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Technology-assisted Dysgraphic Children Handwriting Model

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Abstract

Difficulties in handwriting or dysgraphia can have a negative effect on one's self-esteem and academic achievement in school. This phenomenon is considered a detriment when students have difficulty expressing knowledge through writing; causing extra hardship in mastering all subjects they are learning. Past studies did not deliberate on specific components related to the intervention of dysgraphic students' handwriting skills development comprehensively, as can be seen in today's existing handwriting models. Therefore, this study focused on the underlying models of dysgraphic students'involving the main components in the writing process, and the components of ICT support. The principles of modeling with the potential impact of 1) visualization, 2) imagination, and 3) automation in writing need to be considered in addition to the mastery of writing skills. With such a specific model, solutions to these dysgraphic students' handwriting skill problems can be generalized. Therefore, the main objective of this study was to propose a technology-assisted Dysgraphic Children Handwriting Model (DCHM) to address the problems encountered. This DCHM was validated by four experts – three special education teachers and a paediatric and adolescent psychiatrist. The resulting score was calculated as a percentage value based on the total score obtained for each question. The average percentage for all the criteria evaluated was 91.5%. Overall, all four experts agreed on the key components of the DCHM supported by the ICT component. This study is important for considering handwriting development more holistically and to identify the performance of students' handwriting in the context of a robust handwriting model.

Keywords: *Technology-assisted Dysgraphic Children Handwriting Model, dysgraphia, dysgraphic children, letter formation, ICT support.*

1. Introduction

The handwriting difficulty among students is known as dysgraphia, which is categorized as one of the branches of a specific learning difficulty. Generally, dysgraphia refers to the difficulties faced in relation to handwriting and spelling below expected levels, when compared to other students of the same age (Prunty & Barnet, 2017; Lippincott, 2017). Previous studies did not weigh on the specific components related to intervention of handwriting skill development in dysgraphic children, as was reported by Yusop and Walter (2010), Gunarhadi, Heremawan, Maheadika, Rejeki and Yasin (2017), Hanewall (2011), Khaledi, Pak, Mirkhan and Atai (2014), Azimi and Mousavipour (2014), Raza, Arif, Drvagheh and Hajjdiab (2017), Giordano and Maiorana (2014, 2015) and Kandel, Lassus-Sangosse, Grosjacques and Perret, (2017). In a study conducted by Khaledi, Pak, Mirkhan and Atai (2014), Azimi and Mousavipour (2014), Raza, Arif, Drvagheh and Hajjdiab (2017), and Giordano and Maiorana (2014, 2015), as examples, developed software and applications that are able to improve handwriting skills involving students diagnosed with dysgraphia. However, the output of the study was limited and it was not hinged on the development of a specific model of students with dysgraphia.

With the development of specific models, solutions to the dysgraphic students' handwriting skill problems can be realized. Therefore, this study focused on the development of a handwriting model, namely the technology-assisted Dysgraphic Children Handwriting Model (DCHM), in addressing problems encountered by these children. The introduced model is also a combination of existing handwriting models in ensuring that a synergy exists between the assisting components, namely visualization, imagination, and automation, to support students with dysgraphia. The main objective of this study is to design a DCHM model with a positive constructive impact on dysgraphic students' command of handwriting, while being assisted by computer software and hardware. The effects that were considered for this study include visualization, imagination, and automation. This DCHM aims to explore the handwriting weaknesses of dysgraphic students and to improve their writing skills effectively.

In this regard, this model can potentially serve as a reference and possible solution to other specific learning difficulties, as well as for normal students. This is in line with the Malaysian Education Development Plan (*Pelan Pembangunan Pendidikan Malaysia - PPPM*) 2013- 2025 which consists of three Phases, namely Wave 1 (2013-2015), Wave 2 (2016-2020) and, Wave 3 (2020-2025), aiming to provide the best education for all pupils, including Special Needs Students (*Murid Berkeperluan Khas - MBK*). Therefore, technology-assisted DCHM for dysgraphic students is a necessity at present since the government envisages the Zero-reject Policy to be fully implemented for MBK.

