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Development of Kanji Learning Materials for Dysgraphia and EEG Measurement

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Abstract. The primary aim of the research project is to develop instructional materials for Kanji learning, specifically targeting students facing difficulties or disabilities in writing. The effectiveness of traditional methods, emphasizing extensive reading and extensive handwriting to enhance brain working memory, has been questioned due to significant accumulations of fatigue and stress revealed in EEG results. To address these concerns, an innovative approach is proposed, focusing on the efficient development of a method to train the brain's working memory in Kanji learning, heightened by increased awareness of spatial cognition. This method is implemented in high schools and universities, with subsequent measurement of its effects. Iterative improvements is made based on the school feedback and the effectiveness assessments, including enlarging character size and enhancing spatial cognition skills associated with characters to optimize the efficacy of character learning. In this study, we introduce an evaluation of the proposed educational method by the measurement of rhythms in the Electroencephalograms (EEGs).

Keywords: Cognitive Science · Educational Technology · Japanese Language Education · Kanji · Teaching

1 Introduction

In the course of our research aimed at the scientific analysis of written characters and the development of efficient methods for learning them in Japan, we observed that many students are erroneously learning the forms of kanji characters. Traditional methods of teaching kanji involved repeatedly writing the same characters in notebooks, with students required to memorize them through iterations of 10 or 20 repetitions. If a student forgot a particular kanji, they were instructed to write it an additional 10 or 20 times until the character was firmly retained. From a neuroscientific perspective, it is understood that memory is not eternally enduring, and it is believed that reinforcing learning through repeated recall each time it is forgotten contributes to long-term retention. However, despite diligent efforts, accurate memorization is often elusive. Consequently, we have decided to develop instructional methods that facilitate the rapid and accurate memorization of kanji for orderly writing.

Research on pedagogical approaches to kanji acquisition is currently dominated by a culmination of past studies, with significant gaps in continuity. Various methods have been proposed, including those emphasizing extensive handwritten practice, teaching the origin of characters using brushes, and adopting an analytical approach to systematically learn kanji by breaking them down into constituent elements. While each method has its inherent limitations, resolving these challenges remains elusive.

Furthermore, in the field of Japanese language education for non-native speakers, there has been minimal attention given to the pedagogical nuances of kanji instruction. This oversight appears to stem from the perception that kanji learning is considered straightforward and simple compared to the time dedicated to grammar and conversation. Additionally, the scarcity of scholars specializing in kanji instruction within the field of Japanese language education contributes to this research gap.

To address this academic void, our research adopts three distinct strategies. The first focuses on strategies within special education, the second integrates the methodology of cognitive science, and the third explores strategies based on principles of neuroscience.

2 Experimental Method

2.1 Special Support Education Measures

Within the Japanese educational milieu, the historical focus of special support education has revolved around addressing the requirements of children with disabilities, thereby prompting the frequent proposition of inventive pedagogical methodologies. A notable exemplification is the Color Frame Notebook, delineated in Fig. 1, designed as an instructional tool to facilitate letter recognition for children with disabilities who may encounter challenges in discerning letter shapes (Akiko Wakiguchi et al., 2019).

In the capacity of a researcher specializing in Kanji education in Japan, the author has undertaken numerous experiments involving students requiring special support, as illustrated in Fig. 2. Substantive insights have emerged from these experiments.

Primarily, among students facing difficulties in memorizing letter shapes, the experiment disclosed their capacity to acquire such knowledge through a straightforward process involving connecting dots and drawing lines. For students contending with challenges in procedural memory, the hurdle lies in establishing associations and eliciting memory without overtly conveying the learning objective. It is noteworthy that a considerable number of students in mainstream educational settings grapple with concentration issues during learning, leading to compromised learning efficacy. Nevertheless, by integrating strategies informed by special needs education, there is an anticipatory enhancement in learning effectiveness.

