Studies in Second Language Learning and Teaching
Department of English Studies, Faculty of Pedagogy and Fine Arts, Adam Mickiewicz University, Kalisz
SSLLT 0 (0). 2025. 1-32. Published online: 30.10.2025
https://doi.org/10.14746/ssllt.44595
http://pressto.amu.edu.pl/index.php/ssllt

Cross-lagged panel analysis of reciprocal effects of metacognitive knowledge and breadth of vocabulary knowledge in a foreign language context

Mark Feng Teng ✉
Macao Polytechnic University, Macau SAR, China
https://orcid.org/0000-0002-5134-8504
markteng@mpu.edu.mo

Abstract

Metacognitive knowledge significantly influences English vocabulary knowledge. However, few longitudinal studies have explored the reciprocal growth trajectories of metacognitive knowledge and English vocabulary knowledge over time. The present study explores how young primary school learners develop their metacognitive knowledge and vocabulary knowledge from Grade 3 to Grade 6. The longitudinal sample included 361 Grade 3 (third-year primary school) students (M = 9.60 years, SD = 0.85). The participants completed tests of metacognitive knowledge and vocabulary knowledge on four occasions. The metacognitive knowledge test focused on students' cognitive activities, whereas the vocabulary knowledge test focused on learners' breadth of vocabulary knowledge. Cross-lagged panel analysis was employed to explore the reciprocal effects of metacognitive knowledge and the breadth of vocabulary knowledge. The results supported the role of metacognitive knowledge in developing the breadth of vocabulary knowledge, and vice versa. Implications for young learners' longitudinal development of metacognitive knowledge and vocabulary knowledge are discussed.

Keywords: metacognition; metacognitive knowledge; vocabulary knowledge; breadth of vocabulary knowledge

1. Introduction

Metacognitive knowledge empowers learners to evaluate, select, and refine their strategies for setting goals and monitoring their progress (Zimmerman, 2002). Metacognitive knowledge is fundamental to both creative thinking (Schraw, 1994) and language acquisition (Qian et al., 2025). In the realm of vocabulary acquisition, metacognitive knowledge pertains to an awareness of cognitive processes in vocabulary learning, aligning with the beliefs learners hold and their intuitive understanding of the vocabulary learning process (Teng & Mizumoto, 2024). Learners with advanced metacognitive awareness can effectively assess their cognitive processes and utilize their metacognitive knowledge to guide their own learning when acquiring new words efficiently (Shin et al., 2023). These capabilities are also crucial in managing cognition during vocabulary retrieval for both receptive and productive language skills, facilitating efficient access to vocabulary knowledge (Teng, 2022). Moreover, metacognitive knowledge significantly enhances learners' ability to manage cognition when retrieving vocabulary for both receptive (reading) and productive (writing) language skills (Teng & Zhang, 2021). This cognitive management manifests in various ways, such as efficiently accessing mental lexicons (Carcamo, 2023), making informed decisions about word choice based on context (Guo, 2018), and effectively monitoring comprehension (Zhang, 2010).

Read (2000) describes vocabulary knowledge as a complex, multifaceted concept essential for learners to understand and apply words in academic English. This complexity encompasses not only the breadth of vocabulary knowledge (the number of words known) but also the depth of vocabulary knowledge (knowledge about each word, including its semantic nuances, syntactic properties, and pragmatic uses). Schmitt (2008) emphasizes that vocabulary mastery extends beyond mere recognition to include appropriate usage across various contexts. Schmitt (2010) thus highlights the importance of grasping the form and meaning of new words and enhancing comprehension of language, both spoken and written. Webb and Nation (2017) recognize the advancement of vocabulary knowledge as a critical element in language learning, advocating for systematic approaches to vocabulary instruction that consider factors such as word frequency, learner needs, and cognitive load.

While existing literature explores vocabulary and metacognitive knowledge, studies typically examine the two constructs separately, without evaluating the reciprocal effects between learners' vocabulary knowledge and metacognitive awareness from a longitudinal perspective (Teng, 2025). This research gap highlights the need to capture the dynamic interplay between these two crucial aspects over time. Furthermore, the majority of previous research adopts cross-sectional or short-term designs (Guo, 2018; Lee et al., 2022; Teng & Mizumoto, 2024), which are limited in their ability to capture the dynamic, bidirectional interplay between metacognitive knowledge and vocabulary breadth in foreign language learning. The current study adopts a longitudinal perspective to examine the bidirectional effects between metacognitive knowledge and breadth of vocabulary knowledge in a foreign language learning context. This focus on bidirectionality offers a significant shift from traditional unidirectional models of language learning, providing an updated understanding of the complex dynamics between metacognitive and vocabulary knowledge in a foreign language context.

2. Literature review

2.1. Theoretical frameworks

The present study investigates the longitudinal relationship between metacognitive knowledge and breadth of vocabulary knowledge among young learners in rural China, grounding its analysis in well-established theoretical frameworks, such as self-regulated learning (SRL) theory (Zimmerman, 2002) and developmental metacognitive frameworks (White & Frederiksen, 2005). SRL theory underscores the pivotal role of metacognition in effective learning (Flavell, 1979). According to SRL, learners who are aware of and can regulate their cognitive processes are better equipped to employ appropriate strategies for learning (Schunk, 2013). This theoretical perspective suggests that metacognitive awareness empowers learners to actively monitor, evaluate, and adjust their approaches to their learning.

Complementing SRL theory, developmental metacognitive frameworks offer insights into how metacognitive knowledge evolves over time (White & Frederiksen, 2005). These frameworks emphasize that metacognitive skills are not static but develop progressively as learners mature, shaped by age, experience, and cognitive growth. Younger learners, for instance, tend to rely heavily on external guidance, structured learning environments, and explicit instruction to support their metacognitive development. In contrast, older learners gradually acquire the capacity to independently reflect on and regulate their learning processes, adopting more autonomous and sophisticated strategies (Zimmerman, 2002). By integrating these theoretical perspectives, the present study aims to explore the dynamic interplay between metacognitive knowledge and vocabulary knowledge over time.

2.2. Metacognitive knowledge (MCK)

The exploration of metacognition was initiated in the early 1970s. Flavell (1979) framed metacognition as knowledge and cognitive processes aimed at understanding or controlling cognitive activities. This foundational idea highlighted the awareness of processing skills, cognitive tasks, and strategic task execution, emphasizing the reflective and self-regulatory aspects of human thought. Metacognition encompasses not only an understanding of personal and others' cognitive processes but also the executive abilities to plan, monitor, and evaluate cognitive endeavors. This multifaceted construct underscores the role of self-awareness and strategic thinking in learning and problem-solving contexts. Flavell's (1979) work delineated metacognition into three primary components: metacognitive knowledge, metacognitive experiences, and metacognitive skills, each playing a crucial role in cognitive development and academic learning.

The focus of the present study was specifically on MCK, a component of the larger metacognition framework, which has been identified by Flavell (1979) as the declarative aspect alongside children's procedural practices for memory regulation and monitoring during tasks. This emphasis on MCK highlights its fundamental role in shaping learners' approaches to cognitive challenges and their overall learning strategies. Schraw (1994) further characterizes MCK as encompassing three distinct but interrelated facets: person knowledge (awareness of one's cognitive strengths and weaknesses), task knowledge (understanding of the demands of a task), and strategy knowledge (awareness of strategies for task completion). These three facets are essential for learners to internalize and utilize metacognitive knowledge to regulate their cognitive functions effectively. The interplay between these aspects of MCK enables learners to navigate complex learning environments and optimize their cognitive performance across various domains. Building on Flavell's (1979) work, Brown (1987) expands the concept to include a more nuanced understanding of metacognitive knowledge: declarative knowledge (awareness of factors affecting performance and learning outcomes), procedural knowledge (understanding of executing skills), and conditional knowledge (knowing when and under what conditions to use cognitive strategies). Brown's (1987) expansion provides a more comprehensive framework for understanding the multifaceted nature of metacognitive knowledge, emphasizing its dynamic and context-dependent characteristics.

Subsequent research has painted a more nuanced picture, depicting metacognitive knowledge as a cognitive attribute present in learners across various age groups – from those in elementary education (Annevirta et al., 2007; Annevirta & Vauras, 2001) to adolescents in secondary education (Schneider et al., 2017) and individuals in higher education (Cotterall & Murray, 2009). This evolving understanding of metacognitive development across the lifespan has significant implications for educational practices and interventions at all levels of schooling. Sato (2022) suggests that metacognitive development is an individual difference with both trait-like and state-like properties. This dual characterization implies that while some aspects of metacognitive ability may be relatively stable across contexts (trait-like), others can be situationally influenced and potentially improved through targeted interventions (state-like). Wenden (1998) highlights that metacognitive knowledge is crucial for a language learner's ability to develop learning awareness, enhance recall, expedite learning, and improve the quality and speed of cognitive engagement. This multifaceted impact underscores the pervasive influence of metacognition on various aspects of the learning process, from initial encoding to long-term retention and application.