The gap in assistive technology is even more evident when there is no single tool that measures its effectiveness systematically and consistently. This model enables the product to be constructed and its performance measured. The physical construction of the product that is structured, systematic, and organized, is highly dependent on this model. Therefore, the dysgraphic-customized application allows dysgraphic students to practice handwriting using tablets developed based on DCHM components. The application was designed to be interactive to ensure that students are actively involved in the whole assessment process. Intervention using the application focused on the letter-making process to produce and improve the overall writing process. Through this intervention, emphasis was also placed on improving the process of retrieving information quickly from memory and thus improving visual-motor integration. The students were able to use the application using a tablet as a handwriting activity in their respective classrooms. The procedure used was to emphasize the relationship between the use of technology and the problem at hand that is currently being faced.

2. Related Handwriting Models

Various handwriting models have been proposed in past studies, namely Dual-route Model of Spelling (Ellis & Young, 1996; Whitworth, Webster & Howard, 2005), Van Galen's Psychomotor Handwriting Model (Lassus-Sangosse & Grosjaques, 2017), Not-so Simple View of Writing (Costa, 2008), and *Model Seni Bina Aplikasi* (Tariq & Latif, 2016). Even though these four models do not cover the handwriting disadvantages faced by students in particular, they are important and serve as a framework for understanding the development of handwriting among students, which forms the basis of this study. Components of the existing models were also studied to determine and predict the risk of writing difficulties faced by students with dysgraphia.

A study conducted by Kandel, Lassus-Sangosse, and Grosjaques (2017) highlighted that there is an interaction between orthographic processes and peripheral motor production using the Dual-route Model of Spelling, and Van Galen's Psychomotor Model of handwriting as a reference. Studies on the handwriting performance of dysgraphic students reported that these students have difficulty in three of Van Galen's (1991) motor processes, namely selection of allograph, size control, and muscular adjustment (Prunty & Barnett, 2017). Based on the discussed models, a summary of the analysis of the main components related to these models are shown in Table 1.

Table 1: Summary of Literature Related to Model Development

Model	Importance of the Model	Model Components
Not-so-simple view of writing *(Berninger & Winn, 2006)*	Includes full development of children's writing skills	• Transcription • Executive Function • Text Generation • Working Memory
Dual-route model of spelling *(Ellis & Young, 1996; Whitworth, Webster & Howard, 2005)*	Demonstrating word production involving the efficiency of two complex processes: 1) spelling retrieval and 2) motor reproduction.	• Phonology • Lexicon • Orthography • Semantic System • Output Grapheme Buffer
Van Galen's Psychomotor model of handwriting *(1991)*	It is important to outline the processes involved in handwriting skills and the effects of cognitive and motor problems.	• Cognitive / language • Spelling • Motor Process
Model seni bina aplikasi (Tariq & Latif, 2016)	Enhance the development of dyslexic students' handwriting problems with technology assistance.	• Tracing • Copying

Table 1 provides a concise summary of the components involved in the development of handwriting skills. However, these models do not focus on the visual, imagination, and automation components needed by dysgraphic students in the drawing process of producing writing. From research and observation, most dysgraphic students have problems related to their imagination and visualization skills, which involve the ability to visualize the letters and words they want to create (Nalpon & Chia, 2009; Chia, 2005; Julius, Meir, Shechter-Nissim & Adi-Japha, 2016; Chia & Ong, 2009). As such, this study focused on the needs of imagination and visualization, and thus the resulting automation in the handwriting process, and in support of other skills development. Based on the existing models, the components identified for use as reference in designing the DCHM are: 1) transcription (graphomotor and orthography), 2) text generation, and 3) cognition. These components are then combined with the requirements related to imagination, visualization, and automation which are the major disadvantages faced by dysgraphic children.