2.2 Cognitive Science Measures

In order to comprehend strategies for memorizing kanji characters, an examination from the perspective of cognitive science is imperative. Firstly, according to a study conducted at Cornell University in 2011, when a list of words written in the alphabet was presented in various font sizes rather than in kanji, there was a reported increase in the ease of

memorization for words displayed in larger fonts. Additionally, research conducted at Princeton University and Indiana University indicated an improvement in the performance of participants who studied materials presented in difficult-to-read fonts. It is crucial to note, however, that this phenomenon is influenced by the fact that while the alphabet represents only sounds, kanji encompasses both meaning and sound.

To explore this aspect further, we conducted a preliminary experiment. Two sets of characters, one in 170 pt (5 cm) and the other in 18 pt (0.5 cm), were presented to students, and learning sessions comprising 10 characters each were conducted for 5 min. The results revealed that the accuracy rate for larger characters was approximately 60%, whereas for smaller characters, it was about 40% (Fig. 3). These findings suggest a tendency for a relatively higher learning effect with larger characters.

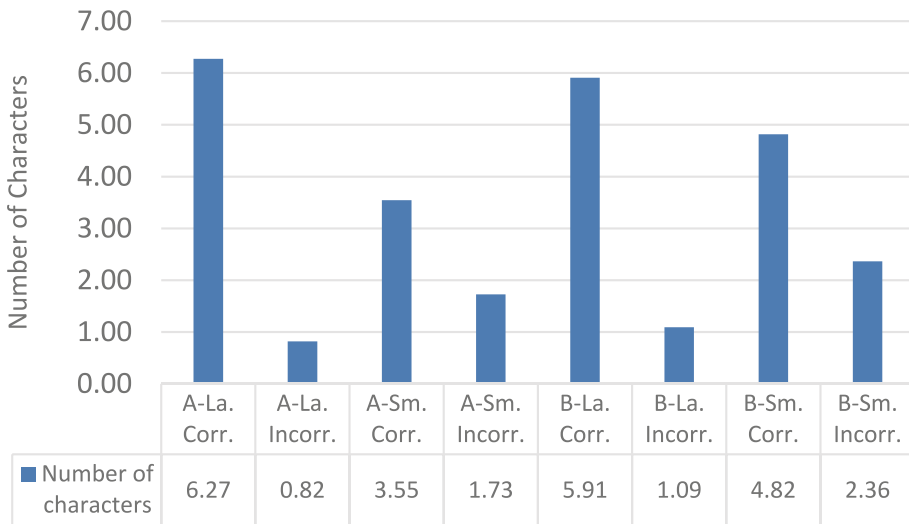


Fig. 3. Memory differences due to learning materials with different font sizes.

2.3 Neuroscientific Measures

The third consideration involves a neuroscientific analysis aimed at optimizing memory resources. Specifically, we focus on the association areas within the cerebral cortex responsible for short-term memory. This region demonstrates a close relationship with sensory inputs and other perceptual modalities, emphasizing its essential role in multi-sensory involvement in the learning process, including activities such as writing, reading, speaking, and listening—a concept akin to what is referred to as working memory in cognitive psychology.

We designate the approach depicted in Fig. 4 as the “Flexible Dimension Modification Learning Method.” This learning method enables a concise explanation of complex cognitive processes, revealing that writing is a high-dimensional memory task. The method involves adjusting the dimensions of learning based on methods, preferences, and necessity.

The conventional method of learning kanji, involving the repetitive handwriting of the same character 20, 30, or even 100 times, is a highly intricate memorization method, and studies have shown that it is time-consuming for rote memorization. Additionally, memory tasks with three or more dimensions can lead to incorrect memories, accompanied by noise.

In contrast, the proposed learning method offers a one-dimensional memory model similar to single-task learning, particularly for children in their early years or those with learning disabilities. For high school students or adults, it provides a high-dimensional learning approach, allowing the utilization of rich memory resources tailored to individual characteristics and optimizing memory retention. While sensory memory inherently has limitations, this method aligns well with the goal of kanji learning, which focuses on acquiring the visual representation of characters.

