Journal of Digital Education and Learning Engineering ปีที่ 1 ฉบับที่ 4 (เดือนตุลาคม – ธันวาคม 2568) หน้า 26-45
Journal of Digital Education and Learning Engineering, Volume 1 No. 4 (October – December 2025) Page 26-45
บทความวิจัย (Research Article)

Journal of Digital Education and Learning Engineering
ดำเนินการวารสารโดย สมาคมการศึกษาดิจิทัลและวิศวกรรมการเรียนรู้

Technology-Enhanced Chinese Language Learning: Effects of Interactive Intelligent Tools on Engagement and Cognitive Outcomes in Thai Primary Classrooms

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Received: November 27, 2025 Revised: December 7, 2025 Accepted: December 13, 2025

Abstract

This study examines the impact of intelligent, technology-enhanced teaching tools on young learners' engagement and cognitive development in primary Chinese language classrooms. Using a quasi-experimental design with 60 sixth-grade students, the study compared lessons supported by animated materials, multimodal resources, and gamified platforms with traditional instruction. Learning analytics from classroom video logs showed that students in the technology-enhanced group sustained exceptionally high levels of engagement (≥ 95%) with minimal fluctuation (CV < 5%), indicating stable and continuous motivation across instructional stages. Cognitive outcomes also improved markedly, with an average post-test gain of 8.47 points and a very large effect size (Cohen's d = 1.62). Students further reported clearer comprehension—especially for abstract vocabulary—when learning activities incorporated animation, contextualized input, and immediate feedback. The findings demonstrate that intelligent teaching tools can significantly enhance learning efficiency, deepen cognitive processing, and create more responsive and motivating classroom environments. The study also highlights key design implications for engineering intelligent learning environments, particularly the integration of multimodal scaffolding, attention-stabilizing features, and interactive feedback loops to support effective technology-enhanced instruction in resource-limited primary school settings.

Keywords: intelligent teaching tools; learning engagement; cognitive outcomes; gamification; multimodal learning

■ Introduction

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Chinese language education in Thailand has expanded rapidly in recent years, driven by closer economic and cultural links with China and the increasing value of Chinese proficiency in a globally connected workforce and education system. Although Chinese is now widely offered as a third language in primary and secondary schools, classrooms still face significant challenges. Chinese language education in Thailand emphasizes a student-centered teaching model to maintain students' enthusiasm for learning. However, due to the lack of an immersive Chinese learning environment and the reliance on a one-to-many teaching model, it faces significant challenges in terms of teaching materials, course management, teaching aids, and teacher resources. Traditional teaching methods, mostly relying on textbooks and blackboards, lack contextual input for language learning and are often quite monotonous. They also fail to satisfy the attention span and motivation needs of younger learners. Moreover, transitions between textbook systems—such as moving from YCT at the primary level to HSK in secondary schooling—can disrupt learning coherence and continuity.

Primary-level Chinese instruction in Thailand remains largely reliant on traditional resources, including textbooks, worksheets, and board-based explanations. While these types of teaching resources can ensure basic knowledge acquisition, for Chinese language learning, paper-based teaching lacks multimodal learning and timely feedback mechanisms. Teachers can only observe whether students are interested and participating in class, but cannot truly understand students' cognitive weaknesses. Furthermore, the most difficult part of language learning is understanding abstract vocabulary and contextual usage. Traditional resources are unlikely to provide much help in this area, and these problems can lead to weak learning motivation and poor cognitive performance among students. With the development of the times, digital technology has gradually permeated education, and more and more intelligent teaching aids are appearing in the classroom. Recent multimodal approaches in Chinese language teaching suggest that using visual, auditory, and contextual cues helps novices understand complex linguistic concepts (Han et al., 2023). Meanwhile, research in technology-enhanced language learning underscores the potential of digital tools to enhance motivation, engagement, and learning outcomes (Nasution & Batubara, 2024). The multimodal, innovative, and interactive features of intelligent teaching aids effectively stabilize students' attention and solve the problem of easy distraction in the classroom. At the same time, the fun brought by gamification alleviates the anxiety and boredom of language learning, and interactive scenarios allow for a more immersive experience of language use, solving the difficulty of understanding abstract vocabulary. Therefore, introducing intelligent tools is necessary not merely as an enhancement but as a direct response to structural limitations in Thai Chinese classrooms. These tools provide contextualized input, real-time feedback, and cognitively aligned learning support—features that traditional materials cannot offer. As a result, intelligent tools address core barriers such as limited immersion, insufficient differentiation, and the lack of timely diagnostic insight into students' cognitive weaknesses.

Gamified and mobile-learning interventions in Chinese language contexts have shown significant improvement in speaking skills, motivation, and student satisfaction (Yang, Karanyathikul, & Kotchasit, .(2024 Yet, empirical evidence remains sparse on integrating intelligent teaching tools—such as animations,

multimodal platforms, and gamified assessments—in Thai primary Chinese classrooms, particularly studies that combine classroom analytics with experimental designs to examine engagement stability and cognitive outcomes. However, it is unclear how these tools function in real classroom settings with Thai primary Chinese learners—especially in terms of motivational stability over instructional stages, cognitive gains in abstract vocabulary, and the engineering of technology-enhanced learning environments. In response, the present study investigates the impact of interactive intelligent teaching tools on primary-school learners' motivation, engagement, and cognitive outcomes in Chinese language instruction in Thailand. By analysing both test performance and behavioural indicators (e.g., attention and participation), the study aims to provide context-specific evidence for designing effective technology-enhanced language learning environments.