3. Technology-assisted Dysgraphic Children Handwriting Model (DCHM)

Overall, DCHM consists of two main areas for achieving proficiency in writing, which are the process of letter formation and ICT support. The letter formation process involves five components that are classified into two categories, namely low-level skills (transcription component that involves graphomotor and orthography) and high-level skills (involving visualization, imagination, text generation, and cognitive components). In general, transcription refers to the process of orthographic representation, neuromuscular activation, and the execution of fine motor movements. Notably, high-level skills involve cognitive processes consisting of syntax, semantics, idea generation, and translating thoughts into written words or forms. Studies on handwriting acquisition showed that coordination of perceptions, motor processes, and cognitive processes are important for the production of proficient and efficient handwriting movements (Giordano & Maiorana, 2015; Gerth, Klassert, Dolk, Fliesser, Fischer, Nottbusch & Festman, 2016). Berninger (1994) emphasized that this transcription skill is fundamental to learning because its failure can be a hindrance to the higher levels of handwriting process.

To enhance letter formation skills, the addition of ICT support components involving letter-forming animation, control, tracing, arrow animation, feedback, and repetition are employed. These components are important to improve the structure of the dysgraphic students' alphabet formation, and thus enable the writing to be smooth and neat. Student handwriting movements require graphomotor support, visual feedback, as well as constant control of movement during writing (Maldarelli, Maldarelli, Kahrs, Hunt & Lockman, 2015; Gerth et al., 2016). This technology-supported component is also intended to enhance dysgraphic students' visual memory skills in enabling them to identify, memorize, and visualize letters. Visual memory deficit can cause problems that may possibly make it difficult for students to store the information needed to build orthographic long-term memory representations (McCloskey & Rapp, 2017). Overall, the DCHM to improve handwriting skills of dysgraphic students can be referred to in Figure 1.

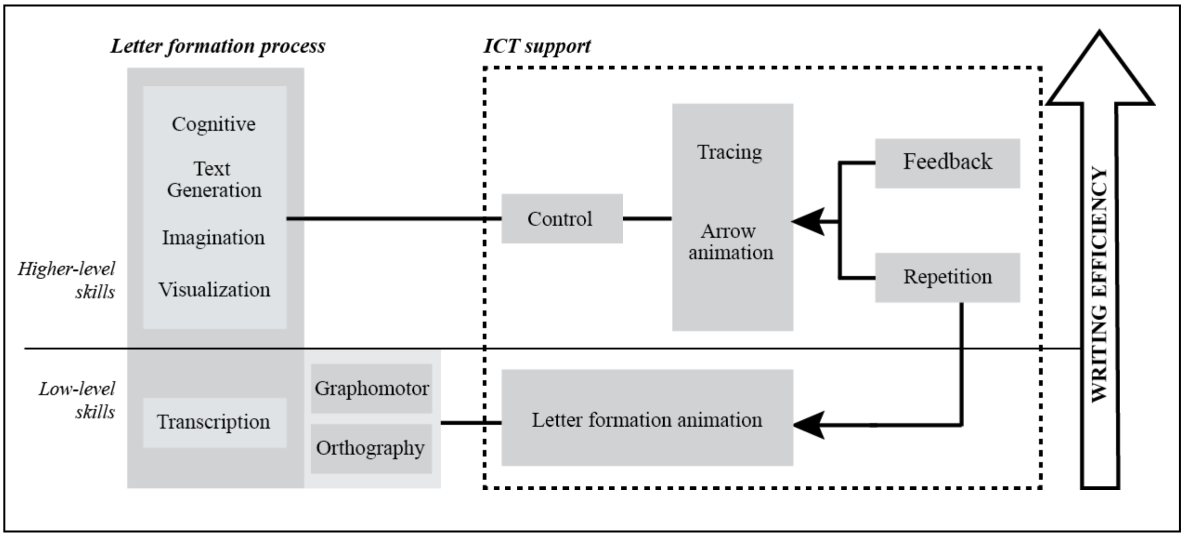

Figure 1: Technology-assisted Dysgraphic Children Handwriting Model (DCHM)

Figure 1 shows the DCHM based on the components required to improve dysgraphic students' handwriting skills. The concept of this model was chosen to clarify the interaction between the process of letter formation and technology support to improve writing efficiency. A comparison of components involving letter formation and technology support, as well as the functions involved, is presented in Tables 2 and 3.

