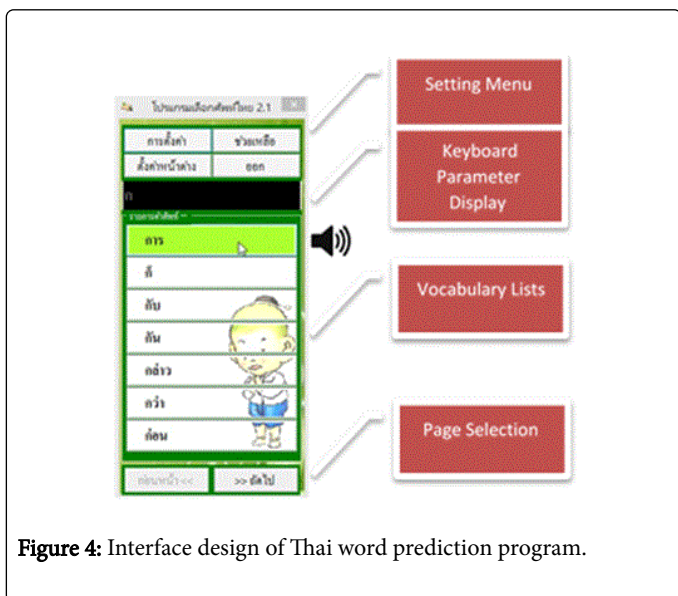


Figure 4: Interface design of Thai word prediction program.

System architectural design of Thai word prediction is divided into 2 main parts (i) System Interface and (ii) Main Program.

System interface: Main function of system interface is to link word prediction program with any word editors using on Windows. System Interface consists of 2 elements: the Hook Keyboard and the Send Message.

Main program: The main program will function on processing for listing available vocabulary upon receiving Hook keyboard in System Interface by searching vocabulary from database based on frequency from the most to least one and selecting certain number to be displayed for selection. In addition, main program also act in managing database including adding frequency and adding new vocabulary to the database.

User interface design

Main page: Main Page of the Thai word prediction program contains 2 parts. Part 1 consists of the user information which requires the user to fill in their user name. Part 2 consists of 2 different parts which are BEST Corpus and Corpus from Thai text books (secondary level).

The component of Thai word prediction: The Component of Thai word prediction illustrates in Figure 4. It consists of 4 parts (1) Setting Menu, (2) Keyboard Parameter Display, (3) Vocabulary Lists, and (4) Page Selection.

Usability engineering for Thai word prediction

As the same with the Thai Word Search Program, the researchers also conduct usability engineering for Thai word prediction (or another word heuristic evaluation). The main goal of heuristic evaluations is to identify any problems associated with the design of user interfaces [19]. Using heuristic evaluation prior to user testing will reduce the number and severity of design errors discovered by users [20].

A Study to Employ Usability Engineering in the Development of Thai word prediction:

Usability testing: To test the usability testing of the program, a workshop was conducted and questionnaires were developed and given to four information technology students who had taken computer science, information system and information technology courses from the International Institute of Technology in Thailand. According to Nielsen, the best usability testing results come from testing no more than 5 users $[U=1-(1-p)n]$ where p is the probability of one subject identifying a specific problem and n the number of subjects or test sessions].

Therefore the researchers developed a questionnaire that would enable computer users to perform heuristic evaluation which based on Nielsen's usability testing and the Questionnaire for user interaction satisfaction [21,22]. The researchers selected useful questions however the researchers did not apply all of the QUIS into the usability questionnaire.

A heuristic evaluation is one of the most informal methods of usability inspection in the field of human-computer interaction. Heuristic evaluation helps identify usability problems in the user interface (UI) design. In this study the authors applied Nielsen's usability inspection and Shneiderman's principles for designing the user interface to the design and development of the program: Thai word prediction [23].

Comment on the Usability Testing of Thai word prediction

Ease of use of program: All examiners are of the opinion that there has none of the information for use direction for the program. In this regard the developer is working out for such concern. In addition, most of the examiners view that the user can independently use the program and installation process is not complicated.

Technical aspects of the program: All examiners agree that it is appropriate to set out on-off function for acoustic and also agree for changing location of vocabulary list as the user wishes. All examiners agree for ability to open many files and to run word guessing program at the same time. In addition, all examiners agree with ability to quit program anytime during use.

Most of the examiners do not agree with that program can change font size, colour and type. In this regard, the developer wishes the program to be able to change font size, colour or type in accordance with the pre-setting theme selected by the user. At the present, the researchers already fixed these problems. Most of the examiners do not agree with ability to change voice speed and also view that program still has errors/bugs. In this study the authors applied Nielsen's usability inspection and Shneiderman's principles for designing the user interface to the design and development of the program: Thai word prediction.

Program management: All examiners are in the agreement for accuracy of word guessing, automatic word completion and addition of vocabulary in the list.