■ Research Questions

1) How do intelligent teaching tools influence students' motivation and engagement in primary Chinese language classrooms?

2) How do these tools affect cognitive gains, vocabulary processing, and comprehension?

3) In what ways does technology integration contribute to the stability of learners' attention and learning processes?

■ Literature Review

Technology-Enhanced Language Learning (TELL)

Technology-enhanced language learning has undergone rapid development, driven by advances in digital platforms, mobile learning, multimodal design, and real-time learning analytics. Recent reviews highlight that TELL environments can provide enriched input, adaptive feedback, and interactive learning pathways, all of which contribute to stronger engagement and improved language acquisition (Nasution & Batubara, 2024). The integration of technology is particularly significant in young learner contexts where motivational declines often occur during traditional instruction. Digital platforms allow teachers to manage varied proficiency levels through differentiated tasks, personalized pacing, and the ability to visualize student progress through analytics dashboards.

Researchers have also noted the increasing importance of multimodal and data-informed design principles in the future of language learning technology. A large-scale bibliometric analysis demonstrated that engagement optimization, multimodal input, and the application of learning engineering frameworks are emerging areas of interest, but empirical evidence from developing countries and lower primary grades remains limited. Much of the existing work still focuses on university-level or adult learners, where self-regulated learning skills are more developed. As a result, more studies are needed to understand how TELL

can support children, who rely more heavily on guided learning, concrete examples, and sustained external motivation.

Intelligent Teaching Tools and Multimodal Input

Intelligent teaching tools—including animation-based lessons, interactive videos, AI-assisted language applications, and multimodal instructional platforms—provide learning environments that align well with the developmental characteristics of young learners. Multimodal input, combining visual, auditory, and contextual cues, plays a crucial role in supporting children's comprehension, especially for languages like Chinese where tone, character formation, and pictographic meaning present unique cognitive challenges (Han et al., 2023). Research suggests that multimodal input increases comprehension depth by reducing the cognitive load associated with abstract information and by offering redundant cues that reinforce semantic understanding.

Recent research has also shown that animated teaching content, such as short animated videos, can help memorize vocabulary and language structures by evoking emotional resonance through visual narratives and role-playing scenarios (Yetti, Yelmi, & Nurbit, 2024; Ridha, Bostanci, & Kurt, 2022). For abstract vocabulary—such as spatial relations, functional terms, or narrative expressions—multimodal input helps younger learners form mental representations more efficiently. These mechanisms align with Mayer's Cognitive Theory of Multimedia Learning and Paivio's Dual Coding Theory, both of which argue that integrating verbal and visual encoding pathways enhances recall, comprehension, and transfer.

Gamification and Interactive Learning

Gamification has proven to be one of the most influential strategies in technology-enhanced language learning. By incorporating elements such as competition, rewards, point systems, leaderboards, and instant feedback, gamified platforms can significantly strengthen motivation, enjoyment, and perseverance in language tasks. Evidence from recent studies indicates that game-based learning improves not only engagement but also language accuracy, speaking fluency, and vocabulary retention (Yang, Karanyathikul, & Kotchasit, 2024). The integration of platforms such as Kahoot, Quizizz, or Wordwall has been shown to deepen participation and encourage repeated practice—behaviors that are essential for learning Chinese tones, characters, and patterns.

Studies in CFL contexts further point out that gamification is particularly effective for younger learners, who respond strongly to competition and immediate reinforcement. However, scholars also caution that technological novelty alone is insufficient; learning outcomes depend heavily on intentional design and the alignment of gamified tasks with instructional goals (Sinnivasagam & Hua, 2023). Properly designed game-based Chinese learning environments can scaffold tone differentiation, contextual usage, and sentence construction more effectively than worksheet-based instruction, but poorly designed gamification may overload learners or shift focus away from meaningful comprehension.

Cognitive Load and Young Learners' Processing in L2 Chinese

Young learners face distinct cognitive processing demands in acquiring Chinese as a foreign language. The visual complexity of Chinese characters, the semantic ambiguity of certain word categories, and tone-based phonology can all impose high cognitive load, particularly in classrooms that rely exclusively on print-based resources. Early foreign language learning research indicates that young learners have limited attention spans and their self-regulation abilities are not yet fully developed. Therefore, minimizing irrelevant cognitive load and maintaining sustained attention are crucial in teaching activities (Sweller, 2020). A decline in attention during lessons is strongly associated with increased errors, reduced comprehension, and inconsistent vocabulary recall.

Multimodal and interactive tools can mitigate these effects by providing scaffolding that distributes cognitive effort across visual, auditory, and kinesthetic channels. For example, animated scenario explanations can place difficult or abstract phrases in real-world contexts, thereby promoting semantic integration; while gamification provides rapid visual feedback, keeping children highly attentive. However, despite these affordances, scholars have noted that attention stability—often assessed through behavioral indicators such as gaze duration, response latency, and task persistence—remains under-examined in Chinese as a Foreign Language (CFL) classrooms. Much of the existing research relies primarily on discrete test scores rather than continuous engagement metrics, limiting the ability to capture in-the-moment attentional fluctuations. Future CFL research would benefit from incorporating multimodal learning analytics to more accurately model how attentional dynamics interact with digital and traditional instructional environments.

