DEVELOPMENT OF ASSESSMENT TOOL FOR DYSLEXIA SCREENING USING FUZZY LOGIC

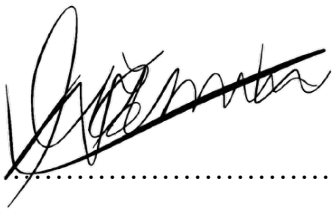
NG LI MUN

A thesis submitted in
fulfilment of the requirement for the award of the
Degree of Master of Electrical Engineering

Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia

FEBRUARY 2021

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged

Student : 
NG LI MUN

Date : 30.03.2021

Supervisor : 
DR. NUR ANIDA BINTI JUMADI

Co-Supervisor : 
DR. FARHANAHANI BINTI MAHMUD

This thesis is wholeheartedly dedicated to my beloved parents and my dearest siblings.

ACKNOWLEDGEMENT

This work would not have been possible for the innumerable amount of help that I have received from different individuals.

First and foremost, I would like to express my sincere gratitude to my supervisor, Dr. Nur Anida Binti Jumadi for the confidence and guidance during my master study. All the invaluable advice, enthusiastic encouragement and useful critiques from her throughout this research work that made the completion of this research project work possible.

A special thanks to Department of Electronic, Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia (UTHM). Besides, I also would like to thank Microelectronics and Nanotechnology Shamsuddin Research Centre (MiNT-SRC), UTHM in providing laboratory facilities to complete this research. I would like to express my gratitude to Research Management Centre (RMC) UTHM for providing funding via Postgraduate Research Grant (GPPS), Grant No. H315.

I would like to express my appreciation to Dr. Farhanahani Binti Mahmud, my co-supervisor who gave me the assistance and dedicated her time and knowledge to complete the project. I would like to thank to Mr. Saifuddin Mohtaram, my external co-supervisor, who is the principal of “Little Genius Multisensory Dyslexia Centre Batu Pahat”, for the assistance and professional support in offering the resources required to run the project.

I would like to extend my appreciation to the school teachers from Taska Khalifah Junior UTHM, SK Parit Raja, SK Pintas Raya, SK Pintas Puding and SK Sri Gading who were willingly participated in my data collection for completing the research project.

Nobody has been more important to me in the pursuit of this project than the members of my family. I would like to thank my parents and my siblings, whose love, support and reassurance are with me in whatever I pursue throughout my studies.

ABSTRACT

Dyslexia is a specific reading difficulty leading to low proficiency in an individual's literacy, affecting 5 to 17.5 % of the population globally and 5 to 15 % of Malaysia's children. The current dyslexia screening test known as *Ujian Pengesanan Awal Disleksia Bahasa Melayu* (D-Test) is administrated manually, and the decision to determine dyslexia risk is time-consuming. Hence, this research's main objective is to develop an assessment tool by implementing fuzzy logic for rapid dyslexia risk outcomes using D-Test as the primary screening framework. The Mamdani-type Fuzzy Inference System (FIS) was developed based on 48 rule conditions, whereas the user interface was built using MATLAB App Designer. The developed assessment tool's performance was evaluated based on quantitative (accuracy, sensitivity, specificity, and precision), qualitative (Technology Acceptance Model (TAM)), and system response time assessments. Phase I study was conducted using the D-Test, and Phase II was carried out using the developed assessment tool with the recruitment of school pupils ($n^{\text{Phase I}}$=117 and $n^{\text{Phase II}}$=74) and teachers (n=29), respectively. The outcome from the quantitative results from Phase I and Phase II demonstrated the capability of fuzzy logic to distinguish between dyslexic and non-dyslexic subjects with an accuracy of 88.89 % and 93.24 %, respectively. Meanwhile, the finding from the qualitative approach investigated using showed the perceptions of external control (R^2 =0.575, p<0.05) and perceived usefulness (R^2 =0.675, p<0.05) were significantly influencing the behavioural intention of the target users towards the developed dyslexia assessment tool. The final finding on the system response time highlighted the developed tool's capability to improve the time taken when determining the dyslexia risk level (15 seconds per subject). In conclusion, the assessment tool for a rapid dyslexia risk status utilising Mamdani-type FIS had been successfully developed. The developed dyslexia assessment tool could be beneficial to assist dyslexia organisations, parents and school teachers in dyslexia screening process.

ABSTRAK

Disleksia merupakan masalah khusus berkaitan kesukaran membaca yang menyumbang kepada penguasaan kemahiran literasi yang rendah menyebabkan 5 hingga 17.5 % dari populasi dunia dan 5 hingga 15 % kanak-kanak di Malaysia terjejas. Ujian Pengesanan Awal Disleksia Bahasa Melayu (D-Test) dilakukan secara manual dan mengambil masa yang panjang untuk mendapatkan keputusan saringan. Oleh sebab itu, penyelidikan ini dilakukan bertujuan untuk membangunkan sebuah perisian dengan penggunaan logic kabur bagi menghasilkan saringan disleksia secara pantas berdasarkan penggunaan D-Test. *Fuzzy Inference System* (FIS) jenis Mamdani telah dibina dengan 48 aturan syarat manakala antaramuka pengguna dihasilkan menggunakan *MATLAB App Designer*. Prestasi perisian yang telah dibangunkan diukur menggunakan pendekatan kuantitatif (ketepatan, kepekaan, kekhususan dan kejituan), kualitatif (*Technology Acceptance Model* (TAM)) dan masa tindakbalas sistem. Kajian Fasa I dijalankan dengan menggunakan D-Test manakala Fasa II dijalankan menggunakan perisian yang telah dibangunkan dengan penglibatan murid sekolah ($n^{Fasa\ I}$=117 dan $n^{Fasa\ II}$=74) dan guru sekolah (n=29). Keputusan daripada analisis kuantitatif bagi Fasa I dan Fasa II menunjukkan kemampuan logic kabur untuk membezakan antara subjek disleksia dan bukan disleksia dengan nilai ketepatan masing-masing iaitu 88.89 % dan 93.24 %. Manakala, hasil daripada analisis kualitatif yang menggunakan menunjukkan bahawa persepsi kawalan luaran (R^2=0.575, p<0.05) dan kebergunaan (R^2=0.675, p<0.05) adalah signifikan dalam mempengaruhi keinginan pengguna terhadap penggunaan perisian yang dicipta. Dapatan kajian membuktikan kebolehan perisian dalam menghasilkan keputusan saringan risiko disleksia secara pantas (15 saat untuk seorang subjek). Kesimpulannya, satu perisian saringan disleksia secara pantas telah berjaya dihasilkan dengan penggunaan logic kabur jenis Mamdani. Perisian yang dibina boleh digunakan untuk membantu petubuhan disleksia, ibu bapa dan guru sekolah dalam proses saringan disleksia.