Most of the examiners support the idea that the program can record use history of the user accurately and agree that program responding time for vocabulary list is in timely manner and it is able to set the language (Thai-English) in the menu. All examiners do not agree that program can delete vocabulary in word guessing list and almost all do not agree that pronunciation for some words still have distorted sound.

System testing analysis

Thai word prediction was designed and developed to use with Operating system such as Windows XP, Windows Vista, Windows 7 and Windows 8. The program is able to work with various text editors: Notepad, WordPad, Microsoft Office 2003, Microsoft Office 2007, Microsoft Office 2010, Microsoft Office 2013, Open Office, and Libre Office.

Experiment

In this study single subject research design (a single-case experimental design) was applied into the experiment. The researchers use this method when the sample size is one or when a number of individuals are considered as one group. These designs are typically used to study the behavioral change an individual exhibits as a result of some treatment [24]. In single-subject design, each participant serves as his or her own control. Material and Equipment used in the study: The student required to use both Thai Word Search Program and Thai word prediction Program at different timelines. He required to take pre-test and post-test.

Thai Word Search Program:

Activity A:

- The subject was required to write 25 vocabularies with pen or pencil on paper.

- The subject was required to type instead of writing the same vocabularies using a word processor with the assist of assistive technology program Thai Word Search.

Activity B:

- The subject was required to summarize the lesson learned in Science class.
- The subject was required to write on favourite activity during the holidays.

After the Science class, Paul was required to summarize the lesson he learned. He was required to accomplish two tasks (i) writing down with a pen or pencil on his workbook and (ii) typing with Word Processor using Thai Word Search program.

Analysis and results

Analysis of the Activity A as follows:

- When Paul wrote 25 vocabularies, he made 23 misspelling words.
- When Paul typed 25 vocabularies with Word Processor and use assistive technology Thai Word Search program, he made a 1 mistake. This is indicated that Paul made less mistakes while he used assistive technology to support him in his writing.
- The researchers examined from his personal log file, Paul used Thai Word Search Program as assistive technology to help him select the right word. However, he made a mistake of word "sa-ded" since he selected "sa-ded" instead of "sa-dej". The pronunciation of "sa-ded" and "sa-dej" are quite similar but both have different meaning.
- From the personal log file, Paul was trying to use Thai Word Search in assisting him to find correct vocabulary such as word sap-pa-ya-korn. He repeated 2 trials because the first round his typing did not match with Soundex or approximation process used within the program. He tried again and this time Soundex was working. Then he finally found the correct word sap-pa-ya-korn which was attempted to be in the third place on the list.
- With the assist of assistive technology, Thai Word Search Program, Paul can be able to select correct vocabularies more than without the assist of assistive technology.
- The pretest post-test shows the value of p is 0.00001. Therefore, the result is significant at $p \leq 0.05$.

Analysis of the Activity B as follows:

- Paul has a strong intention to practice and use assistive technology program on his writing.
- As mentioned from his teachers and shows on Figures 2 and 3 Paul has a severe learning disability in writing however, with the assist of Thai Word Search Program, Paul can perform his writing skill better.
- His writing on the title: Anatomy of Human Body, Paul used assistive technology program Thai Word Search to assist him to choose correct vocabularies. Paul did not make any mistake in his typing therefore he can type correctly 100%.
- His writing on the title: Makha Bucha Day, Paul used assistive technology program Thai Word Search to assist him to choose correct vocabularies. He made a few mistakes. In this topic, Paul can type correctly 91.67%.
- The pronunciations of some vocabularies are similar; hence Paul made a few mistakes because the meanings of those vocabularies are different.

Thai word prediction

Activity A:

- The subject was required to write ten vocabularies with pen or pencil on paper.
- The subject was required to type instead of writing the same vocabularies using a word processor with the assist of assistive technology program Thai word prediction.

Activity B:

- The student needed to take turn typing two different topics ten times.
- The teacher collected the data and recorded.

Analysis and results

Analysis and results of activity A:

- When Paul wrote ten vocabularies, he made seven misspelling words.
- When Paul typed ten vocabularies with Word Processor and use assistive technology Thai word prediction program, he made no mistake. This is indicated that Paul had learning improving 70%.

The pretest post-test shows the value of p is 0.00027. Therefore, the result is significant at $p \leq 0.05$.

Analysis and Results of Activity B (Practicing for Topic Number 1):

- Topic number 1 had 327 keystrokes, however with Thai word prediction program Paul used 258 keystrokes in his typing for the first time. Therefore, the program can reduce his keystrokes 26.74%.
- For the fifth typing, Paul typed his work along with Thai word prediction program. This time he used 245 keystrokes in his work. Therefore, the program can reduce his keystrokes 33.47%.
- For the tenth typing, Paul typed his work and used Thai word prediction program. He used 208 keystrokes. Therefore, the program can reduce his keystrokes 57.21% (Figure 5 and 6).