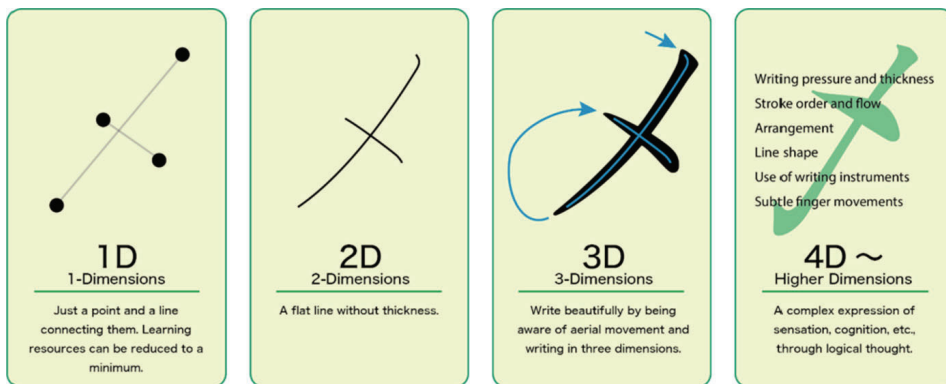


Fig. 4. Character recognition and efficient use of memory resources.

3 Method

To begin with, the creation of instructional materials for acquiring kanji through tracing or drawing lines with fingers is proposed. To mitigate the effects of the hot and humid environment, the materials are printed with pigment ink resistant to smudging from sweat, rain, or beverages. The target audience includes students ranging from elementary to university level in the southeastern region of Thailand, specifically in Songkhla, Hat Yai, and neighboring areas, with an estimated target group of around 100 individuals. The intended students are beginners and intermediate learners with limited exposure to the Japanese language, anticipating a proficiency level between 0% and 5%. Considering that the proficiency level for first-year university students in kanji learning ranges from 5% to 20%, the materials are designed to cater to this demographic.

These instructional materials cover an extensive range of kanji, accommodating 1006 characters for elementary school, 1110 for middle school, and 1026 for high school. Consequently, the materials can be adjusted to suit the desired proficiency level of Thai learners, spanning from an introductory level equivalent to Japanese first-grade students

to a high school level. Although the Japanese Language Proficiency Test (JLPT) designates N5 as the proficiency level equivalent to middle school graduation, the materials also consider the utilization of kanji beyond that level. Additionally, these materials are crafted with consideration for students with developmental disorders in Japan. If successful, the implementation of a similar system is planned for Thai script instruction in elementary schools and kindergartens in the future, as well as for foreign language acquisition.

Following the utilization of the materials, surveys and quizzes are conducted, and subsequent analysis take place. The surveys are administered to both students and teachers. While integrating principles of cognitive science to create engaging materials that stimulate students' motivation, the surveys serve as an assessment tool to evaluate the on-site situation.

The quizzes focus on issues such as spelling errors and the structural composition of kanji, aiming to elucidate learning challenges. Following the implementation of the instructional materials, a comprehensive evaluation is conducted through surveys, quizzes, and subsequent analysis. Thorough scrutiny encompasses responses from both the survey and quiz results. The survey seeks input from both students and teachers, aligning with an educational approach that integrates insights from cognitive science to design engaging materials that stimulate students' interest in learning. Simultaneously, the survey functions as a tool to measure the effectiveness of the instructional materials under real-world conditions.

The assessment through quizzes aims to identify learning challenges, including spelling errors and structural composition of kanji. Through this analytical process, the intention is to gain valuable insights into the effectiveness of the developed materials and possibilities for improvement.

After the utilization of the instructional materials, a comprehensive survey and quiz are conducted, and the results is herein analyzed. The survey would gather responses from both students and teachers. While leveraging principles from cognitive science to create engaging materials that enhance students' learning motivation, the survey aims to understand the dynamics and perceptions in the field. The quizzes are specifically designed to focus on issues like spelling errors and the structural composition of kanji, aiming to reveal learning challenges.