CONTENTS

TITLE		**i**
DECLARATION		**ii**
DEDICATION		**iii**
ACKNOWLEDGEMENT		**iv**
ABSTRACT		**v**
ABSTRAK		**vi**
CONTENTS		**vii**
LIST OF TABLES		**xii**
LIST OF FIGURES		**xv**
LIST OF SYMBOLS AND ABBREVIATIONS		**xviii**
LIST OF APPENDICES		**xxi**
CHAPTER 1	**INTRODUCTION**	**1**
	1.1 Overview	1
	1.2 Background and motivation	1
	1.3 Problem statement	2
	1.4 Research objectives	3
	1.5 Scopes of study	3
	1.6 Contribution	4
	1.7 Thesis organisation	5

CHAPTER 2 LITERATURE REVIEW 6

2.1 Overview 6
2.2 Dyslexia 7
2.3 Dyslexia screening 8
2.3.1 Types of dyslexia screening test 9
2.3.1.1 Conventional dyslexia screening tests 9
2.3.1.2 Computerised dyslexia screening tests 10
2.3.1.3 Online dyslexia screening tests 11
2.3.2 Dyslexia screening tests from Malaysia perspective 12
2.3.2.1 *Instrumen Senarai Semak Disleksia* (ISD) 12
2.3.2.2 Literacy and Numeracy Screening (LINUS) 13
2.3.2.3 Literacy and Numeracy Screening 2.0 (LINUS 2.0) 14
2.3.2.4 *Ujian Pengesanan Awal Disleksia Bahasa Melayu* (D-Test) 14
2.3.2.5 Research on dyslexia screening applications 15
2.3.2.6 Challenges in Malaysia 18
2.3.3 Dyslexia screening issues 19
2.3.3.1 Delay in results interpretation after screening 19
2.3.3.2 Accuracy of dyslexia screening instruments 20
2.3.3.3 Teacher training issues 20
2.4 Data mining 21

	2.4.1 Fuzzy logic	21
	2.4.2 Waikato Environment for Knowledge Analysis (WEKA) data mining tool	23
2.5	Technology Acceptance Model (TAM)	23
2.6	Partial Least Square (PLS)	26
	2.6.1 Smart PLS	28
2.7	System response time	28
2.8	Summary	29
CHAPTER 3	**RESEARCH METHODOLOGY**	**30**
3.1	Overview	30
3.2	Determination of dyslexia risk status using fuzzy logic	33
	3.2.1 Guideline for dyslexia risk screening system based on D-Test	33
	3.2.2 Determination of dyslexia risk screening indicators	35
3.3	Development of dyslexia assessment tool based on fuzzy logic	35
	3.3.1 MATLAB Fuzzy Logic Designer	36
	3.3.1.1 FIS Editor	38
	3.3.1.2 Membership Function Editor	38
	3.3.1.3 Rule Creator	42
	3.3.2 MATLAB App Designer	44
	3.3.3 MATLAB Compiler	47
3.4	Experimental procedures and data collection	48
	3.4.1 Phase I data collection	48
	3.4.1.1 Schools and subjects' selections for Phase I data collection	48
	3.4.1.2 Experiment protocol for Phase I data collection	49
	3.4.1.3 WEKA data mining tool	54

3.4.2 Phase II data collection 57
3.4.2.1 Schools and subjects' selections for Phase II data collection 58
3.4.2.2 Experiment protocol for Phase II data collection 58
3.5 Evaluation of system performance 60
3.5.1 Quantitative: Statistical evaluation 60
3.5.1.1 Confusion matrix and statistical formula 61
3.5.2 Qualitative: User acceptance and satisfaction 64
3.5.2.1 Technology Acceptance Model (TAM) 65
3.5.2.2 Smart PLS 67
3.5.3 System response time 70
3.6 Summary 71

CHAPTER 4 RESULT AND DISCUSSION 72

4.1 Overview 72
4.2 Determination of dyslexia risk status in FIS 72
4.3 Assessment tool for dyslexia screening 75
4.4 Evaluation of statistical performance 77
4.4.1 Statistical performance analysis and discussion for Phase I data collection 78
4.4.1.1 WEKA analysis based on Phase I data collection 80
4.4.1.2 Discussion on the performance of FIS and WEKA data mining tool towards the identification of dyslexic and non-dyslexic subjects 84

	4.4.2 Statistical performance analysis and discussion for Phase II data collection	85
	4.5 Evaluation of user acceptance and satisfaction using TAM	87
	4.5.1 Training session outcome	87
	4.5.1.1 Construct reliability and validity of measurement model for training session	87
	4.5.1.2 Evaluation of structural model for training session	89
	4.5.2 Implementation session outcome	91
	4.5.2.1 Construct reliability and validity of measurement model for implementation session	92
	4.5.2.2 Evaluation of structural model for implementation session	94
	4.5.3 Discussion on TAM outcome during training and implementation sessions	95
	4.6 Comparison of the response time between Phase I (D-Test manual screening) and Phase II (developed dyslexia assessment tool)	97
	4.7 Summary	99
CHAPTER 5	**CONCLUSION**	**100**
	5.1 Overview	100
	5.2 Conclusion	100
	5.3 Recommendations	102
	REFERENCES	**103**
	APPENDICES	**113**

LIST OF TABLES

1.1	List of selected tests employed in the dyslexia	3
2.1	Tests in The Slingerland High School Level Screening	10
2.2	Tests available in Lucid CoPS and LASS Tests available in Lucid CoPS	11
2.3	Tests available in D-Test	15
2.4	Summary on research related to dyslexia screening test in Malaysia	17
2.5	Comparison between dyslexia screening manuals on time required to compute dyslexia screening result	19
2.6	Classification confusion matrix in a screening test	20
2.7	Summary of two TAM research studies	25
2.8	Table of summary on the decision of using dyslexia screening framework and data mining technique	29
3.1	Dyslexia risk screening indicators based on the D-Test	35
3.2	Input and output variables with membership function parameters for dyslexia	39
3.3	Membership functions for all the input and output variables	41
3.4	16 possible conditions of risk assessment for each age group in the creation of rule	42