MCK may be developed through structured or unstructured means, and acquired either intentionally through explicit instruction or by chance through incidental learning experiences (Schneider et al., 2022). It embodies learners' self-awareness, enabling them to become aware of and express their knowledge about their own cognitive processes. Schneider et al. (2022) posit that access to MCK enhances learners' cognitive processing and self-regulatory practices. Their research underscores the dynamic connection between metacognitive awareness and cognitive performance in childhood and adolescence, particularly in domains such as memory and reading comprehension. Meanwhile, Sato and Dussuel Lam (2021) report that while young learners' metacognitive development may be nascent or imprecise, metacognitive teaching can significantly refine their metacognitive abilities and participation in the classroom setting. This finding emphasizes the malleability of metacognitive knowledge and the potential for targeted interventions to enhance learners' metacognitive knowledge, even at early stages of development.

Person, task, and strategy knowledge evolve from the onset of primary education and continue to advance into young adulthood (Schneider, 2008). This developmental trajectory suggests a gradual refinement of metacognitive abilities, influenced by both maturation processes and educational experiences. With a strong understanding of their own self-regulation, individuals are less prone to engage in maladaptive motivated reasoning that excuses indulgent behavior through misguided beliefs. When equipped with metacognitive insights into tasks and strategies, they may use self-licensing (the process by which individuals give themselves permission to engage in behaviors) in a way that supports rather than undermines their pursuit of goals (Hennecke & Kulkarni, 2024). According to the episodic-context account (Karpicke et al., 2014), additional retrieval cues arise from connecting knowledge elements with different episodic contexts encountered during learning and retrieval. Integrating metacognitive knowledge into this framework, learners can become more aware of the strategies and contexts that optimize their retrieval practice. By understanding how their cognitive processes interact with episodic contexts, learners can deliberately enhance their retrieval cues, leading to more effective learning and memory retention (Endres et al., 2024). This expanded understanding of metacognitive knowledge development provides a rich foundation for exploring its interplay with vocabulary knowledge in a foreign language learning context.

2.3. Vocabulary knowledge (VK)

VK is a cornerstone of language learning. Nation (2022) identified three key aspects of VK: form, meaning, and use, each further divided into receptive and productive knowledge. Receptive knowledge involves understanding words, while productive knowledge pertains to using words in speaking or writing. A crucial element in mastering vocabulary is understanding the form-meaning connection. To address the challenges of measuring vocabulary knowledge, researchers have proposed analytical models, such as distinguishing between the breadth and depth of vocabulary knowledge (Anderson & Freebody, 1981). Schmitt (2014) explains that breadth of vocabulary knowledge (BVK) refers to the number of words a learner knows, while depth of vocabulary knowledge (DVK) involves understanding individual lexical aspects, such as multiple meanings, and a comprehensive mastery, including a rich knowledge of the associative network around a word.

Nassaji (2004) highlights the intricate and multifaceted nature of VK, noting that understanding a word encompasses various dimensions, including its spelling, pronunciation, register, morphological and stylistic features, syntactic and semantic connections. This comprehensive knowledge also involves understanding the meanings of collocates and relationships such as antonymy, synonymy, and hyponymy. Mastery of both BVK and DVK is crucial for independently interpreting written (Qian, 2002) and spoken language (Cheung, 2023). For instance, a learner's receptive second language (L2) vocabulary size is linked to their ability to elaborate on word meanings and forms (Candry et al., 2017). Research by Uttl (2002) found a strong correlation ($r = 0.75$) between scores on a vocabulary definition task and the North American Adult Reading Test (NAART), which involves reading irregularly spelled English words aloud. This correlation was consistent across different age groups. Kavé et al. (2019) suggest that vocabulary knowledge enhances orthographic retrieval not only by improving knowledge of specific words through reading but also by adopting a spelling strategy that relies more on full lexical retrieval than on sound-to-letter conversion. Changes in vocabulary knowledge contrast sharply with changes in other verbal abilities, particularly word retrieval (Kavé, 2024). Teng (2025) supports the positive relationship among metacognitive knowledge, vocabulary knowledge, and reading, especially the longitudinal mediating role of breadth of vocabulary knowledge in the relationship between metacognitive knowledge and reading.

Read (2000) emphasizes that simply knowing basic word meanings is insufficient; learners must develop a detailed and holistic understanding of each word item to effectively use a language. BVK is particularly well-suited to deliberate learning strategies, whereas DVK demands extensive exposure to the target language, making it more difficult to acquire (Schmitt, 2010). Interestingly, DVK can sometimes be acquired or mastered more quickly than BVK (Schmitt, 2008). These insights highlight the varying developmental levels of vocabulary knowledge among primary school students at different stages of acquisition (Teng, 2022). Exploring the progressive nature of vocabulary learning can offer a more comprehensive view of a learner's vocabulary knowledge. Investigating the developmental trajectory of young learners' vocabulary acquisition is thus valuable. The swift growth of vocabulary in young learners highlights the importance of being able to deduce and build word meanings from context to enhance their reading comprehension abilities (Butler, 2020). The most effective ways to learn words are through direct life experiences and reading. However, early childhood experiences in these areas vary significantly, leaving some children with limited vocabularies (Schneider et al., 2023).

Overall, vocabulary knowledge is not isolated; it significantly impacts word retrieval and reading. These interconnections highlight the importance of vocabulary as a foundational element in language proficiency. The development of VK is distinctive because it is potentially influenced by cognitive abilities. This interaction suggests that metacognitive knowledge may play a role in how vocabulary knowledge develops and changes over time.

2.4. Overview of metacognitive knowledge and vocabulary knowledge

Empirical research supports the connection between metacognitive awareness and vocabulary knowledge. For instance, Teng (2022) studied 426 first-grade students and found that both metacognitive and vocabulary knowledge, including BVK and DVK, improved from Grades 1 to 4, though not in a straightforward manner. The study revealed a strong correlation between students' metacognitive awareness and their vocabulary proficiency, indicating that a deeper understanding of cognitive processes enhances vocabulary acquisition. Teng and Mizumoto (2024), a cross-sectional study focusing on 776 Chinese university students, highlighted that effective vocabulary acquisition involves a sophisticated interaction between metacognitive knowledge and vocabulary knowledge. This interplay suggests a synergistic relationship where improvements in one domain can catalyze advancements in the other, creating a positive feedback loop in vocabulary learning. Song et al. (2014), a longitudinal study focusing on 264 native Chinese children, argued that vocabulary development in young learners was dependent on metacognitive skills, which improved with schooling and cumulative learning experiences. This perspective emphasizes the intertwined nature of cognitive development and educational exposure in shaping a child's linguistic capabilities.

Moreover, Lee et al. (2022) explored the complex interactions between vocabulary learning strategies, categorized into memory, cognitive, and metacognitive, and vocabulary knowledge within a self-regulated learning framework. Their study involved 185 secondary-level Korean students and demonstrated that vocabulary learning strategies mediated the relationship between motivation and vocabulary knowledge. Similarly, Shin et al. (2023) investigated 66 fifth-grade Korean students' metacognitive awareness and motivation. The findings showed that metacognitive awareness, particularly the use of mental translation strategies, moderated the effects of listening to stories. Students with greater awareness of these strategies learned more words from listening activities compared to those with less awareness. This evidence underscores the role of metacognitive knowledge in enhancing vocabulary learning and supports the Matthew effect, where initial advantages in cognitive knowledge can lead to greater vocabulary gains (Perc, 2014).

Several studies have examined the longitudinal development of metacognitive knowledge and vocabulary knowledge in young learners. Teng and Zhang (2022) investigated the developmental trajectories of 112 ethnic minority *Yao* students and 101 ethnic majority *Han* students from Grade 3 to Grade 6. Results revealed that both morphological knowledge and morphological awareness developed in tandem for both groups, although *Yao* students lagged significantly behind *Han* students in these areas. The study also demonstrated the influence of metacognitive knowledge on morphological awareness, highlighting the disparity between *Yao* and *Han* students in their developmental progress. In a subsequent study, Teng and Zhang (2024a) explored the growth of metacognitive knowledge and English vocabulary breadth among 115 ethnolinguistic *Yao* minority students and 108 ethnolinguistic majority *Han* students. Both groups showed cumulative improvements in these areas from Grade 3 to Grade 6. Metacognitive knowledge consistently predicted the breadth of English vocabulary knowledge across the school years, yet notable differences in development were observed between the two groups.

While growth in vocabulary knowledge among young students is expected, it often coincides with the development of metacognitive skills. However, there is still insufficient data on the reciprocal effects of metacognitive knowledge and vocabulary knowledge. Young learners may experience limited vocabulary growth due to inadequate comprehension monitoring and metacognitive skills (e.g., Zargar et al., 2020). The dynamic and reciprocal effects between metacognitive knowledge and vocabulary knowledge remain an open question, warranting further investigation.

3. The study

The review of the literature suggests an anticipated deepening of MCK and VK among primary school learners across grades. Although previous research has examined metacognitive knowledge and vocabulary knowledge, the bidirectional impact between MCK and BVK, especially in young learners' early language learning stages, remains under-explored. There is a need for empirical evidence to substantiate the mutual influences of these constructs throughout primary education in a foreign language context. The current study was designed to explore the bidirectional effects longitudinally, providing insights into the dynamic and reciprocal relationship between MCK and BVK over time. The study poses the following research question:

> *Does a reciprocal effect exist between metacognitive knowledge and breadth of vocabulary knowledge during primary school grades?*

3.1. Research design

This longitudinal study was conducted to understand the reciprocal effects of MCK and BVK across four time periods for primary school learners. The measures were identical across the examined periods (Grade 3 to Grade 6). The test results did not exhibit floor or ceiling effects (e.g., per the skewness and kurtosis values in Table 1). Coefficient alpha values ranged from .83 to .86 for the MCK tests, indicating sound reliability. The coefficient alpha values for the VK tests ranged from .84 to .89, also indicating sound reliability.