4 Results

While instructing Japanese in Thailand, several challenges have been identified. The inherent complexity of Kanji characters, compounded by their vast quantity, renders comprehensive instruction challenging. Consequently, learners of Japanese in Thailand often exhibit low proficiency in recognizing correctly spelled characters.

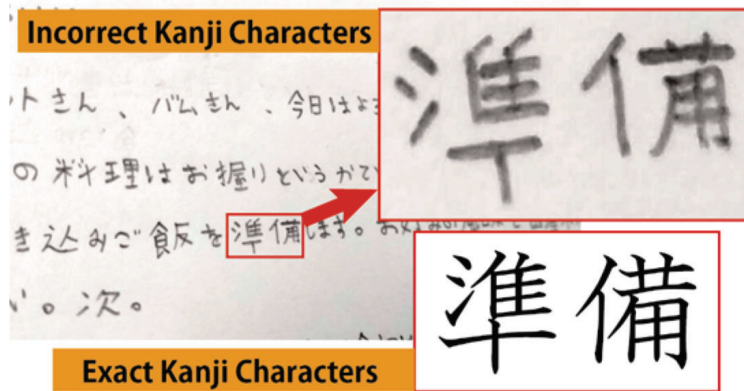
In comparison to Thai characters, Japanese characters are notably larger and more intricate. The diminutive size of Japanese characters presents a significant impediment to character recognition during practice. Given the abundance of similar characters, the likelihood of misrecognition increases substantially if precise identification is not achieved (Fig. 5a).

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to character recognition during practice. Given the abundance of similar characters, the likelihood of misrecognition increases substantially if precise identification is not achieved (Fig. 5b).

We herein measured the Electroencephalograms (EEGs) to evaluate the abovementioned educational method and analyzed those rhythms in accordance with the Fast Fourier Transform (FFT) (Fig. 6).

(a)



(b)

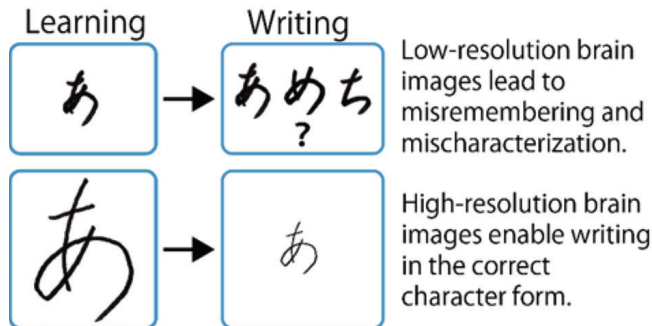


Fig. 5. Analysis of the reasons for the appearance of misspellings and their shapes (a), On the phenomenon of mistaking letters by writing them smaller and confusing them with similar letters (b).

5 Discussion

The objective is to design pioneering instructional materials for written character education. This involves the creation of an innovative letter teaching material integrating numerical and color elements to infuse an enjoyable element, thereby motivating students to discern the correct form of letters through perceptual augmentation. The strategic enlargement of letter size contributes to this perceptual enhancement. Additionally, the incorporation of colored dots serves to anchor spatial perception, thereby amplifying the overall efficacy of the learning experience.

