# Enhancing Chinese character achievement in primary education through multimedia-assisted deep learning module

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| Article Info | ABSTRACT |
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| | Chinese character literacy is essential for developing literacy competence in primary education; however, traditional instructional methods often rely on rote memorization, limiting student engagement, and deep learning. This study examined the effectiveness of a multimedia-assisted deep learning (MADL) module, designed based on the cognitive theory of multimedia learning (CTML) and cognitive semantic theory, in enhancing primary students' academic achievement in Chinese character learning. A quasi-experimental design was adopted with 222 second-grade students from three schools, with an experimental group (MADL, n=110) and a control group receiving traditional instruction (n=112). Academic achievement was assessed using pre-test and post-test, measuring overall scores, reading, writing, and understanding. Non-parametric Mann–Whitney U tests and Wilcoxon signed-rank tests revealed that the MADL group significantly outperformed the control group in overall post-test scores (p<.05) as well as in reading, writing, and understanding subtests. Within-group analyses further showed greater improvements in the MADL group. These findings indicate that the MADL module is an effective and pedagogically grounded tool for enhancing Chinese character learning in primary education. The study contributes empirical evidence supporting the integration of MADL strategies into early literacy instruction.<br><br>*This is an open access article under the [CC BY-SA](#) license.* |

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## 1. INTRODUCTION

Mastery of Chinese character forms the foundation for reading and writing, which serves as a cornerstone for developing core competencies in Chinese language, enhancing cultural literacy, and fostering intellectual growth [1]. However, learning Chinese characters presents considerable cognitive and instructional challenges for young learners. Cognitively, Chinese is a morpho-syllabic script in which sound, form, and meaning are intricately combined within each character, making it fundamentally different from alphabetic systems and inherently complex to acquire [2], [3]. The vast number of characters and their visual complexity place a substantial burden on learners' memory, particularly when instruction relies on traditional approaches such as rote memorization and repetitive copying [3]–[5]. Additionally, orthographic awareness—the ability to recognize and analyze the structural components of characters—is essential for effective character acquisition but is often difficult to develop, especially for students unfamiliar with the logographic nature of Chinese writing [6]. It causes wrongly written characters due to component confusion, stroke errors, and misused characters from difficulty in differentiation [7].

From an instructional perspective, conventional pedagogical methods often fail to address these learning difficulties effectively. Instructional practices that overemphasize memorization tend to yield low engagement and limited long-term retention [8], resulting in students' lack of interest and intrinsic motivation in learning Chinese characters. In many cases, teachers neglect the composition rules of Chinese characters, making it difficult for students to connect the shape of Chinese characters with their meanings [9].

In recent years, deep learning has become a key focus in the field of education, emphasizing higher-order cognitive processes such as deep understanding, problem solving, and the ability to transfer knowledge to novel situations [10]. However, contemporary teaching practices often fail to promote these 21st-century competencies, particularly in language instruction contexts, where rote memorization remains dominant [11]. Extending this agenda, the National Research Council (NRC, 2012) and the American Institutes for Research (AIR, 2014) outline a deeper-learning compatibility framework comprising six interconnected competencies: i) mastery of core academic content; ii) critical thinking and problem solving; iii) effective communication; iv) collaboration; v) learning how to learn (self-directed learning); and vi) academic mindsets [12], [13]. The first two competencies constitute the cognitive domain. Consistent with our measures and design, this sub-study examines only the cognitive domain's first competency— mastery of core academic content, operationalised here as Chinese character achievement.

In contrast, emerging approaches such as technology-enhanced learning environments have shown potential in improving students' motivation and character learning outcomes [3], [14]. Among these, multimedia-assisted instruction is particularly noteworthy. Grounded in the cognitive theory of multimedia learning (CTML), multimedia learning helps learners process information through visual and auditory elements, actively engaging them in the cognitive process, which enhances retention, transfer, and ultimately, learning achievement [15], [16].