3.2. Participants

The participants were 361 Grade 3 (third-year primary school) students. Their mean age was 9.6 years (*SD* = 0.85). There were 176 girls (48.75%) and 185 boys (51.24%). The participants were from primary schools located in the western rural part of

China. They received formal English instruction from Grade 3, and English was a foreign language for the participants. They were followed from Grade 3 to Grade 6.

The original sample consisted of 410 learners. However, 49 students who were unable to complete the entire study were excluded from the data analysis. Specifically, 32 participants failed to complete key sections of the survey or assessment tools, while 17 students dropped out of the study after transferring to different schools. The exclusions were primarily due to technical issues during data collection, such as incomplete responses or eligibility concerns, which were unrelated to participants' characteristics. This pattern of missing data aligns with the missing completely at random (MCAR) framework, meaning the missingness occurred randomly and did not introduce bias into the results. As such, analyses were able to proceed without significant adjustments, using methods like complete case analysis. Maintaining a consistent number of 410 participants across all four testing points would have been critical for preserving the internal validity of longitudinal research.

3.3. Measures

3.3.1. Metacognitive knowledge (MCK)

The assessment of MCK in foreign language learning was carried out through a series of tasks, adapted from Teng and Zhang (2024b). The focus of this assessment was on learners' cognitive processes. In each task, children were presented with three pictures (line drawings) depicting familiar situations for young learners in which they were asked to remember, understand, and learn something (Annevirta & Vauras, 2001). The test included a total of 24 tasks, accompanied by three pictures for each task. Figure 1 shows a sample picture task that measured participants' knowledge about remembering a new word.

The teachers verbally described each picture. The participants looked at the drawings and listened to the experimenter's explanations. The learners then selected the best option in mind and answered the question "Why is the picture you chose the best possible way to remember a new word?"). If learners found it hard to answer the question, the teacher could guide the learners through telling them to imagine themselves as the child in the given situation. The purpose of providing prompts was to help learners reflect on and explain their cognitive processes. The young learners were guided to provide explanations or answers that reflect their thoughts and experiences.

Task: Loading a memory

Cognitive activity: Remembering a word

A student was trying to remember a word. What was the best way for the student to remember a word?

1 2 3

1. A teacher reads aloud the word for the students.
2. Students learn to memorize the word by themselves.
3. A teacher explains the word.

Why is the picture you chose the best possible way to remember a new word?

Figure 1 An example MCK test item

Participants' explanations were rated based on a 4-point scale, ranging from 0 (no response) to 4 (highest score). Zero points were given for no answers (e.g., "I don't know"). One point was for some irrelevant or simple answers (e.g., "Just read it" or "It should be just like that"). Two points were awarded for implicit or indirect answers (e.g., "Reading a book is helpful for word learning," "I can find something new from reading," or "I just think reading books is helpful"). Three points were awarded for fairly adequate answers that reflected cognitive processing (e.g., "You need to read the story again and again for learning words" or "You can know more about the new words when you think about what happened in the story"). Four points were awarded for more explicit explanations that reflected their cognitive processing (e.g., "Vocabulary knowledge is learned through practice," "You have to be active in taking some notes for better remembering of new words," or "Remembering words relies on sharing stories with friends or learning from our past experiences").

Scores of each cognitive task were then summed, resulting in a maximum score of 96 points for the MCK test. Their reflections and accounts of cognitive processing were consistent with Flavell's (1979) framework, which posits that metacognitive knowledge encompasses an individual's understanding of cognitive operations and the ability to regulate these processes effectively. The participants' responses were recorded and transcribed. Three independent judges who had not taught the participants were recruited to handle the scoring requirement. They rated participants' verbal explanations twice. Interrater reliability between the three judges reached 87% to 95% agreement in the second round of rating, and disagreements were resolved through discussion until consensus was reached.

3.3.2. Breadth of vocabulary knowledge

The assessment of BVK was conducted using the Picture Vocabulary Size Test (PVST; Anthony & Nation, 2017). This standardized test provides a quick estimate of young learners' receptive vocabulary size and knowledge development. This test includes 96 items. Each item includes four pictures. The participants first listened to an audio clip twice and then were required to choose one picture that best represented the meaning of the corresponding stimulus word. The test was discontinued when a student incorrectly answered six consecutive items. The PVST yields raw scores that represent the correct number out of 96 possible points. The participants received five training words and image plates prior to the test. This procedure helped learners become familiar with the test requirements.

3.4. Procedure

The participants' parents signed a consent form, indicating their willingness to allow their children to participate in the study. They viewed this as an opportunity to gain insight into their children's development of vocabulary knowledge. Data collection began at the end of the second semester of third grade. The reason for focusing on third-grade students was that they began receiving formal English instruction in Grade 3. They had received nearly one year of English learning by the time of the study. Testing took place in the classroom and was conducted annually through Grade 6. The teachers individually administered both assessments to each participant. They also received a training session to become familiar with the test requirements.

3.5. Data analysis

We first utilized latent class growth analysis (LCGA), a statistical method used to identify distinct subgroups within a population based on their developmental trajectories over time (Jung & Wickrama, 2008). LCGA is a specialized form of growth mixture modeling that allows researchers to identify heterogeneous subpopulations within a larger group. Data analysis was then subjected to cross-lagged panel (CLP) analysis with four-wave data. CLP is helpful for understanding the developmental relationships between metacognitive knowledge and breadth of vocabulary knowledge. Figure 2 shows a simple CLP model with two observed variables measured at four time points. In the hypothesized model, Variable A at Time 1 (A1) predicts Variable B at Time 2 (B2), and conversely, Variable B at Time 1 (B1) predicts Variable A at Time 2 (A2) (i.e., cross-lagged effect). In this way, CLP modeling allows for assessing the possible reciprocity of developmental relationships and the prediction of each other's change over time between two or more variables (Selig & Little, 2012).

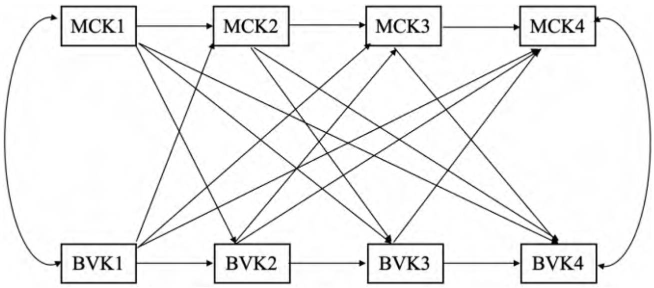

Figure 2 Hypothesized cross-lagged panel with four-wave data

To construct a CLP model, Time 1 metacognitive knowledge was hypothesized to predict Time 2 metacognitive knowledge and breadth of vocabulary knowledge based on previous findings regarding the dynamic relationships between metacognitive knowledge and vocabulary knowledge (Teng, 2022). Given the earlier discussion in this paper on the possible role of vocabulary knowledge in metacognitive knowledge, we hypothesized that Time 1 breadth of vocabulary knowledge would conversely predict Time 2 metacognitive knowledge as well.

The model was tested with the help of R (version 4.4.1). Maximum likelihood estimation was adopted. Model fit indexes were evaluated according to Hu and Bentler (1999), with a cutoff value close to .95 for GFI, TLI, and CFI; a cutoff value close to .06 for RMSEA; and a cutoff value close to .08 for SRMR. All data and coding were shared through OSF (https://osf.io/4wxur/).

4. Findings

4.1. Descriptive statistics and bivariate correlations

We first reported the descriptive statistics and bivariate correlations. Table 1 presents descriptive statistics for all measures at the four data collection points.

Based on Table 1, the participants demonstrated increased performance with increasing age and grade. The standard deviations indicate individual differences in developing MCK and BVK. While the full score of the BVK test was 96, participants' scores ranged from 0 to 27, which might initially suggest concerns about the test's sensitivity. However, the observed range does not necessarily indicate ceiling or floor effects. A ceiling effect occurs when participants cluster near the maximum score, and a floor effect occurs when participants cluster near the minimum score. In this case, no participants scored close to the maximum score of 96, ruling out any ceiling effect. Similarly, while some participants scored at the lower end of the scale, the range extends well beyond the minimum score of 0, suggesting that the test captured variability even among lower-performing individuals. In addition, the scores were spread across the lower range (e.g., 0 to 27) rather than clustering tightly at the very bottom (e.g., 0-5), indicating that the test provides enough differentiation among participants with lower proficiency. The kurtosis and skewness values also showed acceptable levels of data distribution. The results based on repeated ANOVA showed significant differences among the four grades for MCK, F (1, 360) = 4214.849, $p < .001$, $\eta^2 = .921$, and BVK, F (1, 360) = 11687.820, $p < .001$, $\eta^2 = .970$.