3.5	Output range of fuzzy sets representing all three conditions	43
3.6	Rule conditions made in Rule Creator	43
3.7	Subject distribution for Phase I data collection	49
3.8	Training and testing datasets used in WEKA	55
3.9	Subject distribution for Phase II data collection	58
3.10	Confusion matrix of Phase I data collection	61
3.11	Confusion matrix of WEKA	62
3.12	Confusion matrix of Phase II data collection	62
3.13	Definitions for each of the determinants in TAM questionnaire	66
3.14	Hypotheses of examining the TAM model in the research	67
4.1	FIS outcome and dyslexia risk level	73
4.2	Summary of statistical performance in FIS after data cleaning process	79
4.3	Summary of the results generated from testing data (n = 108) with classification model created using Set I (n =100) training data based on Naïve Bayes, Decision Table and Random Forest	82
4.4	Summary of the results generated from testing data (n = 108) with classification model created using Set II (n =200) training data based on Naïve Bayes, Decision Table and Random Forest	84
4.5	Synopsis of final results between FIS and WEKA data mining tool towards the combination of dyslexic and non-dyslexic subjects	85
4.6	Result summary for the response of questionnaire during training session of the developed dyslexia assessment screening tool	87
4.7	Cross-loadings of the measurement model for Fornell And Larcker Criterion during training session	89

4.8	HTMT result for training session	89
4.9	Collinearity of the structural model for training session (inner VIF)	90
4.10	PLS result obtained for training session	91
4.11	Results summary for the response of questionnaire during implementation session of the developed dyslexia assessment tool	92
4.12	Discriminant validity of the measurement model for Fornell And Larcker Criterion during implementation session	93
4.13	HTMT for implementation session	93
4.14	PLS-SEM result for implementation session	95
4.15	Comparison between dyslexia manual screening (Phase I) and developed dyslexia assessment tool (Phase II)	98

LIST OF FIGURES

2.1	General block diagram of literature review	7
2.2	Fundamental of PLS algorithm	27
3.1	Overview of the research methodology	31
3.2	Overall block diagram of methodology stages	32
3.3	Guideline for dyslexia risk screening system based on D-Test dyslexia screening manual	34
3.4	Overview for dyslexia assessment tool development	36
3.5	General modelling process of FIS	37
3.6	Main elements of MATLAB Fuzzy Logic Designer	38
3.7	Interface for FIS Editor	38
3.8	Triangular membership function and trapezoidal membership function	40
3.9	General process of using MATLAB App Designer	45
3.10	User interface of the design view in MATLAB App Designer	46
3.11	User interface of the code view in MATLAB App Designer	46
3.12	Commands for the integration of FIS and App Designer	47
3.13	Screenshot of the deployment application button used for MATLAB Compiler	47
3.14	Process of subject testing for Phase I data collection	50

3.15	Process for Test 1: Rapid Naming	51
3.16	Process for Test 3: One-Minute Reading	52
3.17	Process for Test 5: Two-Minute Spelling	53
3.18	Process for Test 7: Pseudowords	54
3.19	Process of using WEKA data mining tool	55
3.20	Example of new project creation in WEKA	56
3.21	Example of data training with training dataset and its output	56
3.22	Example of data testing using the collected data (n=108)	57
3.23	Example of output obtained in WEKA	57
3.24	Process of subject testing for Phase II data collection	60
3.25	Process for the evaluation of user acceptance and satisfaction	65
3.26	Framework of TAM in the evaluation of user acceptance and satisfaction towards the developed dyslexia assessment tool	66
3.27	Process of using Smart PLS software	68
3.28	TAM measurement model produced in Smart PLS	69
3.29	Output assessment guideline of Smart PLS	70
4.1	FIS crisp output for high risk in dyslexia	73
4.2	FIS crisp output for low risk in dyslexia	74
4.3	FIS crisp output for no risk in dyslexia	74
4.4	User interface of homepage	75
4.5	FIS output in the fuzzy calculator panel of the assessment tool for high risk in dyslexia	76
4.6	FIS output in the fuzzy calculator panel of the assessment tool for low risk in dyslexia	76
4.7	FIS output in the fuzzy calculator panel of the assessment tool for no risk in dyslexia	77

4.8	Statistical performance of the 117 subjects in Phase I data collection	78
4.9	Statistical performance of the 108 subjects in Phase I data collection	79
4.10	Statistical performance of 108 subjects using Naïve Bayes in WEKA (training data Set I: n=100)	80
4.11	Statistical performance of 108 subjects using Decision Table in WEKA (training data Set I: n=100)	81
4.12	Statistical performance of 108 subjects using Random Forest in WEKA (training data Set I: n=100)	81
4.13	Statistical performance of 108 subjects using Naïve Bayes in WEKA (training data Set II: n=200)	82
4.14	Statistical performance of 108 subjects using Decision Table in WEKA (training data Set II: n=200)	83
4.15	Statistical performance of 108 subjects using Random Forest in WEKA (training data Set II: n=200)	83
4.16	Statistical performance of the 74 subjects in Phase II data collection	86
4.17	Statistical performance of the 73 subjects in Phase II data collectionStatistical performance of the 73 subjects in Phase II data collection	86
4.18	PLS-SEM result for training session	90
4.19	PLS-SEM result for implementation session	94

LIST OF SYMBOLS AND ABBREVIATIONS

A		Fuzzy set named A
f^2		Effect size
m		Mean
n		Non control group (dyslexia and slow learner)
n_c		Control group (normal)
p		Significance of structural path coefficient
R^2		Coefficient of determination
t		Significance of structural path coefficient
U		Universal set of fuzzy set
β		Strength of relationship in PLS
ANN	-	Artificial Neural Network
ARHQ	-	Adult Reading History Questionnaire
AVE		Average Variance Extracted
BI	-	Behavioural Intention
BM	-	Bahasa Malaysia
CAD		Coronary Artery Disease
CLDQ-R	-	Colorado Learning Disabilities Questionnaire – Reading Subscale
COPD		Chronic Obstructive Pulmonary Disease
CSE	-	Computer Self-Efficacy
CFS		Correlation Based Feature Selection
DCCC	-	Dyslexia Checklist for Chinese Children
DCS	-	Diagnostic and Classification System
DEST	-	Dyslexia Early Screening Test
DST	-	Dyslexia Screening Test
D-TEST	-	*Ujian Pengesanan Awal Disleksia Bahasa Melayu*
ENJ	-	Perceived Enjoyment