Moreover, effective curriculum design for Chinese character learning must take into account learners' cognitive load and incorporate strategies that enhance structural awareness and meaningful learning [17], [18]. However, existing research mainly focuses on theoretical strategies for improving Chinese literacy or emphasizes higher education, and there is a research gap in empirical research and the development of deep learning modules for primary education [10], [19]. To address these challenges and fill the research gap, the present study evaluates the effectiveness of a purposefully designed multimedia-assisted deep learning (MADL) module on primary students' Chinese character learning achievement. To guide this investigation, the study posed the following research question: how effective is the developed module in improving primary school students' deep learning in academic achievement (including pronunciation of reading, writing, and understanding of Chinese characters)? Based on the research question, four null hypotheses were formulated to examine the effects of the MADL module on overall and component-specific aspects of Chinese character learning:

−   Ho1: there is no significant difference in post-test scores between the MADL group and the traditional learning (TRAD) group in overall academic achievement.
−   Ho2: there is no significant difference in Chinese character reading post-test scores between the MADL and TRAD groups.
−   Ho3: there is no significant difference in Chinese character writing post-test scores between the MADL and TRAD groups.
−   Ho4: there is no significant difference in Chinese character understanding post-test scores between the MADL and TRAD groups.

## 2. LITERATURE REVIEW
### 2.1. The cognitive and semantic foundations of Chinese character learning

Chinese characters are the oldest and only writing system still in use in the world, which was developed for Chinese writing [20]. According to Christensen and Warnick [21], every Chinese character is composed of one or any combination of the following three elements: a glyphic component (shape), a phonemic component (sound), or a semantic component (meaning) [22]. Among them, pictophonetic character is a combination of phonetic and semantic components [20]. Its semantic components express its meaning, and the voice parts represent the phonological information of characters [23]. Therefore, learning Chinese characters is not only about memorizing individual characters, but also a complex cognitive activity involving the mutual construction between character shape, pronunciation and meaning, which is especially evident in children's early language acquisition stage.

Cognitive semantic theory provides a theoretical basis to understand how learners mentally organize and connect visual components (radicals) to conceptual meanings [24]. Applied to Chinese character learning, this suggests that radicals are not arbitrary but serve as cognitive anchors that activate related semantic domains in the learner's mind [24]. Effective teaching methods should incorporate visual, semantic,

and embodied aspects of characters. This includes using image-based teaching methods and emphasizing the role of semantic radicals in understanding character meanings [25]. Consequently, effective character learning interventions should aim to reduce cognitive load by leveraging semantic transparency, radical awareness, and contextual meaning-making. Instruction that focuses solely on rote memorization without engaging learners in the semantic structure of characters may limit deep understanding and hinder long-term retention.

## 2.2. Multimedia technology in language teaching and learning

Multimedia, defined as a combination of various media such as text, audio, and video, can effectively facilitate Chinese character learning by engaging multiple sensory channels and promoting meaningful learning outcomes [26], [27]. Studies have consistently shown that multimedia-assisted learning has a positive impact on Chinese character education. Multimedia-enhanced teaching resulted in better character recognition and retention compared to traditional methods [28]. Sound-enhanced flashcards improved pinyin memory among beginners [29]. Moreover, multimedia strategies using stroke-sound and radical-highlighting practices significantly boosted writing and recognition skills [30]. Furthermore, multimedia tools can significantly enhance the effectiveness of Chinese character teaching by disassembling and reorganizing Chinese character components and establishing connections between orthography, semantics, and phonetics [14].

These empirical findings underscore the potential of multimedia to improve Chinese character instruction. CTML [27] provides a theoretical framework for understanding how multimedia instruction facilitates knowledge acquisition. CTML posits that learning is most effective when information is presented through both visual and auditory channels, allowing learners to actively select, organize, and integrate information into coherent mental models. Its core design principles—such as multimedia, redundancy avoidance, and segmentation—are particularly well-suited for Chinese character instruction, where abstract orthographic forms must be systematically linked to sound and meaning.

## 2.3. Existing modules for Chinese character learning

A variety of digital modules have been developed to support Chinese character learning, each addressing different aspects of the complex form–sound–meaning system. Game-based tools such as the Chinese-PP game and integrated game services promote engagement through component-based gameplay and psycholinguistic principles, helping learners recognize and construct characters collaboratively [31], [32]. Recognition and writing systems like the unified character recognition (UCR) framework and augmented character profile matching (ACPM) leverage radical-level decomposition for improved accuracy [33], [34], while mobile and gesture-based platforms, including stroke-sequencing apps and Kinect-based systems, increase accessibility and learner interaction [35], [36].

While these modules offer innovative features, they often target isolated skills—such as stroke accuracy, pronunciation, or engagement—without supporting the integrated processing required for deep character understanding. Few systems incorporate all three cognitive dimensions of Chinese characters (orthography, phonology, and semantics), and even fewer are grounded in learning theories that promote long-term retention or meaningful transfer. This lack of theoretical coherence and instructional integration limits their potential to foster deep learning, particularly for young learners at the foundational stage of literacy development. To address these gaps, the MADL module used in this study was developed by the researcher in a separate instructional design project and designed as a curriculum-aligned teaching tool to support deep learning of Chinese characters through multimedia.