Table 1 Descriptive statistics

	Min.	Mx.	*M*	Std.	Kurtosis	Skewness	Cronbach values
MCK1	24	47	30.150	5.128	.36	-.954	.84
MCK2	25	61	38.097	7.970	.456	-.688	.83
MCK3	31	73	46.859	10.125	.462	-.993	.85
MCK4	38	80	55.089	11.160	.316	-1.225	.86
BVK1	0	10	2.875	1.858	1.859	4.743	.87
BVK2	4	17	9.463	2.300	.763	1.248	.84
BVK3	10	24	15.197	3.168	.657	-.217	.89
BVK4	12	27	18.139	3.498	.316	-1.101	.88

Note. MCK = metacognitive knowledge, BVK = breadth of vocabulary knowledge

The box plot in Figure 3 provided a visual summary of the distribution of scores for MCK and BVK across different groups. It indicates that there were notable differences in performance or development trajectories between the MCK and BVK measures. In particular, the MCK groups (MCK1, MCK2, MCK3, MCK4) showed varying median scores, with MCK2 having the highest median and MCK1 the lowest. The spread of scores (IQR) also varied, indicating different levels of consistency in scores across these groups. The BVK groups (BVK1, BVK2, BVK3, BVK4) similarly showed distinct median scores, with BVK2 appearing to have a higher median than the other BVK groups. The variability among BVK groups also differed, as seen in the width of the boxes. The correlations between all the variables were all significant at $p < .001$.

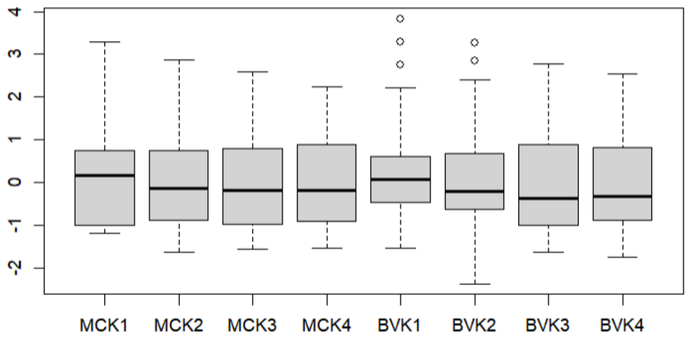

Figure 3 Box plot for the variables

The next step was to use LCGA through R software (version 4.4.1) and gbmt package to construct a group-based trajectory model. The model was fitted with different numbers of groups (*ng* = 1, 2, ..., 8), and the optimal model was selected based on the Bayesian Information Criterion (BIC). Lower BIC values indicated a better fit while penalizing model complexity. From the results, the BIC decreased as the number of groups increased, with the lowest BIC observed at 8 groups for all models (m1, m2, and m3). However, the final chosen model divided the population into 7 latent subgroups instead of 8, likely balancing interpretability and model parsimony as increasing the number of groups may lead to overfitting or less meaningful subgroup distinctions.

The final model is represented as: MCK = b0 + time + $time^2$ + e, where time represents the grade levels (1, 2, 3, 4), b0 is the intercept, and e is the error term. The model includes both linear (time) and quadratic ($time^2$) terms, reflecting potential nonlinear trajectories over time. The model was applied to 361 students, dividing them into seven latent subgroups, each with distinct trajectory patterns. Each subgroup's trajectory was modeled using a linear regression with quadratic terms. Subgroup 1 exhibited moderate growth with an intercept of 24.84, a linear term of 6.04, and a slight acceleration (quadratic term = .34). The model explained 93.82% of the variance in this subgroup's trajectory (R^2 = .9382). Subgroup 2 showed higher growth with an intercept of 24.49, a linear term of 8.24, and a slight acceleration (quadratic term = .37), with an R^2 of .9562. Subgroup 3 had a steep growth rate (linear term = 18.08) but significant deceleration (quadratic term = -1.10), with an R^2 of .9791. Subgroup 4 demonstrated moderate growth, with an intercept of 20.49, a linear term of 3.90, and a slight acceleration (quadratic term = .46), achieving an R^2 of .9494. Subgroup 5 exhibited rapid growth (linear term = 13.13) but deceleration (quadratic term = -.56), with an R^2 of .9498. Subgroup 6 had moderate growth (linear term = 5.95) and slight acceleration (quadratic term = .29), but with a slightly lower explanatory power (R^2 = .8723). Subgroup 7 showed the steepest growth (linear term = 29.21) but also significant deceleration (quadratic term = -3.44), with an excellent fit (R^2 = .9602).

The results highlight distinct trajectory patterns among the subgroups, with some showing accelerating growth (e.g., Subgroup 1, Subgroup 2, Subgroup 4) and others exhibiting decelerating growth after an initial steep increase (e.g., Subgroup 3, Subgroup 5, Subgroup 7). The adjusted R^2 values for all subgroups were very high, ranging from 87.23% to 97.91%, indicating that the models explained most of the variance in the data.

Figure 4 illustrates the developmental trajectory of MCK. The plot presents multiple lines that represent different data series over a range of values on the x-axis, which spans from Time 1 to Time 4. The y-axis shows increasing values, likely reflecting a specific measurement or score. Each colored line, numbered from 1 to 7, signifies distinct categories or groups, and the variety of colors aids in differentiating them. Generally, the lines exhibit an upward trend, indicating a positive correlation as the x-axis variable increased.

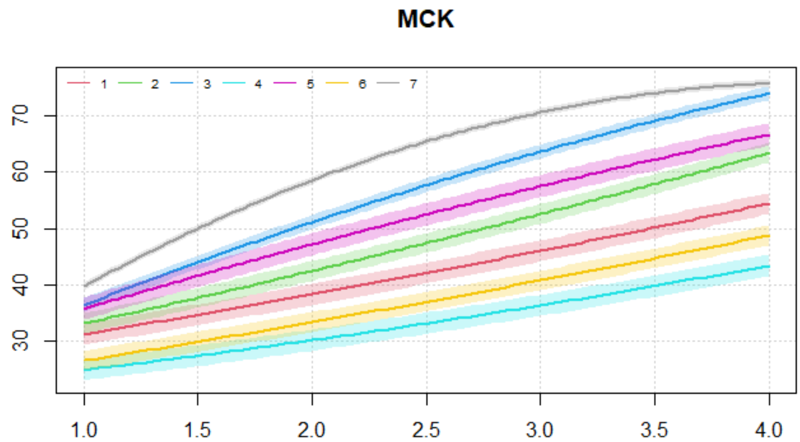

Figure 4 Developmental trajectory of MCK

Figure 5 presents a series of scatter plots that explore the relationship between breadth of vocabulary knowledge (x-axis) and metacognitive knowledge (y-axis) across different grades, specifically Grades 3, 4, 5, and 6. The fitted regression line is displayed, accompanied by an equation and the coefficient of determination (R^2) value for each grade. The R^2 value indicates the proportion of variance in metacognitive knowledge that can be explained by vocabulary breadth. For instance, Grade 3 has an R^2 of .83, suggesting a strong correlation, while Grade 4 has a similar value of .89. These high R^2 values across the grades imply that as students' vocabulary knowledge increases, their metacognitive knowledge tends to improve significantly. Moreover, the data points are accompanied by p-values, all of which are extremely low ($\leq$ 2.2e-16), indicating that the relationships observed are statistically significant. Overall, this figure effectively illustrates a positive relationship between vocabulary breadth and metacognitive knowledge across the grades, highlighting the importance of vocabulary development in enhancing students' metacognitive knowledge.