Gaps in Current Research

Although digital learning tools and gamification have demonstrated strong potential across various language contexts, several gaps remain. First, empirical studies in primary-school Chinese language classrooms are limited, particularly in Southeast Asian contexts. Second, prior research has rarely combined experimental designs with behavioral learning analytics—such as engagement tracking or fluctuation analysis using coefficients of variation—to capture how young learners respond to technology across different lesson stages. Third, little is known about how intelligent tools can enhance comprehension of abstract vocabulary, which is often a persistent challenge for novice Chinese learners. This study addresses these gaps by examining both cognitive outcomes and engagement stability through the integration of intelligent teaching tools in real classroom settings.

■ Theoretical Framework

Constructivist Learning Theory

Constructivism advocates for a learning environment where students are not passive recipients of information but active participants who construct their own knowledge systems through interaction with the environment and teaching tools (Piaget, 1954). For example, the Kahoot and Wordwall programs mentioned in this study align with constructivist principles. These tools promote autonomous learning through interactive collaboration and problem-solving activities, enabling students to actively engage with the learning materials. For instance, Kahoot provides opportunities for interactive games, encouraging learners to explore, answer questions, and develop critical thinking skills.

This study utilizes a constructivist framework, leveraging the interactivity and collaboration of these teaching aids to help students establish meaningful connections with the learning materials, thereby promoting deeper understanding and retention. Furthermore, integrating intelligent teaching aids into the classroom, using "Easy Chinese," aligns with constructivist principles that emphasize situated and social learning, providing a language learning approach that balances real-world contexts and meets the needs of language learners.

Multiple Intelligences Theory

This theory emphasizes that each individual possesses a unique combination of intelligences, which influences how they learn and process information. In terms of instructional aids, intelligent instructional tools are particularly effective at providing multi-sensory experiences, thereby meeting a wider range of intelligence needs (Gardner, 1983, pp. 3-34). For example, the contextual interaction in "Easy Chinese" stimulates spatial intelligence through animated visual representations and kinesthetic intelligence through interaction and bodily engagement. These tools enable students to explore concepts in a way that aligns with their natural learning preferences, thus promoting deeper engagement and understanding.

Gardner's framework of multiple intelligences provides a valuable perspective for understanding how intelligent instructional aids support the development of multiple intelligences, leading to more personalized and effective teaching methods. Based on this theory, we can promote learning engagement, improve learning outcomes, and ensure the construction of a more inclusive and student-centered educational model.

Motivation Theory

Motivation theory emphasizes the intrinsic drives that motivate students to actively participate in learning activities. These drives typically manifest as a strong thirst for knowledge, curiosity, interest, and a serious and proactive learning attitude. Intelligent teaching aids, such as gamified learning tools like Kahoot or Wordwall, can provide instant feedback and dynamic interaction, fundamentally enhancing students' learning motivation. Competitive stimuli can stimulate students' desire for achievement, cultivate their sense of accomplishment and competitive spirit, thereby further increasing their learning engagement.

Teaching strategies and content delivery methods have a significant impact on students' learning motivation (Ahmad et al., 2023).

Motivation theory forms the foundational perspective of this study, emphasizing the crucial role of intelligent teaching tools in shaping students' learning attitudes, aiming to provide actionable insights into how to make Chinese language education more effective and student-centered.

■ Methodology

Participants

Participants were 60 sixth-grade students enrolled in Chinese language courses at a public primary school in Chiang Mai, Thailand. The school offers Chinese as a third language following the YCT curriculum. Students were taught under the commonly adopted 3+1 teaching model.

The school offers Chinese as a third language following the YCT curriculum. Students were taught under the commonly adopted 3+1 teaching model. The 3+1 teaching model is a teacher organization model used in Thai primary schools that have Chinese or English program groups, provided there are sufficient teachers. Taking the Chinese program group in this study as an example, "3" refers to three Thai teachers, all of whom have HSK (Chinese Proficiency Test) scores and Chinese teaching qualifications, and are primarily responsible for listening, reading, and writing lessons. "1" refers to a Chinese teacher, who may be a Chinese national working in Thailand or a Chinese student studying there. This Chinese teacher is primarily responsible for speaking lessons and assists the three Thai teachers, striving to localize the Chinese teaching as much as possible.

Research Design

This study employed a quasi-experimental mixed-methods design to investigate the effects of intelligent teaching tools on primary learners’ engagement and cognitive outcomes in Chinese language instruction. The research process followed a structured sequence that ensured systematic comparison between traditional and technology-enhanced lessons. The overall procedure is illustrated in Figure 1, which outlines the major stages of the study. The study began with a pre-test administered to all participants to establish baseline proficiency in vocabulary recognition, sentence construction, and basic comprehension. Following this, an eight-week instructional intervention was implemented. The experimental group received lessons supported by animated explanations, multimodal materials, and gamified applications, while the comparison group continued with traditional instruction using textbooks, worksheets, and board-based explanations.

Throughout the intervention, classroom video recordings were collected from a fixed-angle camera to capture learners’ behavioral indicators of engagement, including attention, participation, and on-task responses. These recordings were later analyzed to extract learning analytics, such as engagement rates

and coefficient of variation (*CV*), which allowed the study to assess the stability of learners' motivation and attentional patterns across different instructional stages. Upon completion of the intervention, a post-test was administered to measure cognitive improvement. Learners also completed a 15-item Likert-scale motivation questionnaire, which provided additional insight into their perceptions of intelligent tools and their learning experiences. This integrated design enabled a comprehensive understanding of how technology-enhanced instruction influenced both cognitive performance and behavioral engagement in a real classroom context.