## 3. METHOD
### 3.1. Research design

A quasi-experimental design was adopted in this study to investigate the differences in Chinese character learning achievement, including its three dimensions: reading, writing, and understanding. In the experimental group, the MADL module was implemented, incorporating both the MADL booklet and multimedia materials into the teaching process to enhance students' deep learning of Chinese characters. In contrast, the control group used conventional method. By comparing the achievement of the experimental and control groups, this study aims to evaluate the effectiveness of the MADL module in Chinese character learning.

### 3.2. Samples

Participants were second-grade students aged between 8 and 10 years, recruited through convenience sampling. Three public primary schools in eastern China (pseudonymously referred to as

School A, School B, and School C) were selected based on existing professional contacts with their teachers, and each school provided both an experimental and a control class. Class inclusion was determined by the teachers' consent to participate and the results of a pre-test, which ensured comparable Chinese character learning levels between the experimental and control groups prior to the intervention. In total, 110 students were assigned to the experimental group and 112 to the control group. Participation was voluntary, with informed consent obtained from the students' parents or guardians, the schools, and the participating teachers.

### 3.3. Learning materials

The learning materials for this study were designed to align with the compulsory education Chinese language curriculum standards [1] and tailored to the cognitive and developmental levels of second-grade students. For the experimental group, the materials included the MADL module, which consisted multimedia components such as animated character stories, visual radicals, stroke order animations, audio pronunciation clips, and interactive exercises. These materials were structured into seven lessons and integrated with cooperative learning tasks and visual thinking strategies to support the development of deep learning in Chinese character reading, writing, and understanding.

Take the lesson of teaching "棚" ("shed") for example, as in Figure 1. In the lesson on "棚", students first see a real-world image of a stable labelled "马棚", which anchors meaning in familiar context (schema activation) while avoiding decorative elements (coherence). Next, the character is decomposed as "木" + "朋", with the target character in blue and components in red (signaling); brief on-screen notes place the semantic radical "木" ("material for building a shed") and the phonetic "朋" ("péng") adjacent to the glyphs (spatial contiguity). Text on the slide is kept minimal and non-redundant with the visuals (redundancy principle). Content is revealed in small steps—image → whole character → components → short prompt—so that learners process one element at a time (segmenting). A quick check then asks students to infer the role of 木 in new items with the same radical (e.g., recognizing that the radical cues "wood/material"), reinforcing form–meaning mapping predicted to support achievement in reading and writing. Overall, these choices aim to reduce extraneous load and strengthen structure–meaning integration, providing a CTML-based rationale for the observed gains in Chinese character achievement. In contrast, the control group received conventional instruction without the MADL module support. All learning materials were reviewed by experts to ensure content validity, language and grade-level appropriateness, and consistency with the national curriculum.



Figure 1. Lesson of recognizing the character "棚" in relation to its meaning

### 3.4. Research instrument

Pre-test and post-test sheet for testing Chinese character learning achievement was developed regarding the compulsory education Chinese language curriculum standards issued by the Ministry of Education of China [1]. It consists of 13 questions, which measures three aspects, namely Chinese character reading, writing, and understanding. Reliability analysis showed a strong internal consistency, with a Pearson correlation coefficient of r=.897. Content validity was also high, with a scale-level content validity index (S-CVI) of .91.