FIS	-	Fuzzy Inference System
FN	-	False Negative
FP	-	False Positive
GA	-	Genetic Algorithm
GUI	-	Graphical User Interface
HTMT		Heterotrait-Monotrait Ratio of Correlations
ISD	-	*Instrumen Senarai Semak Disleksia*
KNN	-	K Nearest Neighbours
Lucid CoPS	-	Lucid CoPS Cognitive Profiling System
LASS	-	Lucid Assessment System for Schools
LINUS		Literacy and Numeracy Screening
MATLAB		Matrix Laboratory
MOE		Ministry of Education Malaysia
NKRA		Education National Key Results Area
OUT		Output Quality
PEC	-	Perceptions of External Control
PEOU	-	Perceived Ease of Use
PLS	-	Partial Least Square
PU	-	Perceived Usefulness
REL		Job Relevance
RES	-	Result Demonstrability
Rhino	-	Retinal Health Information and Notification System
SEM	-	Structural Equation Modelling
SME		Small and Medium-sized Enterprises
SVM		Support Vector Machine
TAM	-	Technology Acceptance Model
TN	-	True Negative
TP	-	True Positive
UNESCO		United Nations Educational, Scientific and Cultural Organization
UNICEF	-	United Nations Children's Fund
UTAUT		Unified Theory of Acceptance and Use of Technology
VIF		Inner Collinearity
WEKA	-	Waikato Environment for Knowledge Analysis data mining tool

WISC - Wechsler Intelligence Scale for Children

WMA - World Medical Association

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Official Ethical Committee Approval Letter	114
B	Consent Form	115
C	Answer Sheet for Phase II Data Collection	116
D	Technology Acceptance Model Questionnaire	117
E	Executable Dyslexia Assessment Tool User Guide	118
F	Image taken during data collection of Phase I and Phase II	127
G	List of publications	130

CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter introduces the background and motivation of this study. This chapter also addresses problem statement, objectives to be achieved at the end of the research and scopes of the study as well as contribution. The chapter ends with the thesis organisation.

1.2 Background and motivation

Dyslexia is a specific reading disability that an individual suffers from difficulties in the development of reading, writing and spelling skills but the intelligence of the children is remained unaffected [1]. The rate of prevalence varies widely according to the populations and country [2]. A report (1987) submitted to United States Congress stated that the rate of dyslexia was between 5 and 17.5 % which was in line with the opinion of Shaywitz (1994) [3] . International Dyslexia Association (2012) stated that 15 to 20 % of the population worldwide demonstrated symptoms of dyslexia [4] whereas British Dyslexia Association (2017) estimated that 10 % of the population could be dyslexic [5]. On the other hand, various studies of dyslexia's prevalence had been conducted, the results from the research done by Moore *et al*. showed that 10 % were affected by dyslexia in Europe [6] but now it has increased to 15 % of people that are dealing with dyslexia based on the report from Pouspourika [7]; a rate ranged from 2 to 12 % was estimated by Xu *et al*. in China [8]; 5 to 17 % of people were affected by dyslexia in India (Sahoo *et al*.) [9]; and as for United Arab Emirates, the report

generated by Aboudan *et al*. showed that 17.6 % of people were dyslexic as they faced difficulties with English and Arabic [10]. Meanwhile the dyslexia statistics for Malaysia showed that 5 to 15 % of children possessed trait of dyslexia (Yuzaidey *et al*.) [11]. Although the prevalence of dyslexia is diverse, it does indicate the significance of getting an early screening for dyslexia so that the reading ability of children may be improved.

1.3 Problem statement

Dyslexia impacts people with varying degrees of dyslexic difficulty [12] as the dyslexic individuals possess non-identical in brain development. They only share the similarity in their reading ability that tends to be lower than people of their age [13].

At present, Dyslexia Association of Malaysia has constructed a manual screening test named "*Ujian Pengesanan Awal Disleksia Bahasa Melayu* (D-Test)" consisting of ten subtests to identify dyslexic condition among children aged from 6 to 10-year-old [14]. The screening instrument is performed by collecting the total score gained throughout all the subtests, and the calculation is carried out manually to analyse the dyslexic condition. However, this process is time-consuming as the test scores obtained from the dyslexia screening need to be manually calculated and analysed based on the percentile table leading to delay in dyslexia risk confirmation [15].

Lee *et al.* [16] have recently developed a reading assessment battery for dyslexia evaluation. In this study, the researchers were able to identify the children who were at risk of dyslexia and who were at no risk of dyslexia using the assessments in terms of language, literacy, and sublexical-reading aspects. The instrument was able to identify the children who were having risk in dyslexia with high reliability and validity. Despite its reliability and validity, the instrument suffers from manual administration for computing the dyslexia result.

Based on the limitations, the need to develop a computerised risk screening tool for dyslexia is presented here. This research aimed to develop an assessment tool that could assist in calculating dyslexia result to replace with the manual calculation method. Specifically, fuzzy logic was employed to act as the classification method that

could identify the dyslexic and non-dyslexic children. In this research, qualitative and quantitative approaches were utilised to gather all the data required.

1.4 Research objectives

The main aim of this research was to develop a screening tool with generation of dyslexia result rapidly and instantaneously. To achieve the main aim, the project is divided into several components and carried out systematically with the listed research objectives as follows.

(i) To determine the dyslexia risk status using fuzzy logic

(ii) To develop dyslexia assessment tool system with fuzzy logic integration for the ease of use during dyslexia screening test session

(iii) To evaluate the performance of the developed system based on quantitative, and qualitative analysis as well as the system response time

1.5 Scopes of study

The scopes of study of this research are listed as below:

(i) D-Test was employed to identify the tendency of having dyslexia as the foundation of the screening tool. As such, four out of ten manual tests were selected and utilised as referred in Table 1.1 based on the recommendation from Mr. Saifuddin, the dyslexia expert from Little Genius Multisensory Dyslexia Centre Batu Pahat. MATLAB Fuzzy Logic Designer was applied to rule out all the dyslexia conditions based on the reference from the D-Test screening manual.