Tables 2: DCHM Process of letter formation components

	Components	Function
Low-level skills	Transcription	Handwriting (graphomotor) – Supervises a series of motor movements required for handwriting. Spelling (orthography) – Storing and retrieving orthographic code (letter shape) from memory.

Higher-level skills	Visualization	Learn, describe, and memorize each letter or word recognition technique supported by memory and motor cues.
	Imagination	Thoughts and ideas are important for producing a written product.
	Text Generation	Refers to the transformation of ideas into languages and the main goals of writing. Occurs when dysgraphic students learn to produce letters.
	Cognitive	The process that involves attention is the activation of the purpose of writing. At this stage automatic writing can be generated.

Table 3: DCHM ICT support components

Component	**Function**
Letter formation animation	Assists students learn and understand the techniques of letter formation through the animation of the whole text which creates positive impact
Control	Allows teachers to determine the level of development for each student and can monitor his/her progress through the scoring data obtained.
Tracing	Requires students to do finger tracing and assistance in the form of instructions is easy.
Arrow animation	Introduces correct order of letter formation to students using arrow animations.
Feedback	Provides instant and effective feedback in visual as well as sound.
Repetition	Improves the efficiency and fluency of writing by repeated letter-writing activities

4. Main Components of DCHM

The transcription skill is the first skill that needs to be learned and it is essential to reflect the students' capability and proficiency in writing. Difficulty in mastering this skill can lead to disruption of high-level processes required for text composition (Berninger & Hooper, 2006; Berninger, Abbott, Augsburge & Garcia, 2009; Richards, Berninger & Fayol, 2009). Handwriting difficulties can be effectively assisted at the basic level of writing by teaching early specialization in transcription to support and enhance the writing composition.

According to King (2000) and Duel (1995), students with dysgraphia also face challenges that result in producing unreadable texts. This reflects on their inability to visualize letters from memory and difficulty in memorizing motor letter patterns. The inability to draw letters refers to the problem of visualization, as they need to memorize every letter and word (Kay, 2007). Visualization also requires students to master the visual space organization to estimate the space between letters and words. Students with learning difficulties face significant barriers when it comes to text generation because they lack fluency and automaticity in the required skills, such as word retrieval, spelling, grammar, and even the process of handwriting itself (Santangelo, 2014; Berninger & Winn, 2006). Collectively, these difficulties can adversely affect students' handwriting and affect their ability to generate text in other critical processes, such as planning and revising handwriting. In addition to mastering handwriting skills, modeling principles and techniques with impact probabilities involving 1) visualization, 2) imagination, and 3) automation need to be taken into account.

Technology assistance is needed to enhance the basic skills required by dysgraphic students in forming letters, and thus enhancing their overall ability in the handwriting process. Especially for dysgraphic students, technology support in DCHM provides components that can enhance the performance of letter formation. The control component allows students to engage in handwriting activities with varying degrees of difficulty based on their learning level. Through this component, learning and teaching can be performed specifically where the teacher determines the learning level and assesses each student's progress based on the previously identified weaknesses. Additionally, the tracing component that employs arrow animations in the correct order for letter formation can give students a visual representation of correct letter formation procedure, as supported by a study by Khan, Hussain, Ahsan, Nadeem, Ali, Mahmood & Rizwan (2017). Animations in the display of text in the correct sequence can have a positive effect and help students to memorize letter-forming techniques visually. Tracing using fingers can improve the memory process in recovering the letter-forming procedure. The level of performance of the handwriting skills, including letter formation, can be attributed to repeated tracing exercises (Lifshitz & Har-Zvi, 2015; Puranik & Al Otaiba, 2012).