### 3.5. Data collection and research procedure

The quantitative data were collected from the results of the Chinese character achievement pre-test and post-test. Its purpose is to compare the differences between the experimental group and the control group in terms of achievement, including overall score, reading, writing, and understanding of Chinese characters. Figure 2 shows the procedure of this quasi-experiment. This experimental study spanned 7 weeks, including three main phases: pre-test, experimental intervention, and post-test. A pre-test was given to both experimental and the control groups before learning in the first week. Then, the interventional instructions were implemented. A post-test was conducted after completing the instructions in both experimental and control group. this study is part of a larger research project. The experimental procedure illustrated in Figure 2 was used across all sub-studies, including the present investigation on other cognitive skills, e.g., critical thinking and problem-solving.
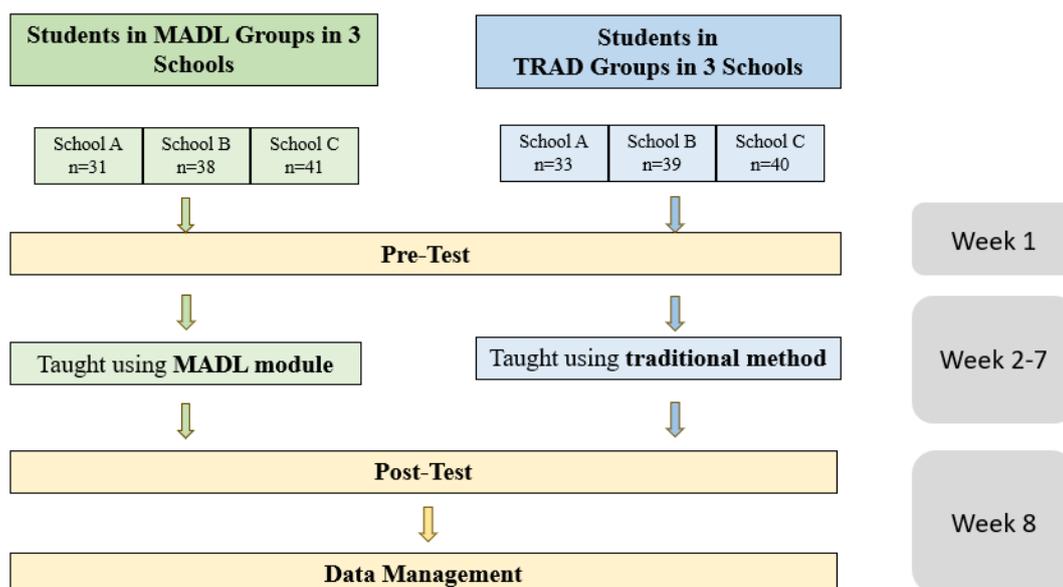


Figure 2. Procedure of the experiment in the study

## 4. RESULTS

A Shapiro–Wilk test was initially conducted to examine the normality of the pre-test and post-test scores for each dependent variable. The results, as shown in Table 1, indicate that all pre-test and post-test scores in both the MADL and TRAD groups deviated significantly from normality ($p<.05$; $|Z|>1.96$), except for the MADL group's writing and understanding pre-test scores, which showed only slight deviations ($Z=3.13$ and $Z=1.88$, respectively). Consequently, non-parametric statistical tests were applied for most comparisons, with parametric tests used only where normality was approximately met.

To ensure baseline equivalence, a Mann–Whitney U test was adopted to compare the pre-test scores of the MADL and TRAD groups, as the data were not normally distributed, as in Table 1. The results, as seen in Table 2, showed no significant difference between groups ($p=.417>.05$), with mean ranks of 107.97 (MADL) and 114.96 (TRAD). This suggests that both groups were comparable in Chinese character achievement prior to the intervention.

As the data did not follow a normal distribution, as in Table 1, the Wilcoxon signed rank test was used to conduct within-group comparisons. The results, as in Table 3, revealed that all post-test scores were significantly higher than pre-test scores ($p<.001$, $r>.5$), indicating strong gains after the intervention. As shown in Table 4, the between-group comparisons using the Mann-Whitney U test revealed that the MADL group obtained a significantly higher mean rank (127.60) than the TRAD group (95.68), meaning MADL group outperformed TRAD on overall achievement ($U=4388.50$, $Z=-3.703$, $r=.249$, common language effect size (CLES)=.644, $p<.001$). This indicates a statistically significant difference overall academic achievement between the two groups at the post-test stage. Thus, the null hypothesis (Ho1) was rejected, suggesting that the MADL module had a positive effect on students' Chinese character learning achievement.