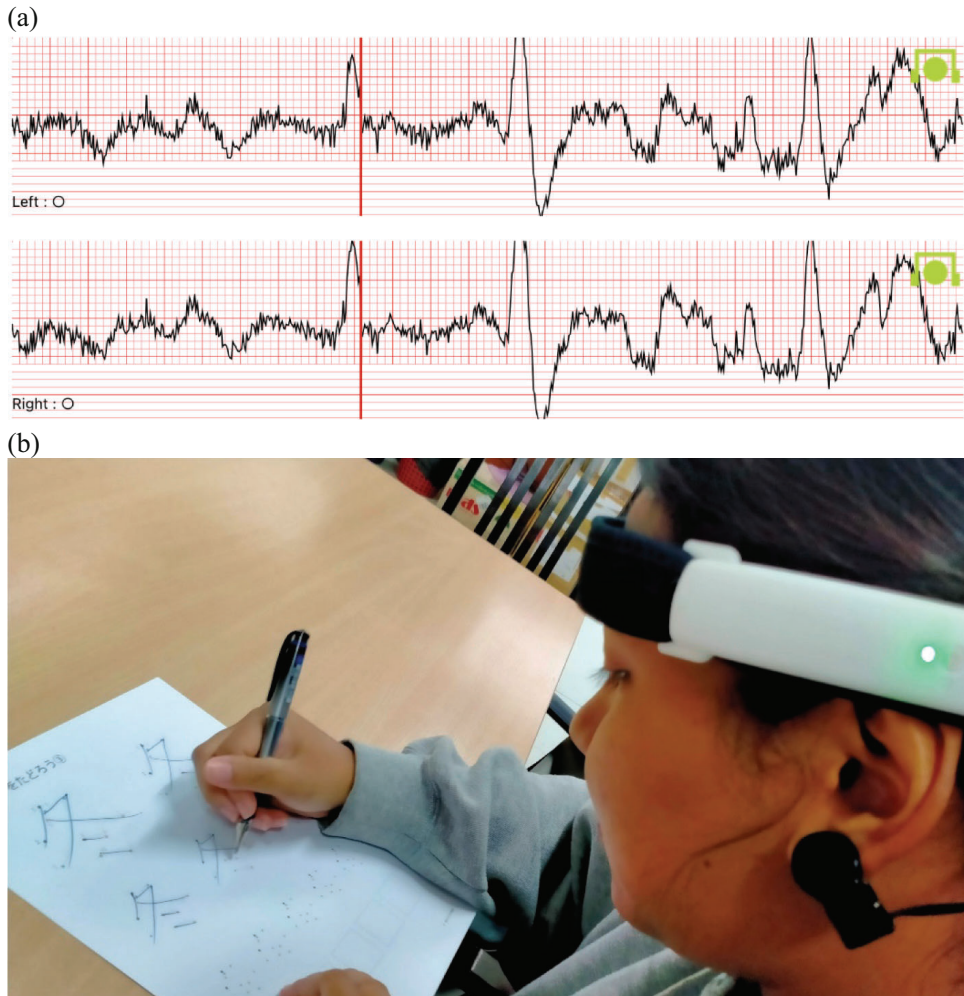


Fig. 6. Example of EEG when tracing text (a), An experiment in writing letters (b)

This developmental initiative was conceived and implemented within the educational landscape of Japan. Despite its successful implementation within the Japanese context, it has yet to be deployed in educational settings beyond the borders of Japan.

In our examination of the iPad utilization among students, it became apparent that a prevalent practice involves the use of scanned printed texts. The quality of the images is characterized by a coarse and low resolution, and the textual content is marred by inaccuracies. A marked distinction exists when comparing texts of high quality to those of low quality, significantly influencing the overall impression (Fig. 7a). It is noteworthy that even classrooms equipped with high-performance iPads encounter these issues.

The aforementioned trifecta of problems is poised to induce confusion and erode the learners' confidence, consequently leading to a substantial diminution in the efficacy of the learning process (Fig. 7b).