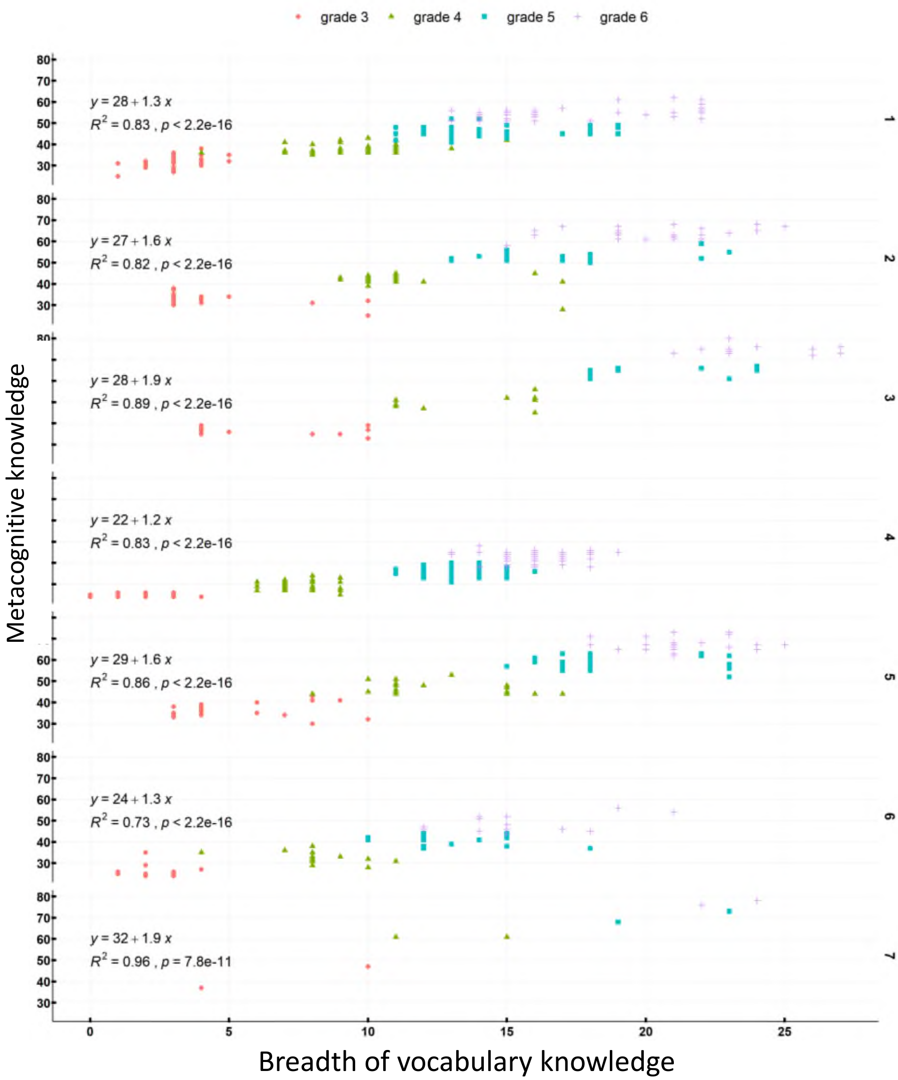

Figure 5 Developmental trajectory of MCK and BVK

Results presented in Figure 6 consist of seven scatter plots (A through G) that further examine the relationship between BVK (x-axis) and MCK (y-axis) across different conditions or groups. Each scatter plot contains data points corresponding to various categories, which are color-coded and marked with distinct shapes, allowing for easy differentiation among them.

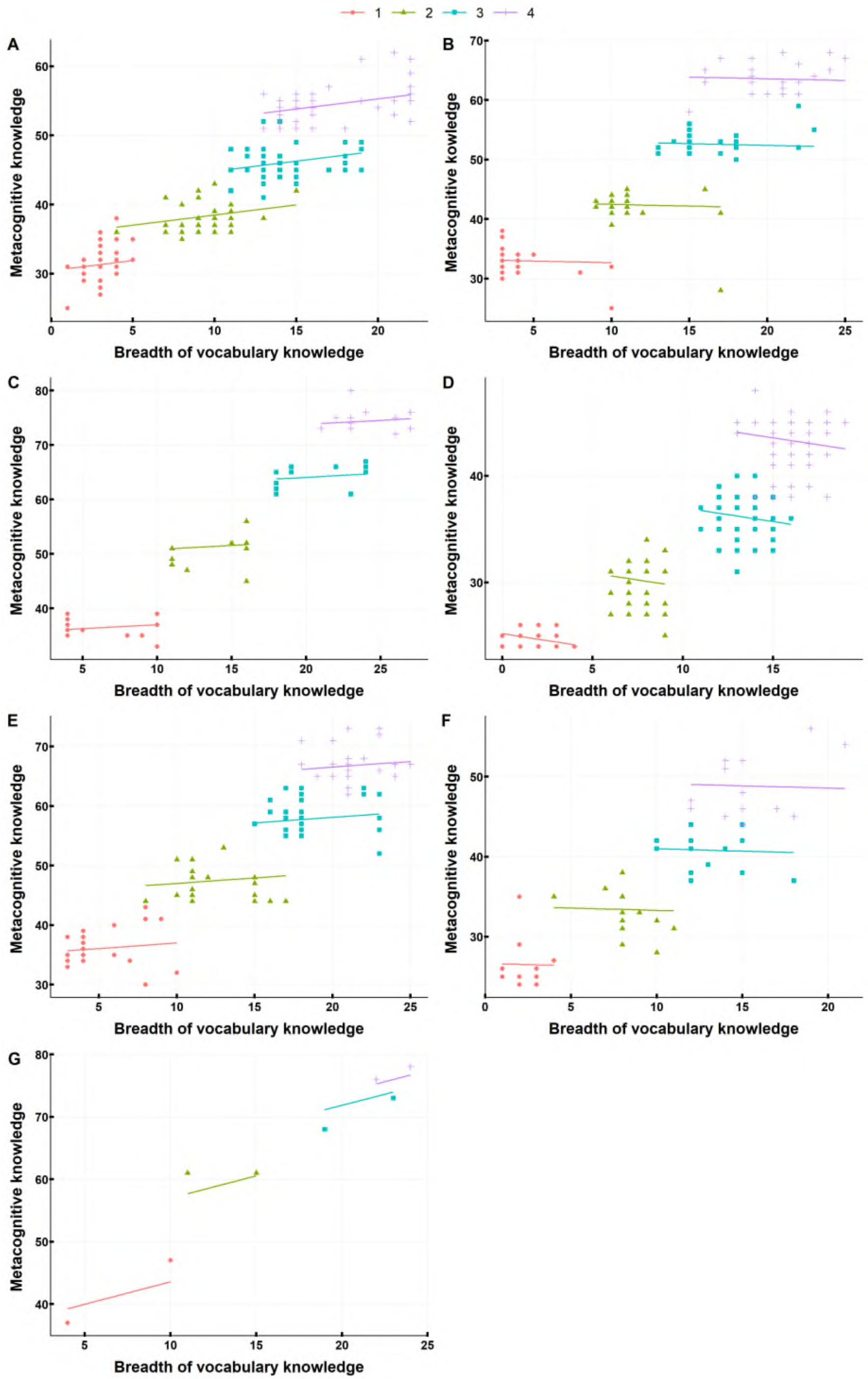

Figure 6 Relationship between breadth of vocabulary knowledge and metacognitive knowledge

According to Figure 6, in plots A, B, and C, a clear positive correlation was observed between vocabulary breadth and metacognitive knowledge. As the breadth of vocabulary increased, metacognitive knowledge also tended to rise, suggesting that students who have a more extensive vocabulary are likely to possess greater metacognitive awareness. The regression lines in these plots indicate a strong fit, with R^2 values reflecting significant explanatory power regarding the variance in metacognitive knowledge. In contrast, plots D, E, and F showed a more nuanced relationship. While there was still a positive trend, the correlation appeared weaker than in the previous plots. The data points in these graphs were more dispersed, indicating variability in metacognitive knowledge that is not fully explained by vocabulary breadth alone. The regression lines reveal lower R^2 values, suggesting that other factors may be influencing metacognitive knowledge in these conditions. Plot G serves as a summary or overall representation of the trends observed across all groups, illustrating a general upward trajectory in metacognitive knowledge as vocabulary breadth increases.

Table 2 shows the detailed relationships between MCK (dependent variable) and BVK (independent variable) within the subgroups generated by the group-based trajectory model, supporting Figure 6. Each subgroup was modeled separately, incorporating time and time² as additional predictors.

Table 2 Subgroup-specific modeling results for MCK with BVK as a predictor

MCK	*Predictors*	(Intercept)	time	time^2	VK	Observations	R^2/ ^{2} adjusted
1	*Estimates*	26.55	3.29	.61	.29		
	CI	24.98-28.11	1.62-4.96	.33-.88	.18-.40	272	.943/.942
	p	< .001	< .001	< .001	< .001		
2	*Estimates*	24.15	8.76	.35	-.06		
	CI	22.07-26.22	6.34-11.18	-.02-.71	-.23-.11	188	.961/.961
	p	< .001	< .001	.064	.508		
3	*Estimates*	19.67	16.87	-1.02	.15		
	CI	17.64-21.71	14.47-19.27	-1.39- -.65	-.01-.31	128	.982/.982
	p	< .001	< .001	< .001	.072		
4	*Estimates*	18.65	6.33	.22	-.26		
	CI	17.45-19.85	4.92-7.75	.04-.40	-.40- -.12	516	.951/.951
	p	< .001	< .001	.019	< .001		
5	*Estimates*	24.36	11.17	-.39	.19		
	CI	22.06-26.65	8.33-14.01	-.80-.02	-.01-.38	216	.951/0.950
	p	< .001	< .001	.065	.065		
6	*Estimates*	19.92	6.49	.24	-.06		
	CI	16.08-23.76	2.42-10.56	-.42-.89	-.36-.24	108	.878/.874
	P	< .001	.002	.47	.714		
7	*Estimates*	17.35	21.9	-2.84	.72		
	CI	8.13-26.57	10.55-33.26	-4.55- -1.14	-.04-1.48	16	.970/.963
	p	.001	.001	.003	.063		

According to Table 2, for Subgroup 1, the model showed a significant positive relationship between MCK and BVK, with an estimated coefficient of .29