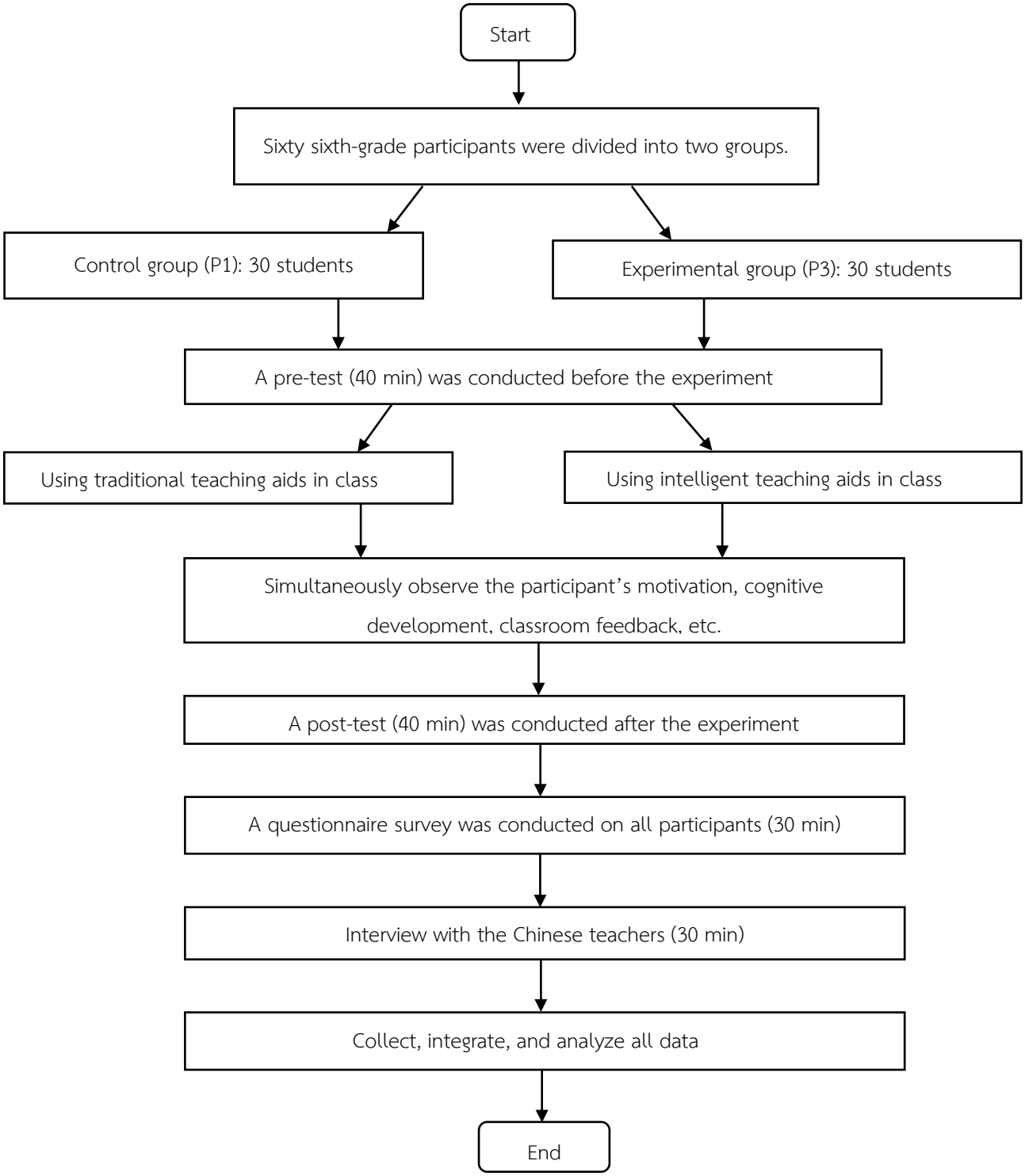

Figure *1*. Experimental Design

Definition of intelligent teaching aids

Intelligent teaching aids are modern classroom management systems. Unlike traditional digital media such as projectors or static courseware, intelligent tools enable interactive learning, automatically generated feedback, and cognitively matched task design.

For educational environments and resources such as primary schools, intelligent teaching aids often take the form of electronic platforms, including websites and software frequently used by schools, such as Kahoot, Google Classroom, Quizlet, and Wordwall. These intelligent teaching tools typically run as computer plugins or applications, integrating curriculum design with high interactivity and adaptability. They enhance the learning process by supporting attention regulation, reducing cognitive load, and strengthening memory through repetitive adaptive practice. They also have management and scoring functions, enabling timely formative assessments and connecting students, teachers, and knowledge in a clear and transparent manner (De la Torre, n.d.; Wang & Tahir, 2020).

Intervention and Intelligent Teaching Tools

The intervention integrated three types of intelligent teaching tools:

1) Animated Multimodal Instruction (Easy Chinese): The animated teaching software "Easy Chinese" is a teaching plugin independently developed by the Confucius Institute at Chiang Mai University. This software incorporates a narrative-based multimodal scaffolding design, presenting visual cues and spoken input simultaneously to promote dual coding and reduce the external cognitive load of learning abstract vocabulary in Chinese. The software uses units as its learning structure, including modules such as "vocabulary, grammar, situational dialogues, simulated dialogues, and immersing oneself in real China," enabling students to gradually construct language meaning in simulated scenarios and master abstract sentence structures and authentic communicative expressions in an engaging and enjoyable way. Its intelligent features include automatically embedded attention-stabilization mechanisms, such as sudden question prompts, real-time interactive responses, and game-reward elements. These features create cognitive arousal that helps sustain attention. By integrating multimodal input, real-time interaction, and motivational regulation, Easy Chinese functions as more than simple digital multimedia; it supports active cognitive processing and encourages learner immersion.