Table 1.1: List of selected tests employed in the dyslexia assessment tool

Test	Name of the test
1	Rapid Naming
3	One-Minute Reading
5	Two-Minute Spelling
7	Pseudowords

(ii) An assessment tool for dyslexia screening was developed using MATLAB App Designer with the integration of MATLAB Fuzzy Logic Designer to

REFERENCES

[1] W. H. Organization and W. Bank, “World Report On Disability 2011,” 2011.

[2] E. Nagourney, “Geography Of Dyslexia Is Explored,” *The New York Times*, 2001. [Online]. Available: https://www.nytimes.com/2001/04/10/health/geography-of-dyslexia-is-explored.html. [Accessed: 04-Apr-2019].

[3] A. M. Hayes, E. Dombrowski, A. H. Shefcyk, and J. Bulat, “Learning Disabilities Screening and Evaluation Guide for Low- and Middle-Income Countries,” *RTI Press Occas. Pap.*, no. April, pp. 1–53, 2018.

[4] International Dyslexia Association, “Dyslexia Basics,” 2012.

[5] A. Protopapas and R. Parrila, “Is Dyslexia a Brain Disorder?,” *Brain Sci.*, vol. 8, no. 4, pp. 1–18, 2018.

[6] L. Moore, V. Parker, A. Findlay, L. Cunningham, and L. Robinson, “Supporting children and young people with reading difficulties,” 2017.

[7] K. Pouspourika, “Learning difficulties in Europe,” 2019. [Online]. Available: https://ied.eu/project-updates/learning-difficulties-in-europe/. [Accessed: 05-Jan-2019].

[8] M. Xu, L. H. Tan, and C. Perfetti, “Developmental Dyslexia in Chinese,” *Dev. Dyslexia across Lang. Writ. Syst.*, pp. 200–226, 2019.

[9] H. R. Shah, J. K. V. Sagar, M. P. Somaiya, and J. K. Nagpal, “Clinical practice guidelines on assessment and management of specific learning disorders,” *Indian J. Psychiatry*, vol. 61, no. 8, pp. 211–225, 2019.

[10] A. El Kah and A. Lakhouaja, “Developing effective educative games for Arabic children primarily dyslexics,” *Educ. Inf. Technol.*, vol. 23, no. 6, pp. 2911–2930, 2018.

[11] N. A. M. Yuzaidey, N. C. Din, M. Ahmad, N. Ibrahim, R. A. Razak, and D. Harun, “Interventions for children with dyslexia: A review on current intervention methods,” *Med. J. Malaysia*, vol. 73, no. 5, pp. 311–320, 2018.

[12] International Dyslexia Association, *Dyslexia In The classroom - What Every*

Teachr Needs to Know. 2017.

[13] Christian Nordqvist, "Dyslexia: Symptoms, treatment, and types," *Medical News Today*, 2017. [Online]. Available: https://www.medicalnewstoday.com/articles/186787.php. [Accessed: 07-Dec-2018].

[14] A. S. S. Sariah Amirin, Hazlina Azahari, Saifuddin Mohtaram, Ahmad Naim Che Pee, "Ujian Pengesanan Awal Disleksia Bahasa Melayu," 2017.

[15] N. H. Bt. Ubaidullah and J. Hamid, "A Web-Based Screening System For Dyslexic Pupils: Do Teachers Need It?," *i-manager's J. Educ. Psychol.*, vol. 5, no. 4, pp. 15–23, 2012.

[16] J. A. C. Lee, S. Lee, N. F. M. Yusoff, P. H. Ong, Z. S. Nordin, and H. Winskel, "An Early Reading Assessment Battery for Multilingual Learners in Malaysia," *Front. Psychol.*, vol. 11, no. July, 2020.

[17] J. Stein, "What is developmental dyslexia?," *Brain Sci.*, vol. 8, no. 2, 2018.

[18] S. E. Shaywitz and J. Shaywitz, "The Historical Roots of Dyslexia," in *Overcoming Dyslexia: Second Edition, Completely Revised and Updated*, Hachette UK, 2020, pp. 9–17.

[19] G. R. Lyon, S. E. Shaywitz, and B. A. Shaywitz, "Defining dyslexia, comorbidity, teachers' knowledge of language and reading: A definition of dyslexia," *Ann. Dyslexia*, vol. 53, pp. 1–15, 2003.

[20] B. Peter, H. Lancaster, C. Vose, K. Middleton, and C. Stoel-Gammon, "Sequential processing deficit as a shared persisting biomarker in dyslexia and childhood apraxia of speech," *Clin. Linguist. Phonetics*, vol. 32, no. 4, pp. 316–346, 2018.

[21] R. Van Hecke *et al.*, "Vestibular Function in Children with Neurodevelopmental Disorders: A Systematic Review," *J. Autism Dev. Disord.*, vol. 49, no. 8, pp. 3328–3350, 2019.

[22] M. A. V. Marta Ferrero , Gillian West, "Is crossed laterality associated with academic achievement and intelligence? A systematic review and meta-analysis," *PLoS One*, vol. 12, no. 8, pp. 1–18, 2017.

[23] A. B. Kuerten, M. B. Mota, and K. Segaert, "Developmental dyslexia: A condensed review of literature," *Ilha do Desterro*, vol. 72, no. 3, pp. 249–270, 2019.

[24] B. D. Association, *Code of Practice Employers*, 6th ed. Printroom House, 2015.

[25] C. Maxwell, "Teacher Education on Dyslexia: An Analysis of Policy and Practice in Australia and England.," *Educ. Res. Perspect.*, vol. 46, pp. 1–19, 2019.

[26] W. J. M. Glover and J. Gunnar, *Principles and practice of screening for disease*, vol. 16, no. 4. World Health Organization, 1968.

[27] C. Singleton, "Intervention for dyslexia: Review of international research.," *Res. Stud.*, pp. 1–157, 2009.

[28] J. M. Carroll, J. Solity, and L. R. Shapiro, "Predicting dyslexia using prereading skills: The role of sensorimotor and cognitive abilities," *J. Child Psychol. Psychiatry Allied Discip.*, vol. 57, no. 6, pp. 750–758, 2016.

[29] A. E. Reynolds and M. Caravolas, "Evaluation of the Bangor Dyslexia Test (BDT) for use with adults," *Dyslexia*, vol. 22, no. 1, pp. 27–46, 2016.

[30] "Slingerland Screening," 2020. [Online]. Available: https://slingerland.org/Teachers/Screening. [Accessed: 09-Sep-2020].

[31] G. Reid, *Dyslexia: A Practitioner's Handbook*, 5th ed. Wiley-Blackwell, 2016.