(95% CI: .18-.40, $p < .001$). The intercept was 26.55, indicating the baseline MCK value when all predictors were at zero. Both time (3.29) and time² (.61) were also significant predictors, suggesting a positive linear and quadratic trend over time. The model explained 94.3% of the variance ($R^2 = .943$) in MCK, indicating an excellent fit with the data. In Subgroup 2, the relationship between MCK and BVK was not statistically significant ($p = .508$), with an estimated coefficient of -.06 (95% CI: -.23-.11). The intercept was 24.15, and time (8.76) was a strong positive predictor, while time² (.35) was marginally significant ($p = .064$). The model achieved a high explanatory power, with 96.1% of the variance ($R^2 = .961$) in MCK explained. For Subgroup 3, BVK showed a marginally significant positive effect ($p = .072$) with an estimated coefficient of .15 (95% CI: -.01-.31). The intercept was 19.67, and time (16.87) was a strong positive predictor, while time² (-1.02) was significantly negative, indicating a deceleration in growth. The model explained 98.2% of the variance ($R^2 = .982$), reflecting an excellent fit. In Subgroup 4, BVK had a significant negative relationship with MCK (-.26, 95% CI: -.40- -.12, $p < .001$). The intercept was 18.65, and both time (6.33) and time² (0.22) were significant positive predictors. The model explained 95.1% of the variance ($R^2 = 0.951$), showing strong predictive performance. For Subgroup 5, BVK showed a marginal positive relationship with MCK (.19, 95% CI: -.01-.38, $p = .065$). The intercept was 24.36, and time (11.17) was a strong positive predictor, while time² (-.39) was marginally significant ($p = .065$), suggesting a deceleration in growth. The model explained 95.1% of the variance ($R^2 = 0.951$), indicating a good fit. In Subgroup 6, BVK did not have a significant relationship with MCK (-.06, 95% CI: -.36-.24, $p = 0.714$). The intercept was 19.92, and time (6.49) was a significant positive predictor ($p = .002$), while time² (.24) was not significant ($p = .47$). The model explained 87.8% of the variance ($R^2 = .878$), which was lower compared to other subgroups but still substantial. For Subgroup 7, BVK showed a marginally significant positive relationship with MCK (.72, 95% CI: -.04-1.48, $p = .063$). The intercept was 17.35, and time (21.90) was a strong positive predictor, while time² (-2.84) was significantly negative ($p = .003$), indicating a sharp deceleration in growth. Despite the small sample size (16 observations), the model explained 97.0% of the variance ($R^2 = .970$), reflecting a very strong fit.

4.2. Cross-lagged panel (CLP) modeling results

This section reports the results of CLP modeling. The first step was to examine longitudinal measurement invariance to ensure the consistency of construct measurement across time points (Meredith, 1993). Configural invariance was tested first to ensure that the factor structure of MCK and BVK remained the same across time. Following this, metric invariance was tested by constraining the factor loadings to be equal across time points. Finally, scalar invariance was tested by constraining the intercepts to be equal across time.

The results of these tests indicated that the constructs of MCK and BVK were comparable across time points. The model specified structural equations to assess the relationships between MCK and BVK over four time points (MCK1-MCK4 and BVK1-BVK4). These relationships include lagged effects (how earlier MCK and BVK influence later values), cross-lagged effects (how earlier MCK influences later BVK and vice versa), and covariances (relationships between MCK1 and BVK1, MCK 1 and BVK2, MCK 1 and BVK 3, MCK1 and BVK4, etc.). The analysis used maximum likelihood (ML) estimation, and the data were standardized before analysis. The chi-square test results indicated that the model does not perfectly fit the data as the p-value was significant ($p < .001$). However, given the sample size of 361, the chi-square test is highly sensitive, and even minor deviations from perfect fit can lead to significant results. Furthermore, the comparative fit index (CFI) of .978 suggests excellent fit as it exceeds the commonly accepted threshold of .95. Similarly, the Tucker–Lewis index (TLI) of .955 indicates acceptable fit as it is above .90. The root mean square error of approximation (RMSEA) was 0.058, which meets the acceptable threshold of lower than .06. The standardized root mean square residual (SRMR) was .016, which indicates excellent fit as it is well below the threshold of .08. These results suggest that the model demonstrated fit. The structural parameters for the longitudinal relationships between the two measures are shown in Figure 7.

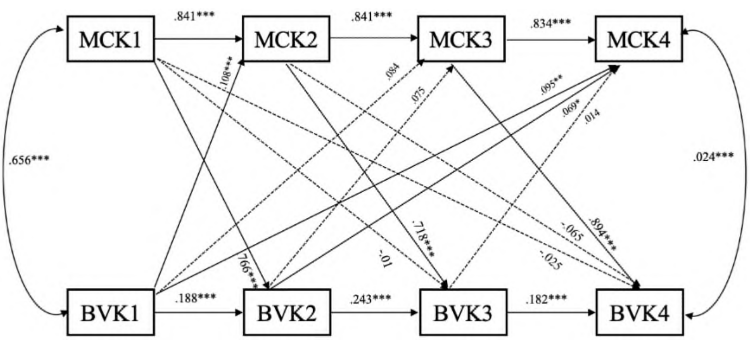

Figure 7 CLP model illustrating the reciprocal effects between metacognitive knowledge and breadth of vocabulary knowledge ($P < .05$ *, $p < .01$ **, $p < .001$ *** MCK = metacognitive knowledge; BVK = breadth of vocabulary knowledge)

The CLP model revealed several significant relationships between MCK and BVK across multiple levels. For MCK2, the coefficient for MCK1 was .841, indicating a strong positive relationship, as confirmed by a *z*-value of 24.331 and a *p* value of <.001. This suggests that as MCK1 increased, MCK2 also significantly increased. Additionally, the influence of BVK1 on MCK2 was positive and statistically significant (Estimate = .108; p <.001), further supporting the notion that a greater breadth of vocabulary contributes to higher metacognitive knowledge. In the subsequent regression for MCK3, MCK2 also showed a strong positive influence (Estimate = .841, $p < .001$), while the impact of BVK2 (Estimate = .075, p = .097) was not statistically significant at the conventional level, implying a potential but weak relationship. The influence of BVK1 remained positive but was not statistically significant for MCK3 (p = .112). Moving to MCK4, the regression indicated a slightly reduced influence from MCK3 (Estimate = .834, $p < .001$), while BVK3 had no significant effect (Estimate = .014, p = .627), though the influence of BVK2 (Estimate = .069, $p < .05$) and BVK1 (Estimate = .095, $p < .01$) showed noteworthy contributions.

The analysis of covariances suggested significant relationships between MCK1 and BVK1 (Estimate = .656, $p < .001$), indicating that higher metacognitive knowledge was associated with a broader vocabulary at the initial stage. The covariance between MCK4 and BVK4 (Estimate = .024, $p < .001$) also suggested a positive relationship between these variables at the later stages of development.

The influence of MCK1 on BVK 2 was significant (Estimate = .766, $p < .001$), indicating a strong positive relationship. This suggests that as MCK1 increased, BVK2 also significantly increased. However, the influence of MCK1 on BVK 3 and BVK 4 remained negative and also not statistically significant. The coefficient for MCK2 on BVK3 was significant (Estimate = .718, $p < .001$), indicating a strong positive relationship between MCK2 and BVK3. However, the influence of MCK2 on BVK 4 was negative and not statistically significant. The influence of MCK 3 on BVK 4 was also significant (Estimate = .894, $p < .001$).

Finally, the R-squared values indicated that the model explained a substantial proportion of the variance in metacognitive knowledge and vocabulary breadth, with MCK4 having an R^2 of .934 and BVK4 an R^2 of .937. This suggests that the model effectively captured the relationships between these constructs, affirming the importance of vocabulary breadth in enhancing metacognitive knowledge and the importance of metacognitive knowledge in improving vocabulary breadth across different levels of assessment.

5. Discussion

The aim of this study was to investigate and clarify the bidirectional relationship between metacognitive knowledge and the breadth of vocabulary knowledge among primary school students, from Grade 3 to Grade 6. Overall, young learners need to engage in metacognitive thought to gain reflective experiences and cognitive awareness for vocabulary learning, and vocabulary learning outcomes can assist learners in identifying and expanding their metacognitive knowledge. The research question aimed to explore the reciprocal effect between metacognitive knowledge and breadth of vocabulary knowledge. As the results showed a reciprocal effect, the following discussion is divided into two sections to explore the role of MCK in BVK, and vice versa.

5.1. The role of MCK in BVK

The findings demonstrate the crucial role of learners' metacognitive knowledge in shaping their breadth of vocabulary knowledge throughout the primary school years. This relationship is not merely correlational but demonstrates a dynamic and iterative process of development. The results reveal that students engage in a continuous, complex process of developing metacognitive knowledge, through which they actively attempt to foster their metacognitive knowledge in different forms (person, task, and strategy) and concurrently develop and apply concrete metacognitive strategies to monitor and regulate their vocabulary learning.

The cumulative development of MCK serves a dual function: It enhances students' metalinguistic awareness (Zargar et al., 2020) and facilitates the accumulation of vocabulary knowledge (Teng & Mizumoto, 2024). This finding supports and extends Teng's (2022) assertion of a positive relationship between learners' understanding of their cognitive processes and their vocabulary acquisition. The observed growth in learners' metacognitive knowledge is strongly correlated with improvements in vocabulary breadth, indicating a symbiotic relationship between these two constructs.