Because handwriting involves motor skills, continual practice and repetition are necessary. Students must at the very least practice and be exposed to each letter at least five to ten times before being engaged in the next activity (Dinehart, 2015; Hoy, Egan, & Feder 2011). This will automatically improve handwriting speed and can reduce problems related to slow movement, difficulty with movement perception, difficulty with letter-forming from memory, and drawing letters before forming them. Repetition is necessary to enable the learning to be set in long-term memory. In addition, the feedback component is also important as an instant reference for students in relation to a mistake. Feedback is provided during the tracing process in visual and audio forms. Instant feedback should encourage them to focus on the mistakes made and correct them immediately. Visual feedback should be accompanied by objective parameters that students understand.

Overall, handwriting requires training to produce automaticity in writing. Automation is achieved when students are able to generate alphabets from memory as quickly as possible while taking into consideration readability and proper arrangement. Accurate and automatic abilities in letter formation can reduce the use of cognitive resources that can be channeled or used during high-level cognitive processes while writing (Berninger, 2002; Graham, 2010). Generating letters quickly is an automatic ability in the writing process where letters and how to form them are stored and recalled from memory instantly.

5. Validation of DCHM

The model validation process was implemented by four specialists, consisting of three special education teachers and one paediatrician specializing in adolescent and child psychiatry from Sultanah Bahiyah Hospital. All experts are those involved in the Outreach Program conducted by the Kedah State Education Department and have at least 12 years of experience. Details of the DCHM model and the relationship between the components are explained to the expert in advance. Subsequently component assessment is done with awareness of evaluation criteria ranging from various skills to cognitive processes involved in writing skills through assessment instruments in the form of questionnaires. The selection of experts in this field was made based on the components found in the DCHM model. The components involved are components related to the dysgraphic students' handwriting skills. The results of the evaluation showed that the experts have endorsed the DCHM components.

6. Finding

The criteria used are in line with the criteria to be considered in the handwriting process, such as the assessment of fine motor difficulties, the inability to remember the motor pattern of each letter, the problem of recalling the letters as well as the cognitive process (Julius, Meir, Shechter-Nissim, & Adi-Japha, 2016; McCloskey & Rapp, 2017; Black & Jones, 2018). The assessment criteria can range from various motor processes to cognitive processes involved in writing skills and are categorized as general criteria. The evaluation instruments used were referred to and modified from the Shahbani 2011 study (as cited in Yusnita, 2018). The questionnaire-based assessment instrument consisted of 10 questions using a Likert scale of 1 (strongly disagree) to 5 (strongly agree). Question 1 to Question 6 included general assessment criteria for the entire model, while Question 7 to Question 10 assessed the components of the letter-forming and technology support processes.

The criteria covered in this study are S1) the model is easy to understand, S2) the sequence and process involved are clear, S3) the proposed DCHM components are appropriate and necessary to enhance the dysgraphic students' handwriting skills, S4) this model assists in understanding and learning handwriting by emphasizing skills involved from transcription to cognitive processes, S5) the principles and techniques of modeling with the potential impact on handwriting mastery are emphasized to ensure synergy in each component used, S6) DCHM can contribute to the development of handwriting applications that address specifically the needs of dysgraphic students, S7) transcription components that involve orthography (letter shaping) and graphomotor (hand and finger coordination for producing handwriting), aided by technology support components including letter-forming animation and required repetition in low-level skills, S8) technology support components (control, tracing, arrow animation, feedback, and repetition) are needed to improve the efficiency of high-level skills of letter-forming components, S9) automaticity at the cognitive level is important for producing letters from memory in a short period of time with proper formation procedures which in turn improves writing efficiency, and S10) the DCHM which emphasizes visualization, imagination, and automation as well as technology support can have an impact on the overall dysgraphic students' handwriting ability. The resulting score was calculated as a percentage value based on the total score obtained for each question. The results obtained are shown in Table 4.