[32] J. Hautala, R. Heikkilä, L. Nieminen, V. Rantanen, J. M. Latvala, and U. Richardson, "Identification of Reading Difficulties by a Digital Game-Based Assessment Technology," *J. Educ. Comput. Res.*, vol. 58, no. 5, pp. 1003–1028, 2020.

[33] G. Brookes, V. NG, B. H. Lim, W. P. Tan, and N. Lukito, "The Computerised-based Lucid Rapid Dyslexia Screening for the Identification of Children at Risk of Dyslexia: A Singapore Study," *Educ. Child Psychol.*, vol. 28, no. 2, pp. 119-, 2011.

[34] F. L. Bowman and V. Culotta, "Do I Have Dyslexia?," *International Dyslexia Association*. [Online]. Available: https://dyslexiaida.org/dyslexia-test/. [Accessed: 01-Sep-2020].

[35] R. D. Davis, "Is it Dyslexia?," *Davis Dyslexia Association International*. [Online]. Available: https://www.testdyslexia.com/. [Accessed: 21-Nov-2018].

[36] I. Smythe and J. Everett, "Dyslexia Test," *Dyslexic Advantage*, 2001. [Online]. Available: https://www.dyslexicadvantage.org/dyslexia-test/. [Accessed: 21-Nov-2018].

[37] "Screening for Dyslexia - Nessy UK." [Online]. Available: https://www.nessy.com/uk/screening-for-dyslexia/. [Accessed: 21-Nov-2018].

[38] Lexercise, "Z-Screener." [Online]. Available:

https://www.lexercise.com/tests/dyslexia-test. [Accessed: 21-Nov-2018].

[39] S. W. A. W. Norudin and S. Baba, "Literacy Difficulties of Dyslexic Students in Bahasa Malaysia : A Case Study in Kelantan," *Insa. Online J. Lang. Commun. Humanit.*, vol. 1, no. December, pp. 9–24, 2018.

[40] A. A. Abd Rauf, M. A. Ismail, V. Balakrishnan, and K. Haruna, "Dyslexic Children: The Need for Parents Awareness," *J. Educ. Hum. Dev.*, vol. 7, no. 2, 2018.

[41] F. Bungga, "School education's LINUS programme to end next year," *New Straits Times*, 2018.

[42] Y. L. Yu, M. F. Bin Othman, M. H. A. Wahab, S. Z. S. Idrus, and M. F. Bin Othman, "Unique English: An English Learning Application for Remedial Program Using Gamification Approach," *J. Phys. Conf. Ser.*, vol. 1529, no. 3, 2020.

[43] R. U. Khan, J. Lee, A. Cheng, and O. Y. Bee, "Machine Learning and Dyslexia : Diagnostic and Classification System (DCS) Machine Learning and Dyslexia : Diagnostic and Classification System (DCS) for Kids with Learning Disabilities," vol. 7, no. January, pp. 97–100, 2018.

[44] S. E. Shaywitz, M. D. Escobar, B. A. Shaywitz, J. M. Fletcher, and R. Makuch, "Evidence That Dyslexia May Represent the Lower Tail of a Normal Distribution of Reading Ability," *N. Engl. J. Med.*, vol. 326, no. 3, pp. 145–150, 1992.

[45] N. C. Pee *et al.*, "The framework of mobile dyslexia screening test using multiple-deficit theories," *Adv. Sci. Lett.*, vol. 23, no. 5, pp. 4000–4004, 2017.

[46] S. Nor *et al.*, "Classification Techniques for Early Detection of Dyslexia Using Computer-Based Screening Test," *World Appl. Sci. J.*, vol. 35, no. 10, pp. 2108–2112, 2017.

[47] S. N. W. Shamsuddin, N. S. F. N. Mat, and M. Makhtar, "Relevant test set using feature selection algorithm for early detection of dyslexia," *J. Fundam. Appl. Sci.*, vol. 9, no. 6S, 2017.

[48] F. J. Valverde-Albacete and C. Peláez-Moreno, "100% classification accuracy considered harmful: The normalized information transfer factor explains the accuracy paradox," *PLoS One*, vol. 9, no. 1, 2014.

[49] N. C. Pee, P. H. Leong, M. A. Othman, H. A. Sulaiman, M. F. I. Othman, and Y. A. Rahim, "DycScreen—Cross-Platform Dyslexia Screening Test for

Malaysian Children Through Hybrid Applications," *Lect. Notes Electr. Eng.*, vol. 362, pp. 891–902, 2016.

[50] S. Arumugam *et al.*, "DEVELOPING SYMPTOMATIC BEHAVIOR SCREENING TOOL (SYMBEST) FOR CHILDREN WITH BEHAVIOR PROBLEMS : A FUZZY DELPHI," vol. 3, no. 2, pp. 141–171, 2019.

[51] *Malaysia Education Blueprint 2013 - 2025 (Preschool to Post-Secondary Education)*. Ministry of Education Malaysia, 2013.

[52] N. Binti Abdullah and H. Binti Hanafi, "The Rights of Persons with Disabilities in Malaysia: The Underlying Reasons for Ineffectiveness of Persons With Disabilities Act 2008," *Int. J. Stud. Child. Women, Elder. Disabl.*, vol. 1, no. 1, pp. 127–134, 2017.

[53] K. Moore and J. Bedford, *Childhood Disability in Malaysia A Study of Knowledge, Attitudes and Practices*. United Nations Children's Fund (UNICEF) Malaysia, 2017.

[54] C. Singleton, "Using computer-based assessment to identify learning problems," *ICT Spec. Educ. Needs a Tool Incl.*, pp. 46–63, 2004.

[55] A. Casale, "Identifying Dyslexic Students : The need for computer-based dyslexia screening in higher education," *Estro Essex Student Res. Online*, vol. 1, no. 1, pp. 68–80, 2006.

[56] M. Khalid and G. Anjum, "Use of remedial teaching approaches for dys- lexic students : Experiences of remedial tea- chers working in urban Pakistan Maham Khalid and Gulnaz Anjum," *Cogent Psychol.*, vol. 6, 2019.

[57] A. Baratloo, M. Hosseini, A. Negida, and G. El Ashal, "Part 1: Simple Definition and Calculation of Accuracy, Sensitivity and Specificity," *EMERGENCY-An Acad. Emerg. Med. J.*, vol. 3, no. 2, pp. 48–49, 2015.