Table 1. Results of normality tests

| Group | Variables | Shapiro-Wilk Statistics | df | p | Skew/Kurt Z | Distribution | Statistical test type |
|---|---|---|---|---|---|---|---|
| MADL | Pre-test (overall) | .953 | 110 | .001 | 3.40 | Significantly deviate | Non-parametric |
| | Reading | .926 | 110 | .000 | 4.43 | Significantly deviate | Non-parametric |
| | Writing | .960 | 110 | .002 | 3.13 | Slightly deviate | Parametric |
| | Understanding | .965 | 110 | .006 | 1.88 | Slightly deviate | Parametric |
| | Post-test (overall) | .897 | 110 | .000 | 4.88 | Significantly deviate | Non-parametric |
| | Reading | .794 | 110 | .000 | 7.85 | Significantly deviate | Non-parametric |
| | Writing | .910 | 110 | .000 | 4.61 | Significantly deviate | Non-parametric |
| | Understanding | .899 | 110 | .000 | 4.38 | Significantly deviate | Non-parametric |
| TRAD | Pre-test (overall) | .947 | 112 | .000 | 3.43 | Significantly deviate | Non-parametric |
| | Reading | .927 | 112 | .000 | 3.44 | Significantly deviate | Non-parametric |
| | Writing | .941 | 112 | .000 | 3.83 | Significantly deviate | Non-parametric |
| | Understanding | .954 | 112 | .001 | 3.13 | Slightly deviate | Parametric |
| | Post-test (overall) | .936 | 112 | .000 | 4.35 | Significantly deviate | Non-parametric |
| | Reading | .916 | 112 | .000 | 4.41 | Significantly deviate | Non-parametric |
| | Writing | .952 | 112 | .001 | 3.57 | Significantly deviate | Non-parametric |
| | Understanding | .917 | 112 | .000 | 4.93 | Significantly deviate | Non-parametric |

Note: Skew/Kurt Z refers to the ratio of skewness or kurtosis to its standard error. "Slightly deviate" indicates minor deviation from normality ($Z<\pm1.96$); "significantly deviate" indicates significant deviation from normality ($Z>\pm1.96$) [37].

Table 2. Mann-Whitney U test for pre-test scores

| Group | N | Mean rank | Sum of ranks | Mann-Whitney U | Wilcoxon W | Z | p |
|---|---|---|---|---|---|---|---|
| MADL | 110 | 107.97 | 11877.00 | 5772.000 | 11877.000 | -.811 | .417 |
| TRAD | 112 | 114.96 | 12876.00 | | | | |
| Total | 222 | | | | | | |

Further analysis of sub-skills revealed consistent results. For reading Chinese characters, the MADL group had a significantly higher mean rank (132.46) than the TRAD group (90.92), and the advantage was larger (U=3854.50, Z=−4.827, r=.324, CLES=.687, p<.001). For writing, the MADL group's mean rank (124.95) also exceeded that of the TRAD group (98.29), with U=4680.00, Z=−3.095, r=.208, CLES=.620, p=.002. Similarly, for understanding, the MADL group (124.46) outperformed the TRAD group (98.77), with U=4734.00, Z=−2.982, r=.200, CLES=.616, p=.003. All differences were statistically significant, leading to the rejection of Ho2, Ho3, and Ho4, respectively. Overall, effects were small-to-moderate. These findings provide strong evidence for the effectiveness of the MADL module in enhancing primary students' academic achievement across reading, writing, and understanding of Chinese characters.

Table 3. Wilcoxon test results for pre-test and post-test comparisons within MADL group

| Group | Dimension | Z | p-value | r |
|---|---|---|---|---|
| MADL | Overall | -9.036 | .000 | .862 |
| | Reading | -7.241 | .000 | .690 |
| | Writing | -8.784 | .000 | .838 |
| | Understanding | -9.076 | .000 | .865 |

Table 4. Mann-Whitney U test for post-test

| Variables | Group | N | Mean rank | Sum of ranks | Mann-Whitney U | Wilcoxon W | Z | p |
|---|---|---|---|---|---|---|---|---|
| Overall | MADL | 110 | 127.60 | 14036.50 | 4388.500 | 10716.500 | -3.703 | .000 |
| | TRAD | 112 | 95.68 | 10716.50 | | | | |
| | Total | 222 | | | | | | |
| Reading | MADL | 110 | 132.46 | 14570.50 | 3854.500 | 10182.500 | -4.827 | .000 |
| | TRAD | 112 | 90.92 | 10182.50 | | | | |
| | Total | 222 | | | | | | |
| Writing | MADL | 110 | 124.95 | 13745.00 | 4680.000 | 11008.000 | -3.095 | .002 |
| | TRAD | 112 | 98.29 | 11008.00 | | | | |
| | Total | 222 | | | | | | |
| Understanding | MADL | 110 | 124.46 | 13691.00 | 4734.000 | 11062.000 | -2.982 | .003 |
| | TRAD | 112 | 98.77 | 11062.00 | | | | |
| | Total | 222 | | | | | | |

## 5.    DISCUSSION

The findings indicate that the MADL module significantly improved students' achievement in reading, writing, and understanding Chinese characters, both in comparison to their pre-test results and relative to the TRAD group. While the control group also showed improvement, the experimental group demonstrated substantially greater gains, underscoring the effectiveness of the MADL approach. One reason for excellent reading achievement may lie in the MADL module's multimodal presentation of characters, which integrates visual, phonological, and semantic cues. This aligns with the modality principle [15], which suggests that learning improves when auditory information complements visual input, thereby reducing cognitive load on the visual channel and freeing capacity for processing character structure and meaning. By combining stroke animations, semantic radical highlighting, and audio narration, the MADL module supports decoding and form-meaning mapping—key components of early reading development.