Table 4: Results of the Model Validation

Questions (S)/ Experts (P)	P1	P2	P3	P4	Total	Percentage
S1	5	5	5	4	19	95%
S2	5	5	4	4	18	90%
S3	5	4	4	4	17	85%
S4	5	4	5	4	18	90%
S5	5	5	4	4	18	90%
S6	5	5	5	4	19	95%
S7	5	5	5	4	19	95%
S8	5	5	5	4	19	95%
S9	4	5	5	4	18	90%
S10	4	5	5	4	18	90%
Average Percentage						91.5%

Overall, all four experts agreed on the key components of DCHM supported by the ICT component. The need for ICT support that involves tracing, arrow animation, feedback, and repetition can be seen as very helpful to students suffering from dysgraphia, especially in the proper letter formation process. Students benefit from the aid of this technology, whilst at the same time making the teaching process more effective. The average percentage for all evaluated criteria was 91.5%.

In general, all the experts participating in the validation process agreed on the technology-support components used. Student handwriting movements require graphomotor support, visual feedback as well as constant control of movement during writing. This technology-support component is also aimed at improving the visual memory skills of students with dysgraphia. It is intended to enable them to identify, memorize, and define the visual form of letters. The tracing component, arrow animation, and repetition can be used as letter-forming learning approaches to strengthen recall in relation to the motor sensory process. The components used can improve the handwriting fluency of students with dysgraphia.

7. Discussion and Conclusion

This study can potentially contribute to policy makers, students, parents, researchers, software developers, and especially those in the field of special education, specifically the teachers. This is because, like most other learning problems, dysgraphia can be a lifetime challenge because the ability to produce good handwriting and the correct writing skills are essential for producing a neat, easy-to-read writing product and at the same time boost students' confidence during their learning and teaching processes in school.

Components of the letter-forming process and ICT assistance are seen as indispensable and can provide support to meet the needs of dysgraphic students. Two experts stated that the tool development based on the model can be rated as excellent and can potentially help students with difficulty in writing because the tools are reinforced with visualization components that assist students in the process of visualizing the correct form and shape of writing before translating it into handwriting form. Through teaching experience, it was discovered that students with dysgraphia face short-term and long-term memory difficulties. Therefore, the components of repetition and arrow animation are seen to be very helpful to students in improving their letter-forming process. This in turn would positively affect the sequence of letter formation in their memory to become automatic and it can be translated smoothly into handwriting. Dysgraphic students also have a short attention span in their learning process. The use of this technology is seen as helping students to focus on learning by engaging them over a longer period of time.

Overall, one of the experts stated that this model can be rated as highly accurate with the support of the integrated technology. This is because the model uses motor learning theory which is considered to be very helpful in facilitating the handwriting process. When the handwriting becomes automatic, attention can be directed to the high-level cognitive processes responsible for planning ahead in writing. Proper letter formation is important as it contributes to student academic success. All participating validators agreed on the DCHM components being included with the support of technology to improve the handwriting ability of dysgraphic students. As a summary or recommendation, the questionnaire instrument also provided an opportunity for the expert to come up with suggestions where relevant. Through the suggestions provided by the experts, the use of pencils should also be exposed to students earlier to improve their writing skills in conjunction with the use the computer application.

DCHM can be used to facilitate and improve handwriting proficiency among students with the support of technology. The findings showed that the components of ICT support are seen as very helpful for students in producing handwriting that emphasizes on the actual process of letter formation as the basis for improved learning. Through the implementation of DCHM in the form of an application in a tablet, students are provided with activities that enhance their visualization skills and can therefore result in more proficient automatic writing. Visualization, imagination, and automation are essential for producing good handwriting skills. This DCHM can impact on ensuring synergy in all the supporting components (graphomotor, orthography, memory and word processing, working memory capacity, and language ability) integrated in the application for dysgraphic students. Specific learning and teaching strategies require specific support for each category of students with different learning abilities and difficulties. Amongst all the strategies that have been developed, the one proposed is to create bilateral interactions and social situations in the classroom.

Having achieved the objectives of this research, a new contribution can be made to the special education field in Malaysia, in particular. This study explored the techniques of handwriting through new intervention strategies that have the potential to improve and revolutionize education, especially for students with dysgraphia and special education teachers. The theories, concepts, and methods used in this study are relevant to educators and researchers alike.

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