[58] M. N. Lytle, C. McNorgan, and J. R. Booth, "A longitudinal neuroimaging dataset on multisensory lexical processing in school-aged children," *Sci. data*, vol. 6, no. 1, p. 329, 2019.

[59] C. H. Lee and H. J. Yoon, "Medical big data: Promise and challenges," *Kidney Res. Clin. Pract.*, vol. 36, no. 1, pp. 3–11, 2017.

[60] V. S and D. S, "Data Mining Classification Algorithms for Kidney Disease Prediction," *Int. J. Cybern. Informatics*, vol. 4, no. 4, pp. 13–25, 2015.

[61] L. A. Zadeh, "Fuzzy Sets," *Inf. Control*, vol. 8, pp. 338–353, 1965.

[62] L. A. Zadeh, "A new direction in fuzzy logic-toward automation of reasoning

with perceptions," in *1999 IEEE International Fuzzy Systems Conference Proceedings*, 1999, pp. 1–5.

[63] J. Garza-Ulloa, "Application of mathematical models in biomechatronics: artificial intelligence and time-frequency analysis," in *Applied Biomechatronics using Mathematical Models*, Elsevier Inc., 2018, pp. 373–524.

[64] J. Alcala-Fdez and J. M. Alonso, "A survey of fuzzy systems software: Taxonomy, current research trends, and prospects," *IEEE Trans. Fuzzy Syst.*, vol. 24, no. 1, pp. 40–56, 2016.

[65] H. Selvi and M. S. Saravanan, "A Study of dyslexia using different machine learning algorithm with data mining techniques," *Int. J. Eng. Technol.*, vol. 7, no. 4, pp. 3406–3411, 2018.

[66] R. D. Chande, R. H. Hargraves, N. Ortiz-robinson, and J. S. Wayne, "Predictive Behavior of a Computational Foot / Ankle Model through Artificial Neural Networks," vol. 2017, 2017.

[67] S. Kodati and R. Vivekanandam, "Analysis of Heart Disease using in Data Mining Tools Orange and Weka," *Glob. J. Comput. Sci. Technol. C Softw. Data Eng.*, vol. 18, no. 1, pp. 16–22, 2018.

[68] S. Kodati and R. Vivekanandam, "A Comparative Study on Open Source Data Mining Tool for Heart Disease," *Int. J. Innov. Adv. Comput. Sci.*, vol. 7, no. 3, pp. 81–87, 2018.

[69] A. Haldar, G. P. Raj, and S. V. S. S. Lakshmi, "Comparison of Different Classification Techniques Using WEKA for Diabetic," pp. 509–516, 2018.

[70] F. D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology," *MIS Q. Manag. Inf. Syst.*, vol. 13, no. 3, pp. 319–339, 1989.

[71] V. Venkatesh and F. D. Davis, "Theoretical extension of the Technology Acceptance Model: Four longitudinal field studies," *Manage. Sci.*, vol. 46, no. 2, pp. 186–204, 2000.

[72] V. Venkatesh and H. Bala, "Technology Acceptance Model 3 and a Research Agenda on Interventions Subject Areas: Design Characteristics, Interventions," *Decis. Sci.*, vol. 39, no. 2, pp. 273–315, 2008.

[73] V. Venkatesh, "Determinants of Perceived Ease of Use : Intrinsic Control , Motivation , Integrating and Emotion into the Technology Acceptance," *Inf. Syst. Res.*, vol. 11, no. 4, pp. 342–365, 2000.

[74] F. D. Davis and V. Venkatesh, “Toward preprototype user acceptance testing of new information systems: Implications for software project management,” *IEEE Trans. Eng. Manag.*, vol. 51, no. 1, pp. 31–46, 2004.

[75] R. Noonan, H. Wold, R. Noonan, and H. Wold, “NIPALS Path Modelling with Latent Variables: Analysing School Survey Data Using Nonlinear Iterative Partial Least Squares,” *Scand. J. Educ. Res.*, vol. 21, no. 1, pp. 33–61, 1977.

[76] H. Wold and J.-L. Bertholet, “The PLS (Partial Least Squares) Approach to Multidimensional Contingency Tables,” *METRON*, vol. 40, no. 1–2, pp. 303–326, 1982.

[77] J.-B. Lohmoller, *Latent Variable Path Modeling with Partial Least Sqaures*. Physica-Verlag Heidelberg, 1989.

[78] M. Haseeb, H. I. Hussain, B. Slusarczyk, and K. Jermsittiparsert, “Industry 4 . 0 : A Solution towards Technology Challenges of Sustainable Business Performance is missing,” *Soc. Sci.*, vol. 8, no. 154, pp. 1–24, 2019.

[79] M. J. S. Diño and A. B. De Guzman, “Using Partial Least Squares (PLS) in Predicting Behavioral Intention for Telehealth Use among Filipino Elderly,” *Educ. Gerontol.*, vol. 41, pp. 53–68, 2015.

[80] M. Jung, R. Hun, S. Kim, and K. Chung, “Factors influencing the acceptance of telemedicine for diabetes management,” *Clust. Comput*, vol. 18, pp. 321–331, 2015.

[81] G. Mateos-Aparicio, “Partial least squares (PLS) methods: Origins, evolution, and application to social sciences,” *Commun. Stat. - Theory Methods*, vol. 40, no. 13, pp. 2305–2317, 2011.

[82] J. F. J. Hair, M. Sarstedt, C. M. Ringle, and S. P. Gudergan, “Chapter 1: An Overview of Recent and Emerging Developments,” in *Advanced Issues in Partial Least Squares Structural Equation Modeling*, SAGE Publications, 2018, pp. 1–36.

[83] V. Dutot, F. Bergeron, K. Rozhkova, and N. Moreau, “Factors affecting the adoption of connected objects in e-health: A mixed methods approach,” *Syst. d’Information Manag.*, vol. 23, no. 4, pp. 31–66, 2018.

[84] G. Hancerliogullari Koksalmis, “Drivers to adopting B-flow ultrasonography:contextualizing the integrated technology acceptance model,” *BMC Med. Imaging*, vol. 19, no. 1, pp. 1–13, 2019.

[85] C. F. D. F. Larcker, “Evaluating Structural Eqaution Models with Unobservable

Variables and Measurement Error," *J. Mark. Res.*, vol. XVIII, no. February, pp. 39–50, 1981.