Furthermore, because the majority of Chinese characters are pictophonetic compounds [20], understanding the semantic radical (the meaning component) not only aids in grasping character meaning but also strengthens learners' awareness of structural regularities in character formation [38]. This awareness allows students to infer pronunciation from the phonetic component, thereby enhancing their ability to recognize and read unfamiliar characters through analogy—a foundational skill in Chinese literacy acquisition. Beyond reading, the MADL module also fostered notable gains in writing skills. This can be attributed to the module's focus on radical-level understanding and stroke construction within meaningful contexts. Rather than rote tracing, the MADL design engages learners in understanding the function and position of semantic and phonetic components, which facilitates internalization of structural patterns [14], [38]. This approach promotes constructive learning and supports transfer, particularly in generating novel characters or recognizing variants—skills often underdeveloped in traditional instruction focused solely on stroke memorization [31], [32].

These outcomes are consistent with previous research. Electronic flashcards with audio enhanced beginners' memory for pinyin and character reading [29]. This supports the idea that multimodal input facilitates encoding and recall by activating multiple representational systems. However, combining stroke animations with redundant captions reduced recall accuracy, reflecting Mayer's redundancy principle, which warns against overwhelming learners with duplicative visual input [29]. The MADL module's intentional design—separating narration from visual cues and avoiding on-screen text overload—may explain its superior learning outcomes.

Furthermore, the superior achievement of the MADL group in character understanding may be attributed to the MADL module's use of semantic radicals and contextual cues, which, grounded in cognitive semantic theory, help activate schema-based processing and facilitate deeper conceptual integration [24]. This is consistent with the conclusion that visual animations and contextualized multimedia can enhance students' comprehension of abstract language elements [39]. Multimedia also transforms abstract concepts into concrete visuals, presenting information more effectively while sustaining learner engagement [40].

In summary, these findings reinforce the pedagogical value of integrating multimedia with cognitive learning theories in Chinese character instruction. They not only validate the effectiveness of MADL module but also offer pedagogical implications for designing early literacy interventions. However, further research is needed to examine long-term retention and transfer across broader contexts.

## 6.    CONCLUSION

This study investigated the effectiveness of the MADL module in enhancing primary students' Chinese character learning. Grounded in cognitive semantic theory and the CTML, the MADL module was designed to support the integration of visual form, phonological features, and semantic meaning—three critical dimensions of Chinese literacy acquisition. The findings demonstrated that students who engaged with the MADL module outperformed those in the conventional instruction group in reading, writing, and character understanding. The results not only validate the effect of multimedia-assisted instruction, but also highlight the importance of theory-informed instructional design. By applying principles such as modality, reducing redundancy, and meaning-focused radical instruction, the MADL module effectively reduced cognitive load and promoted deeper, more transferable learning. These findings are consistent with previous literature while advancing the field by demonstrating how well-structured multimedia learning environments can foster deep learning in the context of logographic language acquisition at the primary level.

Despite its promising outcomes, this study has several limitations. First, the intervention was conducted over a relatively short period, which may not fully capture the long-term effects of the MADL module on knowledge retention and transfer; therefore, future research could examine its impact over an extended period. Second, the study was limited to second-grade students within a specific regional context, which may constrain the generalizability of the findings to other age groups or educational settings; thus,

future studies could test the module with learners from different grades, regions, and school contexts. Third, the study primarily relied on quantitative measures, which, while robust, may not capture the nuanced learning experiences or emotional engagement of students; hence, future work could incorporate qualitative methods such as interviews and classroom observations to gain deeper insights.

## AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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|---|---|---|
| C : **C**onceptualization | I : **I**nvestigation | Vi : **Vi**sualization |
| M : **M**ethodology | R : **R**esources | Su : **Su**pervision |
| So : **So**ftware | D : **D**ata Curation | P : **P**roject administration |
| Va : **Va**lidation | O : Writing - **O**riginal Draft | Fu : **Fu**nding acquisition |
| Fo : **Fo**rmal analysis | E : Writing - Review & **E**diting | |


## CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.


## DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article.


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