However, the results diverge from those of Lee et al. (2022), who did not find a pronounced association between any specific group of strategies (e.g., metacognitive, cognitive) and L2 vocabulary knowledge. This discrepancy could be attributed to differences in study design and participant demographics. Lee et al.'s (2022) study involved secondary school students participating in a one-time questionnaire, whereas our research employed a longitudinal approach with younger learners. As Wenden (1998) argues, learners of different ages and varying proficiencies develop learning knowledge that can significantly impact their learning processes and their expectations regarding outcomes. This perspective highlights the diverse nature of metacognitive knowledge development across different learner populations and its broad implications for language learning success.

Flavell's (1979) seminal work, while not explicitly addressing BVK, compellingly underscored the critical role of metacognitive knowledge in young learners' cognitive activities, including a broad spectrum of linguistic skills, such as oral communication, persuasion, comprehension, reading, writing, and language acquisition. The findings of the present study build upon Flavell's (1979) theoretical framework by establishing a direct link between MCK and BVK, a core component of foreign language learning. The findings align with a growing body of research (e.g., Kavé, 2024; Roebers & Spiess, 2017; Teng & Mizumoto, 2024; Teng & Zhang, 2024a) that underscores the significance of MCK in characterizing foreign language learners' vocabulary learning. This supports the Matthew effect, as described by Perc (2014), where initial advantages in cognitive knowledge can lead to greater vocabulary gains. Metacognitive strategies, as argued by Shin et al. (2023), facilitate comprehension and recall of word knowledge. The theory of episodic-context account (Karpicke et al., 2014) further elucidates this process by suggesting that additional retrieval cues emerge when knowledge elements are connected with various episodic contexts encountered during learning and retrieval. Understanding how cognitive processes interact with episodic contexts aids learners in enhancing their retrieval cues, thereby improving learning and memory retention (Endres et al., 2024). This facilitation likely occurs through increased cognitive engagement, improved self-regulation, and more efficient allocation of cognitive resources during vocabulary learning tasks. Thus, the present study provides empirical support for the positive role of MCK in BVK, highlighting its profound implications for educational practices and learner outcomes.

Based on the findings, we argue that the quality and growth of learners' cognitive engagement, specifically how learners become active participants in their own language learning performance, provide the essential knowledge base for the effective acquisition of BVK in a foreign language context. This active engagement, facilitated by metacognitive knowledge, allows learners to approach vocabulary learning more strategically, monitor their progress more effectively, and adapt their learning strategies as needed.

5.2. The role of BVK in MCK

The findings illuminate the complex relationship between BVK and MCK. Both constructs demonstrated consistent growth across the examined grade levels, corroborating previous research that highlights significant increases in young learners' metacognitive knowledge (Annevirta et al., 2007; Annevirta & Vauras, 2001) and vocabulary knowledge (Teng, 2022). However, the direct influence of BVK on MCK was not straightforward. The present study makes a noteworthy theoretical contribution by providing evidence that the development of BVK as part of English learning during the primary school years plays a crucial role in enhancing MCK. This finding aligns with and expands upon prior research (e.g., Guo, 2018), which suggests that proficiency in

L2 facilitates learners' acquisition and application of metacognitive knowledge and strategies. Specifically, BVK, understood as receptive vocabulary knowledge (Schmitt, 2010), is closely related to the construction of word meaning in context (Butler, 2020). It is essential for cognitive monitoring in foreign language learning, contributing to cognitive development and metacognitive awareness (Shin et al., 2023).

One critical theoretical argument is that the interplay between BVK and MCK underscores the importance of vocabulary knowledge as a foundational element in cognitive and metacognitive processes. This relationship suggests that as learners expand their vocabulary, they not only enhance their linguistic capabilities but also improve their ability to monitor and regulate their cognitive processes. Such an understanding emphasizes the integral role of BVK in fostering a deeper level of metacognitive awareness, which is pivotal for effective foreign language learning.

The present study also sheds light on the challenges faced by linguistically weak students, who may struggle with metacognitive learning tasks, often expressing confusion and complaints (e.g., Zhang, 2010). This observation underscores the potential bidirectional relationship between BVK and MCK, suggesting that a certain threshold of BVK is necessary for effective metacognitive strategy use in language learning. An important consideration is the developmental trajectory of vocabulary acquisition in the study population. Most primary school children in the present study were still at the beginning stages of building their vocabulary knowledge. In particular, Grade 3 learners possessed limited vocabulary knowledge as they had only recently begun formal English language instruction. The progression through Grades 4, 5, and 6 marked a shift towards more mature vocabulary learning, potentially influencing the development of metacognitive knowledge.

The limited vocabulary knowledge of younger learners may explain the individual differences observed in the development of MCK. This finding suggests that the development mechanisms of BVK in relation to MCK may not be in line with grade-level requirements, which are often used as a proxy for cumulative ability, experience, and knowledge in language learning. These observations highlight the complex interplay between BVK and MCK development. While increased vocabulary knowledge appears to support metacognitive development, the relationship is not straightforward and may be mediated by factors such as age, prior language learning experience, and individual differences in cognitive development, leaving a critical issue for future studies.

6. Conclusions, limitations, and implications

The present study explored the bidirectional relationship between MCK and BVK in primary school students from Grades 3 to 6. Findings showed a reciprocal effect, with MCK playing a crucial role in shaping BVK by enabling students to actively engage in metacognitive strategies that enhance vocabulary learning. As students' metacognitive knowledge grew, so did their vocabulary breadth, supporting the idea that cognitive engagement and self-regulation are key to effective vocabulary acquisition. Conversely, the development of BVK also contributed to the enhancement of MCK, indicating that expanding vocabulary supports learners' ability to monitor and regulate their cognitive processes. However, this relationship was complex and influenced by factors such as initial vocabulary knowledge, with younger learners' limited vocabulary posing challenges for metacognitive strategy use.

The present study was not without limitations. First, there was a lack of qualitative data, which could have provided deeper insights into the learners' experiences and perspectives. Second, the repeated use of the same tests for MCK and BVK may have introduced test-retest effects as learners might become familiar with the test requirements over time. However, this issue is somewhat unavoidable in a longitudinal study focused on developmental progress. Finally, the study's sample size and specific demographic focus may limit the generalizability of the findings to other populations or contexts.

Despite its limitations, the findings underscore the importance of recognizing and fostering the reciprocal relationship between MCK and BVK throughout primary education. The evidence suggests that the development of one construct can significantly influence the growth of the other, which has important implications for classroom practice. For instance, students who begin with stronger metacognitive awareness tend to make greater gains in vocabulary knowledge over time, while those with a broader vocabulary base are better equipped to develop metacognitive strategies for learning. This widening gap highlights the risk that individual differences in either area, if not addressed early, may compound as students progress through school. Therefore, language educators should prioritize the simultaneous cultivation of both metacognitive and vocabulary knowledge from the earliest stages of language instruction. This can be achieved by integrating explicit instruction in metacognitive strategies, such as planning, monitoring, and evaluating one's own learning, into vocabulary lessons. Teachers can model how to reflect on learning processes, encourage students to set goals for vocabulary acquisition, and guide them in choosing and adapting strategies that suit their individual learning styles. Moreover, vocabulary instruction should move beyond rote memorization to include activities that require students to actively engage with new words through contextualized use, self-assessment, and reflection. Teachers can design tasks that prompt learners to think about how they learn best, what strategies are most effective for them, and how to overcome challenges in vocabulary learning. For curriculum designers and teacher trainers, these findings suggest the need to incorporate metacognitive training into language programs, ensuring that both teachers and students are equipped with the tools to support this dual development. Professional development opportunities should emphasize the importance of metacognitive knowledge, providing teachers with practical strategies for embedding metacognitive instruction within vocabulary learning activities. Ultimately, recognizing the mutually reinforcing nature of MCK and BVK calls for a holistic approach to language teaching, one that supports not only the acquisition of vocabulary but also the development of learners' ability to manage and direct their own learning processes. This approach holds promise for narrowing achievement gaps and supporting all learners in reaching their full potential in second and foreign language contexts.

Acknowledgements

I would like to express my sincere gratitude to the anonymous reviewers and the editors for their valuable feedback and insightful suggestions. I am also very grateful to the participants for their time and energy in taking part in this study.

References

Anderson, R. C., & Freebody, P. (1981). Vocabulary knowledge. In J. T. Guthrie (Ed.), *Comprehension and teaching: Research reviews* (pp. 77-117). International Reading Association.

Annevirta, T., Laakkonen, E., Kinnunen, R., & Vauras, M. (2007). Developmental dynamics of metacognitive knowledge and text comprehension skill in the first primary school years. *Metacognition and Learning, 2,* 21-39. https://doi.org/10.1007/s11409-007-9005-x

Annevirta, T., & Vauras, M. (2001). Metacognitive knowledge in primary grades: A longitudinal study. *European Journal of Psychology of Education, 16*(2), 257-282. https://doi.org/10.1007/BF03173029

Anthony, L., & Nation, I. S. P. (2017). *Picture vocabulary size test* (Version 1.2.0) [Computer Software]. Waseda University. http://www.laurenceanthony.net/software/pvst

Brown, A. L. (1987). Metacognition, executive control, self-regulation, and other more mysterious mechanisms. In F. Weinert & R. Kluwe (Eds.), *Metacognition, motivation and understanding* (pp. 65-116). Erlbaum.