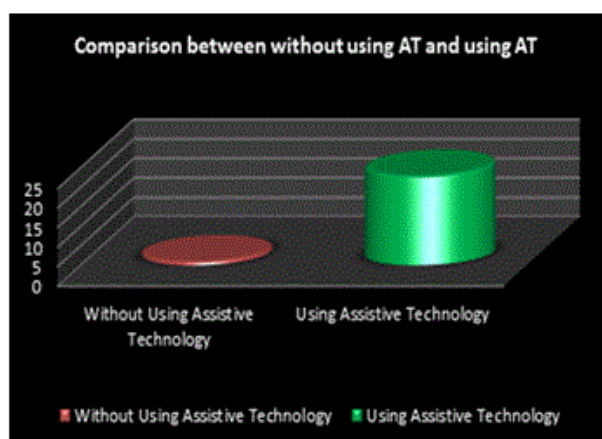


Figure 5: The comparison between without using AT (Thai Word Search) and with using AT.

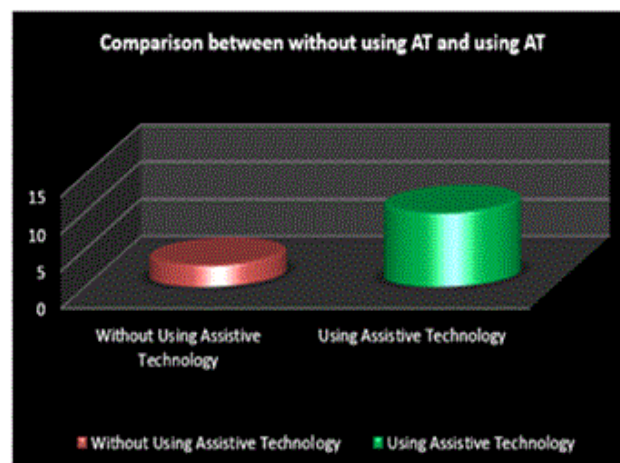


Figure 6: Comparison between without using AT (Thai word prediction program) and using AT.

Analysis and results of activity B (Practicing for topic number 2):

- Topic number 2 had 310 keystrokes, however with Thai word prediction program Paul used 271 keystroke s in his typing for the first time. Therefore, the program can reduce his keystrokes 14.39%.
- For the fifth typing, Paul typed his work and used Thai word prediction program. This time he used 263 keystrokes in his work. Therefore, the program can reduce his keystrokes 17.87%.
- For the tenth typing, Paul used 258 keystrokes. Therefore, the program can reduce his keystrokes 20.16%.

This is indicated that if Paul used the Thai word prediction program every time, the program would then help him to reduce his keystrokes, type faster, and select the right vocabulary while typing. The teacher also added that she has seen Paul's improvement in his writing while using Thai word prediction program.

Analysis on Paul's writing topic "My Father"

- Paul made four mistakes in his writing which are [i-mai-muan→i-mai-malai], [bor-bai-mai→ko-kai], [ou→ouu], [yak→yark].
- If Paul used the program in his typing he would select the right vocabularies and made less mistakes.
- Paul wrote the article better when using Thai word prediction program than without using the program.
- From the teacher's observation, Paul has progress on his writing compare to few months ago.

Analysis on the Table 1:

Name	Text 1: KS used	KS Decrease (%)	Text 2: KS used	KS Decrease (%)
Paul	265.8	61.2	262.2	47.8

Table 1: Comparison of keystrokes (KS) typing between topic 1 and topic 2 in 10 sessions with Thai word prediction (in average percentage).

- Thai word prediction Program helps Paul reduce keystrokes while typing at the average of 22.95% for topic number 1 and 18.23% for topic number 2.
- Paul has typing skill less than average however when he uses Thai word prediction, the program can help him type faster and more accurate.

Conclusion

In conclusion, Paul was in agreement with the advantages of the assistive technology; Thai word Search and Thai word prediction which could help him in his spelling and search words well and fast. Paul also mentioned that the program assisted him to be able to choose vocabulary and print the work correctly. In addition, Paul agreed that both of assistive technology tools were simple, and not complicated. The tools also help him to know how each word is spelled as it provides pronunciation for each word. Although the pronunciation by the program for some word was deviated, Paul admitted that the programs could help him to be able to pronounce vocabulary better than without using the programs. Moreover, in the near future, Thai word search features and Thai word prediction can be applied to work in combination with programs such as Thai spell checker for students with learning disabilities, and Thai word processor for students with learning disabilities in order to enhance them in their learning as well as to optimize their accurate writing.

The researchers therefore are trying to correct all bugs and errors found during the field testing. Hence the researchers expect that both of assistive technology tools will help students with learning disabilities who struggle with writing become better writers.

Acknowledgment

The authors wish to convey sincere thanks and acknowledge the assistance of Miss Wantanee Phantachat, Dr. Putthachart Pothibal, Mr. Alongkorn Wongteeratana, Mr. Waragorn Gestubtim, Mrs. Piyant Noipong, Dr. Somporn Warnset, the Director, the teachers and the students at the School in Bangkok for their time and assistance. Our thanks also extend to the Cluster and Program Management Office (CPMO), National Science and Technology Development Agency (NSTDA) for funding the project.

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