2) Multimodal instructional platforms combining text, imagery, audio, and contextual demonstrations to reinforce comprehension.

3) Gamified learning applications: Kahoot and Wordwall, providing competitive practice, immediate feedback, and repeated reinforcement.

Gamified learning tools such as Kahoot and Wordwall provide competitive practice, immediate feedback, and repeated reinforcement. Gamified instruction incorporates game-based design, interactive elements, and reward mechanisms into non-game learning contexts (Kuo & Chuang, 2018). Kahoot

(introduced in 2013) and Wordwall (launched around 2015) have been widely adopted in educational settings and are consistently reported to enhance classroom engagement (Wang & Tahir, 2020).

The intelligent features of these tools lie in their customizable task design, allowing teachers to transform instructional content into interactive challenges that stimulate learners' cognitive processing. The platforms also provide instant feedback, automated scoring, and real-time ranking, enabling students to monitor their progress while allowing teachers to quickly identify cognitive weaknesses and conduct formative assessments.

Research shows that Kahoot and Wordwall enhance attention, memory encoding, and retrieval by integrating visual, auditory, and cognitive stimuli that support multi-sensory processing (Kuo & Chuang, 2018). Their low cost and ease of use further increase their practicality as intelligent teaching technologies. For young learners, the competitive yet enjoyable environment helps reduce anxiety, build confidence, and sustain motivation. With mechanisms such as real-time analytics, adaptive reinforcement, multi-sensory input, and motivational regulation, gamified learning exhibits capabilities that go beyond standard digital tools and align with the core characteristics of intelligent learning systems.

Research Instruments

Multiple instruments were employed to collect data:

1) Pre-tests and post-tests measuring vocabulary recognition, sentence construction, and comprehension. The tests were validated by three experts in Chinese language education.

Following the "quasi-experimental design" method in educational research, the consistency of pre-test and post-test items will be maintained to ensure that the measurement data observes the "changes" in students' cognition. Furthermore, to guarantee test quality and post-test effectiveness, no answer analysis will be conducted after the pre-test, and the testing intervals within half a semester will be reasonable to reduce the "memory effect." In addition, the test content has been reviewed and approved by four teachers in the Chinese project team; the difficulty and content are appropriate for the participants' educational level, and there is no content exceeding the teaching syllabus.

2) Classroom video recordings used to analyze indicators of engagement, including attention, participation, response timing, and on-task behavior.

Classroom video recordings will select video samples and have them independently encoded by two coders to ensure Cohen's $\kappa > .80$.

3) Learning analytics, including engagement rates and coefficient of variation (CV), extracted from video logs to quantify engagement stability.

4) Fifteen-item Likert-scale questionnaire assessing learners' motivation. The questionnaire collection rate will reach over 80%, and four Chinese teachers will further verify the construct validity of the questionnaire to ensure that the questionnaire questions correspond to learning motivation, cognitive clarity and satisfaction. Reliability from pilot testing produced Cronbach's $\alpha > .80$.

Data Analysis

Quantitative data were analyzed using descriptive statistics, paired-sample t-tests, and effect size calculations to measure cognitive improvement. Engagement stability was assessed using the coefficient of variation (CV) across lesson stages, with lower CV values indicating more consistent engagement. Qualitative data from observations and open-ended questionnaire responses were coded thematically to identify patterns in learner behavior and perceptions. Integrating these data sources enabled a comprehensive understanding of how intelligent teaching tools supported motivation, engagement, and cognitive processing.

This study, based on a two-group experimental design, simply compared pre- and post-test scores and conducted performance analysis to reveal improvements in cognitive abilities. However, simply looking at the "results" is insufficient to answer the research question. The aim of this study is not only to examine learning outcomes but also to explore the impact of intelligent teaching tools on learners' motivation and classroom participation, and whether intelligent teaching aids can facilitate the authentic application of language learning and stimulate language interest.

Therefore, a two-group experiment alone cannot capture the rapidly changing behavioral changes during the teaching process. Thus, other analytical methods were employed for further investigation. Behavioral indicators extracted from classroom videos were analyzed to assess student attention and participation, providing dynamic evidence of learners' engagement throughout the course through the teaching aids. The coefficient of variation (CV) was used to measure the stability of participation; similarly, the questionnaire provided affective analysis, supplementing the cognitive performance data.

In short, this study examines not only the learning outcomes brought about by intelligent teaching aids (what students learned) but also the learning process influenced by intelligent teaching aids (how they learned), thereby achieving sustainable educational development. Therefore, additional analysis is needed, going beyond what a simple two-group comparison can reveal.

■ Results

Engagement Patterns During the Intervention

Analysis of classroom video recordings revealed clear differences in learners’ on-task behavior across the instructional stages of the intervention. Students in the technology-enhanced group consistently maintained high levels of attentional focus throughout presentation, guided practice, and consolidation phases, with engagement rates regularly exceeding 95%. The variability of engagement was notably low, as reflected in coefficient of variation (CV) values below 5%, indicating stable and sustained participation during lessons integrating intelligent teaching tools.