[86] S. N. Ismail, Z. Abdullah, and R. Mustapha, "The practice of professional learning community in trust schools, transformation schools and high performing schools in Selangor Malaysia," *Int. J. Adv. Sci. Technol.*, vol. 28, no. 16, pp. 1853–1868, 2019.

[87] M. Salam and M. S. Farooq, "Does sociability quality of web-based collaborative learning information system influence students' satisfaction and system usage?," *Int. J. Educ. Technol. High. Educ.*, vol. 17, no. 1, 2020.

[88] M. A. Robinson, "Using multi-item psychometric scales for research and practice in human resource management," *Hum. Resour. Manage.*, vol. 57, no. 3, pp. 739–750, 2018.

[89] J. Johnson, *Designing with the Mind in Mind: Simple Guide to Understanding User Interface Design Guidelines*, Third. Katey Birthcher, 2021.

[90] "Fuzzy Logic Toolbox Documentation." [Online]. Available: https://www.mathworks.com/help/fuzzy/. [Accessed: 11-Dec-2018].

[91] M. Langarizadeh, "Applying Naive Bayesian Networks to Disease Prediction : a Systematic Review," *Acta Inform. medica AIM J. Soc. Med. Informatics Bosnia Herzegovina*, vol. 24, no. 5, pp. 364–369, 2016.

[92] S. Bala, A. Kumar, and T. S. Kamal, "An Approach for Diabetes Detection using Data Mining Classification Techniques," vol. 6913, no. 63019, pp. 202–218, 2017.

[93] A. Uzelac, N. Gligorić, and S. Krčo, "System for recognizing lecture quality based on analysis of physical parameters," *Telemat. Informatics*, vol. 35, no. 3, pp. 579–594, 2018.

[94] I. Fishbein, M., & Ajzen, *Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research*. Reading, MA: Addison-Wesley, 1975.

[95] G. C. Moore and I. Benbasat, "Development of an instrument to measure the perceptions of adopting an information technology innovation," *Inf. Syst. Res.*, vol. 2, no. 3, pp. 192–222, 1991.

[96] D. R. Compeau and C. A. Higgins, "Application of Social Cognitive Theory to Training for Computer," *Inf. Syst. Res.*, vol. 6, no. 2, pp. 118–143, 2014.

[97] R. Scherer, F. Siddiq, and J. Tondeur, "The technology acceptance model (TAM): A meta-analytic structural equation modeling approach to explaining

teachers' adoption of digital technology in education," *Comput. Educ.*, vol. 128, no. 0317, pp. 13–35, 2019.

[98] V. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis, "User acceptance of information technology: Toward a unified view," *MIS Q. Manag. Inf. Syst.*, vol. 27, no. 3, pp. 425–478, 2003.

[99] A. Ringle, Christian M., Wende, Sven, Will, "SmartPLS 2.0.M3. Hamburg: SmartPLS.," 2005. .

[100] M. Sarstedt, C. M. Ringle, and J. F. Hair, *Handbook of Market Research*, no. September. 2020.

[101] J. F. J. Hair, G. T. M. Hult, C. Ringle, and M. Sarstedt, *A Primer On Partial Least Squares Structural Equation Modeling (PLS-SEM)*. 2017.

[102] R. P. Bagozzi and Y. Yi, "On the evaluation of structural equation models," *J. Acad. Mark. Sci.*, vol. 16, no. 1, pp. 74–94, 1988.

[103] J. F. Hair, M. Sarstedt, C. M. Ringle, and J. A. Mena, "An assessment of the use of partial least squares structural equation modeling in marketing research," *J. Acad. Mark. Sci.*, vol. 40, no. 3, pp. 414–433, 2012.

[104] J. Henseler, C. M. Ringle, and M. Sarstedt, "A new criterion for assessing discriminant validity in variance-based structural equation modeling," *J. Acad. Mark. Sci.*, vol. 43, no. 1, pp. 115–135, 2014.

[105] C. M. Ringle, M. Sarstedt, R. Mitchell, and S. P. Gudergan, "Partial least squares structural equation modeling in HRM research," *Int. J. Hum. Resour. Manag.*, vol. 31, no. 12, pp. 1617–1643, 2020.

[106] J. F. Hair, C. M. Ringle, and M. Sarstedt, "PLS-SEM: Indeed a silver bullet," *J. Mark. Theory Pract.*, vol. 19, no. 2, pp. 139–152, 2011.

[107] D. Bzdok, M. Krzywinski, and N. Altman, "Machine Learning: A Primer," *Nat. Methods*, vol. 14, p. 1119, 2017.

[108] J. Hulland, "Use of Partial Least Sqaures (PLS) in Strategic Management Research: A Review of Four Recent Studies," *Strateg. Manag. J.*, vol. 20, pp. 195–204, 1999.

[109] J. Gaskin, S. Godfrey, and A. Vance, "Successful System-use: It's Not Just Who You Are, But What You Do," *AIS Trans. Human-Computer Interact.*, vol. 10, no. 2, pp. 57–81, 2018.

[110] A. Raes and F. Depaepe, "A longitudinal study to understand students' acceptance of technological reform. When experiences exceed expectations,"

Educ. Inf. Technol., vol. 25, no. 1, pp. 533–552, 2020.

[111] P. E. Ramírez-Correa, J. Arenas-Gaitán, and F. J. Rondán-Cataluña, "Gender and acceptance of e-learning: A multi-group analysis based on a structural equation model among college students in Chile and Spain," *PLoS One*, vol. 10, no. 10, pp. 1–17, 2015.

[112] L. Y. K. Wang, S. L. Lew, S. H. Lau, and M. C. Leow, "Usability factors predicting continuance of intention to use cloud e-learning application," *Heliyon*, vol. 5, no. 6, p. e01788, 2019.

[113] E. Yeşiltaş, "Examining the Relationship between Social Studies Teachers' Attitudes towards Computer Assisted Education and Their Self-Efficacy Perception," *Int. Online J. Educ. Sci.*, vol. 9, no. 2, 2016.

[114] S. Ozdemir, "Basic Technology Competencies, Attitude towards Computer Assisted Education and Usage of Technologies in Turkish Lesson: A Correlation," *Int. Educ. Stud.*, vol. 10, no. 4, p. 160, 2017.

[115] C. Singleton, "Using computer-based assessment to identify learning problems," *ICT Spec. Educ. Needs a Tool Incl.*, pp. 46–63, 2004.