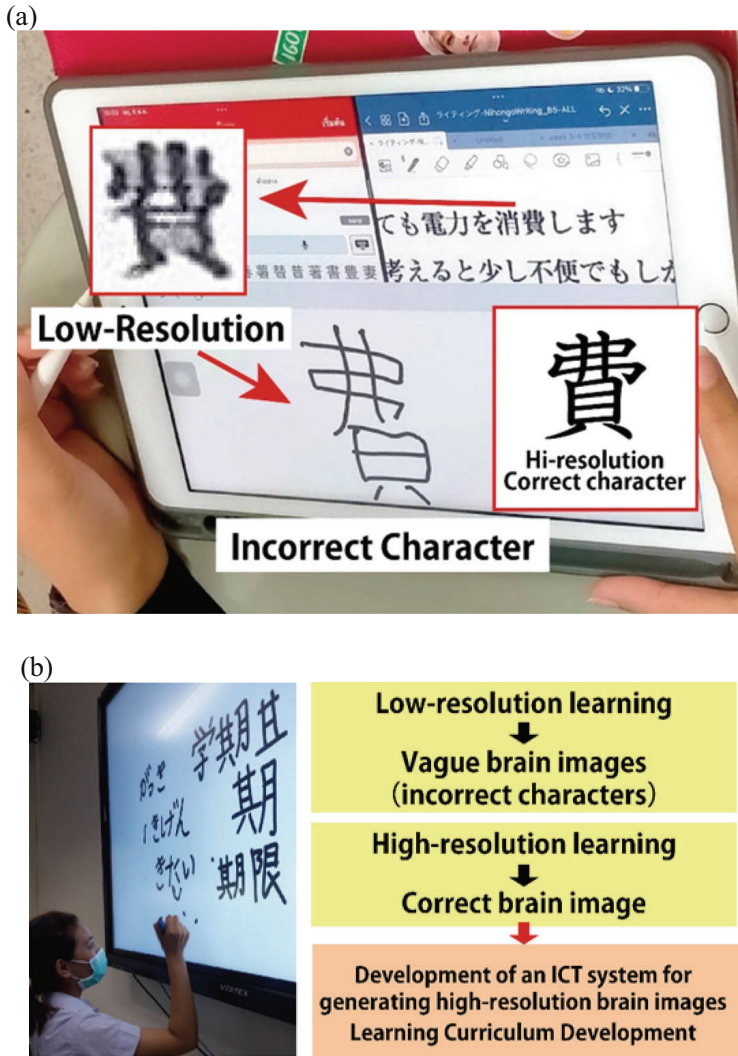


Fig. 7. Example of typographical errors caused by learning from scanned images of printed materials (a), Increasing resolution to help people notice typos and learn the correct letterforms (b).

Brain image creation is the most important factor in character learning [1]. Therefore, we analyzed the algorithm for creating brain images and examine how to apply it. Spatial cognition ability, visual resolution, and working memory in the brain are important for the creation of images in the brain. However, the importance of these factors has not been confirmed for Japanese language education today. In this study, we focused on the resolution in creating brain images.

The effect of learning about “fast reading aloud”, reading aloud quickly, and the development of language skills when applied to Japanese language education were discussed [2]. Test results showed that students who practiced more greatly benefited from the learning effects of accent and inflection, acquired a reading style that made it easier

to speak as a language rather than connecting words in isolation, and reduced reading time. However, the less-learned group was more exhausted, and tasks with more words lowered their performance. High-speed reading aloud was found to be a learning method with significant developmental potential from “reading” to language skills. The importance of short-term memory was confirmed for letter recognition. It is necessary to study the method of short-term memory development.

Kanji characters have an important position in Japanese language education [3]. This paper discusses the relationship between Kanji characters and language skills. Characters have changed their forms with the transition of typefaces to the present, but they still have a wide range of acceptable forms. This is because the development of characters is still continuing, which means that linguistic development has not stopped. In other words, the tolerance of Chinese characters should be considered as a margin adapted to the cultivation of language skills and the development of the ability to respond to the creation of new languages.

As a basis for designing type that can withstand aesthetic appreciation, a letterform evaluation method was examined [4]. Although typeface is basically composed of equally spaced margins, handwritten characters differ from part to part. Using Japanese language textbooks, we examined the relationship between letterforms and picture spacing, and found that there is a correlation between letterforms and picture spacing. If type is designed using this data, it was possible to give a dynamic expression to static type.

A study investigating the sensitivity of learning “Kanji” and “Kana” in non-Kanji speaking Thailand [5]. We investigated the influence of the characteristics of Thai characters on Kanji and Hiragana, and found that Thai characters, Kanji-Kana, and alphabets commonly approximate features such as writing pressure. In other words, the learning of the characters is strongly influenced by the native writing style of the characters. In Japan, this means that if the students still retain their usual writing habits, they did not change much even if they learn well-formed characters, and this has caused a stir in the teaching of character forms in Japan.