As illustrated in Figure 2, both concentration and engagement remained high across animated vocabulary explanation, Wordwall interactive tasks, and Kahoot-based evaluation. Although slight dips appeared during text-focused activities, students’

engagement quickly recovered during subsequent multimodal or gamified segments. This pattern suggests that digital tools—particularly those combining visual cues, animation, and immediate feedback—played a central role in supporting attention during cognitively demanding transitions.

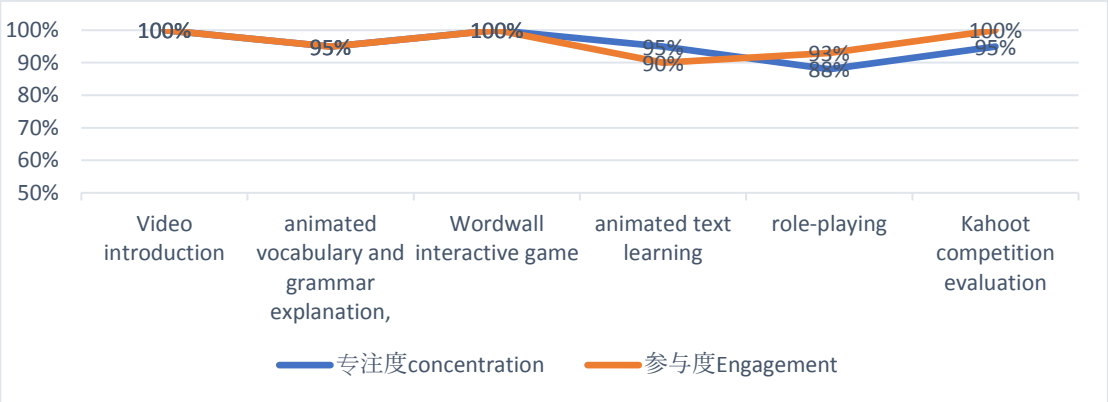

Figure *2. Changes in Focus and Engagement in Intelligent Classrooms*

Supporting these visual trends, Table 1 Summary of Engagement Metrics in the Intelligent-Tool Classroom presents the statistical indicators of students' attentional behavior. Concentration averaged 95.83% (CV = 0.039), while overall engagement averaged 96.33% (CV = 0.045). These values reinforce the stability observed in the video analytics and highlight the consistently high behavioral participation sustained across the eight-week period.

Table 1.

Summary of Engagement Metrics in the Intelligent-Tool Classroom.

Variable	Average Value	*SD*	Min	Max	CV
Concentration	95.83%	3.76%	90%	100%	0.039
Engagement	96.33%	4.32%	90%	100%	0.045

In summary, the integration of animated explanations, multimodal demonstrations, and game-based review tasks contributed to steady attentional engagement throughout lessons. The combination of visual, auditory, and interactive input effectively reduced the cognitive dip points typically observed in traditional classrooms, fostering a more continuous and focused learning experience for primary-level Chinese learners.

Cognitive Outcomes from Multimodal Instruction

The integration of intelligent teaching aids provided learners with rich multimodal input through animated videos, contextualized scenarios, and interactive review tasks. These resources offered visual, auditory, and situational scaffolding that supported elementary learners in constructing meaning and internalizing key Chinese vocabulary. As illustrated in Figure 3, the "Easy Chinese" animated software

introduced background information before each unit through cartoon-based storytelling, helping students grasp cultural context and understand symptoms, polite expressions, and doctor–patient interactions within authentic communicative scenes.

Figure *3. Cognitive Benefits of Video Teaching*

To evaluate learners' comprehension following the animated instruction, a four-item assessment was administered. The results, summarized in Table 2: Student Responses and Accuracy Rates, show that students achieved accuracy levels ranging from 50% to 100%, despite watching the animated video only twice. Tasks requiring recognition of polite expressions reached perfect accuracy, whereas items involving symptom interpretation or understanding the doctor's advice yielded moderate but meaningful accuracy gains (50–60%). These outcomes indicate that multimodal content facilitated rapid comprehension and supported learners in processing both concrete and inferential information.

Students' behavioral responses further demonstrated how multimodal learning enhanced cognitive processing. During video viewing, learners exhibited "sound–image combination" memory behaviors, linking verbal forms with visual cues, contextual actions, and narrative sequencing. This multimodal encoding strengthened their ability to recall and reconstruct information during comprehension checks. During subsequent review tasks in Wordwall, the random selection and rapid-response mechanisms generated a moderate level of cognitive arousal, which sustained attention and reinforced memory through repeated, interactive practice.

Table 2.

Student Responses and Accuracy Rates.

	Q 1: What questions do doctors ask?	*Q2: What polite words did we hear?*	*Q3: What happened to Mario?*	*Q4: What did the doctor say?*
Student answers	Height, weight, age, gender	Hello, thank you, you're welcome, please, sorry	Fever, dizziness	more rest, take medicine, don't go to school
Correct answer	Height, weight, age, gender, symptoms, time, allergies	Hello, thank you, you're welcome, please, sorry	Fever, stomach discomfort, dizziness, vomiting	No shower, more rest, take medicine, don't go to school, take temperature
Accuracy	57%	100%	50%	60%

These instructional effects align with constructivist learning theory, where learners actively build understanding through meaningful interaction with materials, context, and social cues. Classroom observations revealed that students could accurately articulate symptom-related expressions such as “我感觉＋状态” (“I feel + state”) and perform the corresponding physical actions. Even more reserved learners internalized vocabulary through observation and later demonstrated accurate verbal recall. Some students extended their learning further by engaging in creative imitation, signaling a transition from passive repetition to active knowledge construction.

Pre–Post Test Gains (Experimental Group Only)

To examine the impact of intelligent teaching aids on learners’ academic performance, pre- and post-test scores for the experimental group were analyzed using descriptive statistics and paired-samples t-tests. As shown in Table 3: Descriptive Statistics and Paired t-Test Results, students demonstrated a substantial improvement following the eight-week intervention.

The mean pre-test score was 11.93 (*SD* = 3.89), while the post-test mean increased to 20.40 (*SD* = 4.42), reflecting an average gain of +8.47 points. This improvement was statistically significant, as indicated by the paired-samples t-test $t(29) = -8.88$, $p < .001$. The results confirm that learners performed considerably better on vocabulary recognition, sentence construction, and comprehension tasks after receiving instruction supported by intelligent teaching tools.

Table 3.

Descriptive Statistics and Paired-Samples T-Data for the Experimental Group

Experimental group Basic indicators						
Name	Sample	Minimum	Maximum	Average	Standard	Median
pre	30	4.000	20.000	11.933	3.895	12.000
post	30	15.000	29.000	20.400	4.423	20.000

Experimental group Paired *t* -test analysis results - detailed format						
Pairing number	Item	average value	Standard deviation	Mean difference	*t*	*p*
test	pre	11.93	3.89	-8.47	-8.888	0.000
	post	20.40	4.42			

* $p<0.05$ ** $p<0.01$

The effect size calculated using Cohen's *d* was 1.62, which falls within the very large effect range. This magnitude suggests that the intervention had a strong and meaningful impact on student learning outcomes. In addition, the increase in score variability from pre-test to post-test (*SD* +0.53) indicates that although most students improved, some demonstrated exceptionally high gains, reflecting individual responsiveness to multimodal and interactive instruction.

Overall, the statistical evidence shows that intelligent teaching aids played a significant role in enhancing learners' cognitive performance. The combination of visual input, animated explanations, and interactive reinforcement resulted in measurable improvements in comprehension and language application accuracy among primary-level Chinese learners.

Learner Perceptions of Intelligent Teaching Tools

Findings from the post-intervention questionnaire offer additional insights into learners' affective responses toward the intelligent teaching tools. As summarized in Table 4, student evaluations were strongly positive. A total of 73% of learners awarded four or five stars, with 39.7% selecting four stars and 33.3% selecting five stars. The mean rating was M ≈ 4.04, accompanied by a low standard deviation, suggesting that students' satisfaction with the technology-enhanced lessons was both high and consistent.

Table 4.

Statistics on the percentage of five-star questionnaire scores

Score (x)	frequency (f)	Mean
1	0	0%
2	2	2.6%
3	19	24.4%
4	31	39.7%

Score (x)	frequency (f)	Mean
5	26	33.3%

$M = \Sigma(f^*x) / N$

The frequency distribution of ratings is visualized in Figure 4, which highlights the predominance of positive evaluations. These results indicate that learners perceived the intelligent tools as engaging, clear, and beneficial for their overall learning experience. Students commonly reported that the tools improved their interest in Chinese language lessons, enhanced comprehension through visual and contextual cues, and helped them stay focused throughout the class. Many also emphasized that the interactive nature of the activities—particularly gamified elements—made learning more enjoyable and encouraged active participation.

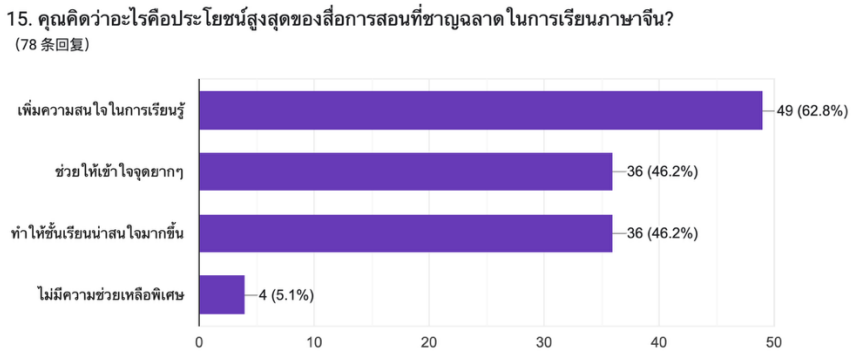

Figure *4.* Distribution of Students' Motivation Ratings on Intelligent Teaching Aids

Further qualitative feedback revealed that students attributed the greatest benefit of intelligent teaching aids to increased learning motivation. Specifically, 62.8% of learners indicated that the tools made lessons more interesting, 46.2% felt that the tools improved their comprehension, and another 46.2% noted that the tools enhanced their enjoyment and willingness to learn. These perceptions suggest that technology-enhanced learning not only strengthens cognitive understanding but also supports students' emotions and learning attitudes by fostering curiosity, confidence, and sustained engagement.