The development of language skills is a priority issue in the Courses of Study, and its application to the Japanese language subject “writing” and Japanese calligraphy is an urgent need [6]. Writing, as a written language, is directly related to the development of language skills, but classes have tended to focus on technique. Metacognition through writing deepens language expression, leads to language skills, and can greatly increase the use of strategies for language activities. Writing should be positioned as a more important basic academic skill, and instruction should be concentrated especially in the early grades.

Although many studies have been conducted on the center of gravity of letters, there is still no study that claims to have correctly captured the center of gravity [7]. Therefore, we experimentally examined the center of gravity of a letter by assuming the center of gravity to be the center of vertical writing. The results of the experiment showed that letters written using the superimposition method lacked balance between the upper and lower centers of gravity, which was unexpected. Those that were centered both vertically and horizontally were the most well rounded in the data, but did not appear to be correct. It was found that the weighting, i.e., placing the weight of the character at the lower

right corner, may indicate that the characters appear stable in the superimposed method of writing.

A study was conducted on the posture of writing that is acquired during daily learning [8]. After analyzing the results separately for writing with a left tilt, middle, right tilt, and writing on the left, middle, and right sides of the body, we found that writing with a left tilt and writing on the left side of the body resulted in faster writing. However, it is more tiring and shorter in duration. The posture that has been considered the most correct is not faster writing, however, it is longer lasting. In other words, changing posture to write faster for homework or writing, etc., causes fatigue, breaks concentration, and reduces the effectiveness of learning. This shows the importance of posture instruction.

In order to understand the letter form structure from a cognitive scientific perspective, we developed a teaching material that uses “dot-connecting” instead of conventional “tracing” to connect the dots, and also allows students to enjoy learning the number of strokes by adding colors [9]. When we conducted experiments with special-needs children with handwriting disabilities, they were able to write the letter shapes correctly, no longer protrude from the frame, and no longer make mistakes in the number of horizontal strokes. Regular college students were also able to recognize the complex shapes of letters with simple dots, which made it easier for them to grasp the shapes and write the letters in the correct form.

It has been found that writing damage, in which the shape of the letter is severely damaged, is caused by problems in the way the writing utensil is used [10]. Poor use of writing utensils can lead to poor concentration and poor academic performance due to fatigue and pain. They may even dislike studying. From the standpoint of character instruction, we proposed a method of teaching learning using a touch panel monitor.

Recently, the existence of developmentally disabled children, especially those with dysgraphia, has become an issue in calligraphy education [11]. Although the name “disability” implies a disability, these children with dysgraphia are simply developmentally delayed, and with appropriate care, their functions can be quickly restored. However, in the field of school education, if instruction is tailored to these children, instruction for other children is delayed, and the appropriate care is not provided. Therefore, we discussed the teaching methods that are appropriate for the lower grades and include care for dysgraphia at the stage when students begin to learn letters in the lower grades.

In the past, it has been said that students should be taught to write fast writing in the running style, but in actual practice, fast writing in the block style is the main form of writing [12]. Therefore, we conducted a scientific investigation of hiragana in fast writing and examined a method of fast writing that does not compromise the form and alignment of the characters. As a result, we found that the most important thing is that the first stroke of the next character is smoothly entered. It was found that it is important to teach students to be aware of the classification of alpha and gamma letterforms.

Hiragana, created from the cursive form of Chinese characters, is a character characterized by its smooth movement [13]. We examined what kind of strokes should be drawn when writing hiragana horizontally at high speed. Experiments using a tablet showed that fast strokes with edges lead to damage of the characters. On the contrary, it was found that drawing smooth edges would also shape the letters.

This is a study on personal space of letters in cognitive psychology [14]. It teaches that the space between horizontal strokes should be equally divided, but there is nothing theoretical about this. So, we conducted a study: a statistical study of over 3000 samples showed that closed forms write smaller. Open shapes were found to be written smaller, and slanted lines and dots were found to be written largest. The study reaffirmed that visual perception has been universal for thousands of years with regard to Chinese characters.

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