The overall pattern of responses aligns with principles of Self-Determination Theory (Deci & Ryan, 1985), which posits that motivation is reinforced when learning environments support autonomy, competence, and relatedness. Intelligent teaching aids provided multimodal input, timely feedback, and opportunities for self-directed exploration, thereby activating learners' intrinsic motivation and deepening their engagement with Chinese language learning. Taken together, the questionnaire findings confirm that the intelligent tools were perceived positively and played a meaningful role in promoting both cognitive and motivational gains among primary-level learners.

■ Discussion and Conclusion

The findings of this study demonstrate that intelligent teaching tools—integrating animated explanations, multimodal input, and gamified practice—can substantially enhance young learners' engagement, comprehension, and overall performance in primary Chinese language instruction. The consistently high engagement rates, accompanied by minimal fluctuation, indicate that technology-enhanced lessons help stabilize attention and sustain motivation during cognitively demanding tasks. These results align with recent evidence showing that multimodal and interactive learning environments enhance attentional persistence and deepen learning among young learners (Nasution & Batubara, 2024; Yang, Karanyathikul & Kotchasit, 2024). Moreover, students who received animated and contextualized input exhibited stronger comprehension and retention, reflecting principles of multimodal learning theory, which posits that convergent visual–verbal cues reduce extraneous cognitive load and support deeper semantic processing (Han, Liu & Sun, 2023). Learners' perceptions further reinforced these results: students consistently reported that animated scenarios enhanced knowledge clarity and comprehension, while interactive games increased learning motivation and engagement. Recent research confirms that digital learning tools can foster intrinsic learning motivation by providing timely feedback, multimodal visual support, and opportunities for autonomous participation (Wang & Tahir, 2020). Collectively, these converging lines of evidence confirm that intelligent teaching tools can offer substantial pedagogical advantages for young learners facing the linguistic and cognitive challenges of learning Chinese as a foreign language.

Despite these promising results, several limitations should be acknowledged. This study was conducted in a single school and over a relatively short intervention period, which may restrict the broader applicability of the findings. Furthermore, the research design did not assess longer-term retention or account for differences in teacher expertise that may influence the effectiveness of technology integration. Future research would benefit from multi-site or cross-regional studies to examine the adaptability of intelligent tools across varied instructional contexts, alongside longitudinal investigations to evaluate the durability of cognitive and motivational gains. Promising directions also include the incorporation of adaptive learning platforms capable of adjusting difficulty and feedback based on real-time analytics, as well as further research on teacher professional development to support the sustainable use of multimodal and gamified instruction. Overall, this study offers meaningful empirical evidence for the value of intelligent teaching tools in creating more equitable, engaging, and cognitively supportive learning environments. When intentionally designed and appropriately implemented, technology-enhanced instruction can help young learners process complex linguistic information more effectively, stay consistently engaged, and develop greater confidence and motivation in learning Chinese as a foreign language.

Originality and Contributions

This study makes an original contribution to the field of technology-enhanced teaching in Thai primary school Chinese language education. Firstly, given the increasing penetration of educational technology into all aspects of teaching, many studies only point out that smart teaching aids help students improve their grades. However, this study introduces the

concept of teaching engagement stability and uses behavioral analysis and the coefficient of variation (CV) to measure students' learning engagement, thereby examining whether students can maintain stable engagement and high learning motivation during teaching activities when using smart teaching aids, especially in language education. This process-oriented indicator is rarely used in research on Chinese as a Foreign Language (CFL), especially in Southeast Asian primary education.

Secondly, this study is based in Thailand and incorporates the concept of a 3+1 teacher partnership. Using smart teaching tools under this teacher-student pairing creates a teaching system that integrates language localization, teacher localization, and technology empowerment. Teachers, students, and technology collaborate to form a systematic fit, providing a coherent framework for building a smart learning environment in resource-constrained settings. Simultaneously, this study aims to create authentic and practical language learning experiences. Beyond simply mastering language knowledge, students should not only be able to pass exams but also cultivate language literacy from a young age, experiencing, loving, and appreciating the culture associated with the language.

Furthermore, this study employs a hybrid approach, combining test performance, behavioral engagement, and learner perception to comprehensively examine the cognitive and motivational impacts of intelligent tools. This multi-layered analytical method transcends traditional two-group comparisons, providing a new methodological perspective on how intelligent technology shapes the learning process. This approach better facilitates the technological integration of modern teaching aids, achieves sustainable educational development, and realizes that the essence of education is enabling students to learn how to learn.

In conclusion, these contributions highlight the originality of this research and its significant role in advancing intelligent teaching practices in Chinese language education.

■ Acknowledgement

We would like to express our sincere gratitude to all individuals and institutions who contributed to the completion of this research.

First, we extend our heartfelt appreciation to Anuban Primary School in Chiang Mai, Thailand, for their full cooperation and invaluable support in teaching arrangements, classroom recording, and data collection. Special thanks are also due to the sixth-grade teachers, students, and their parents, whose active participation and trust provided a strong foundation for the authenticity and reliability of the data. We are equally grateful to the Chinese language education professionals who assisted in evaluating the research instruments; their expert feedback significantly enhanced the validity and reliability of the tools used, thereby ensuring academic rigor.

Furthermore, this study has benefited from the theoretical contributions and research experience of numerous scholars. We acknowledge with respect all the researchers cited in this paper, whose work provided essential theoretical support and valuable research insights.

Finally, we express our deepest gratitude to our advisers for their guidance, encouragement, and moral support throughout the research process. Their assistance was instrumental in the successful and academically rigorous completion of this study.

This paper is dedicated with sincere thanks to all who have supported and contributed to this research.

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