Butler, Y. G. (2020). The ability of young learners to construct word meaning in context. *Studies in Second Language Learning and Teaching, 10*(3), 547-578. https://doi.org/10.14746/ssllt.2020.10.3.7

Candry, S., Deconinck, J., & Eyckmans, J. (2017). Metalinguistic awareness in L2 vocabulary acquisition: Which factors influence learners' motivations of form-meaning connections? *Language Awareness, 26*(3), 226-243. https://doi.org/10.1080/09658416.2017.1400040

Carcamo, B. (2023). The roles of vocabulary knowledge and metacognitive awareness as mediators between prior knowledge and L2 academic reading. *International Journal of Applied Linguistics, 33*(2), 292-326. https://doi.org/10.1111/ijal.12466

Cheung, S. (2023). Exploring the impact of lexical threshold on listening comprehension. *International Journal of TESOL Studies, 5*(4), 37-54. https://doi.org/10.58304/ijts.20230403

Cotterall, S., & Murray, G. (2009). Enhancing metacognitive knowledge: Structure, affordances and self. *System, 37,* 34-45. https://doi.org/10.1016/j.system.2008.08.003

Endres, T., Carpenter, S., & Renkl, A. (2024). Constructive retrieval: Benefits for learning, motivation, and metacognitive monitoring. *Learning and Instruction, 94,* 101974. https://doi.org/10.1016/j.learninstruc.2024.101974

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist, 34,* 906-911. https://doi.org/10.1037/0003-066X.34.10.906

Guo, L. (2018). Modeling the relationship of metacognitive knowledge, L1 reading ability, L2 language proficiency and L2 reading. *Reading in a Foreign Language, 30*(2), 209-231. http://hdl.handle.net/10125/66922

Hennecke, M., & Kulkarni, P. (2024). Metacognitive knowledge about self-control. *Current Opinion in Psychology, 59,* 101861. https://doi.org/10.1016/j.copsyc.2024.101861

Hu, L.-Z. & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1-55. https://doi.org/10.1080/10705519909540118

Jung, T., & Wickrama, K. A. (2008). An introduction to latent class growth analysis and growth mixture modeling. *Social and Personality Psychology Compass, 2*(1), 302-317. https://doi.org/10.1111/j.1751-9004.2007.00054.x

Karpicke, J. D., Lehman, M., & Aue, W. R. (2014). Retrieval-based learning: An episodic context account. *Psychology of Learning and Motivation, 61,* 237-284. 10.1016/B978-0-12-800283-4.00007-1

Kavé, G. (2024). Vocabulary changes in adulthood: Main findings and methodological considerations. *International Journal of Language & Communication Disorders, 59,* 58-67. https://doi.org/10.1111/1460-6984.12820

Kavé, G., Gorokhod, R., Yerushalmi, A., & Salner, N. (2019). Frequency effects on spelling in Hebrew-speaking younger and older adults. *Applied Psycholinguistics, 40*(5), 1173-1188. https://doi.org/10.1017/S0142716419000171

Lee, J. H., Ahn, J. J., & Lee, H. (2022). The role of motivation and vocabulary learning strategies in L2 vocabulary knowledge: A structural equation modeling analysis. *Studies in Second Language Learning and Teaching, 12*(3), 435-458. https://doi.org/10.14746/ssllt.2022.12.3.5

Meredith, W. (1993). Measurement invariance, factor analysis, and factorial invariance. *Psychometrika, 58,* 525-542. https://doi.org/10.1007/BF02294825

Nassaji, H. (2004). The relationship between depth of vocabulary knowledge and L2 learners' lexical inferencing strategy use and success. *The Canadian Modern Language Review, 61*(1), 107-134. https://doi.org/10.1111/j.1540-4781.2006.00431.x

Nation, I. S. P. (2022). *Learning vocabulary in another language* (3rd ed.). Cambridge University Press.

Perc, M. (2014). The Matthew effect in empirical data. *Journal of the Royal Society, Interface, 11*(98), 20140378. https://doi.org/10.1098/rsif.2014.0378

Qian, D. D. (2002). Investigating the relationship between vocabulary knowledge and academic reading performance: An assessment perspective. *Language Learning, 52*, 513-536. https://doi.org/10.1111/1467-9922.00193

Qian, J., Li, C., & Li, D. (2025). Exploring Chinese multilingual students' metacognitive knowledge, strategies, and experiences in academic writing. *Language Awareness, 34*(1), 77-99. https://doi.org/10.1080/09658416.2024.2375629

Read, J. (2000). *Assessing vocabulary.* Cambridge University Press.

Roebers, C. M., & Spiess, M. (2017). The development of metacognitive monitoring and control in second graders: A short-term longitudinal study. *Journal of Cognition and Development, 18,* 110-128. https://doi.org/10.1080/15248372.2016.1157079

Sato, M. (2022). Metacognition. In S. Li, P. Hiver, & M. Papi (Eds.), *The Routledge handbook of second language acquisition and individual differences* (pp. 95-109). Routledge.

Sato, M., & Dussuel Lam, C. (2021). Metacognitive instruction with young learners: A case of willingness to communicate, L2 use, and metacognition of oral communication. *Language Teaching Research, 25*(6), 899-921. https://doi.org/10.1177/13621688211004639

Schmitt, N. (2008). Instructed second language vocabulary learning. *Language Teaching Research*, *12*, 329-363. https://doi.org/10.1177/1362168808089921

Schmitt, N. (2010). *Researching vocabulary: A vocabulary research manual.* Palgrave Macmillan.

Schmitt, N. (2014). Size and depth of vocabulary knowledge: What the research shows. *Language Learning, 64*(4), 913-951. https://doi.org/10.1111/lang.12077

Schneider, J. M., Abel, A. D., & Maguire, M. J. (2023). Vocabulary knowledge and reading comprehension account for SES-differences in how school-aged children infer word meanings from sentences. *Language Learning and Development, 19*(4), 369-385. https://doi.org/10.1080/15475441.2022.2081573

Schneider, W. (2008). The development of metacognitive knowledge in children and adolescents: Major trends and implications for education. *Mind, Brain, and Education, 2*(3), 114-121. https://doi.org/10.1111/j.1751-228X.2008.00041.x

Schneider, W., Lingel, K., Artelt, C., & Neuenhaus, N. (2017). Metacognitive knowledge in secondary school students: Assessment, structure, and developmental change. In D. Leutner, J. Fleischer, J. Grünkorn, & E. Klieme (Eds.), *Competence assessment in education* (pp. 285-302). Springer.

Schneider, W., Tibken, C., & Richter, T. (2022). The development of metacognitive knowledge from childhood to young adulthood: Major trends and educational implications. *Advances in Child Development and Behavior, 63,* 273-307. https://doi.org/10.1016/bs.acdb.2022.04.006

Schraw, G. (1994). The effect of metacognitive knowledge on local and global monitoring. *Contemporary Educational Psychology, 2,* 143-154. https://doi.org/10.1006/ceps.1994.1013

Schunk, D. H. (2013). Social cognitive theory and self-regulated learning. In B. J. Zimmerman & D. H. Schunk (Eds.), *Self-regulated learning and academic achievement* (pp. 119-144). Routledge.

Selig, J. P., & Little, T. D. (2012). Autoregressive and cross-lagged panel analysis for longitudinal data. In B. Laursen, T. D. Little, & N. A. Card (Eds.), *Handbook of developmental research methods* (pp. 265-278). Guilford Press.

Shin, H. W., Sok, S., & Do, J. (2023). Role of individual differences in incidental L2 vocabulary acquisition through listening to stories: Metacognitive awareness and motivation. *International Review of Applied Linguistics in Language Teaching, 61*(4), 1669-1695. https://doi.org/10.1515/iral-2021-0212

Song, S., Su, M., Kang, C., Liu, H., Zhang, Y., McBride-Chang, C., Tardif, T., Li, H., Liang, W., Zhang, Z., & Shu, H. (2014). Tracing children's vocabulary development from preschool through the school-age years: An 8-year longitudinal study. *Developmental Science, 18,* 119-131. https://doi.org/10.1111/desc.12190

Teng, M. F. (2022). Exploring awareness of metacognitive knowledge and acquisition of vocabulary knowledge in primary grades: A latent growth curve modelling approach. *Language Awareness, 31*(4), 470-494. https://doi.org/10.1080/09658416.2021.1972116

Teng, M. F. (2025). Longitudinal analysis of breadth of vocabulary knowledge in mediating metacognitive knowledge and reading in foreign language young learners. *Reading in a Foreign Language, 37*(1), 18-38. https://hdl.handle.net/10125/67496

Teng, M. F., & Mizumoto, A. (2024). Validation of metacognitive knowledge in vocabulary learning and its predictive effects on incidental vocabulary learning from reading. *International Review of Applied Linguistics in Language Teaching*. https://doi.org/10.1515/iral-2023-0294

Teng, F., & Zhang, L. J. (2021). Development of children's metacognitive knowledge, reading and writing proficiency in English as a foreign language: Longitudinal data using multilevel models. *British Journal of Educational Psychology, 91*(4), 1202-1230. https://doi.org/10.1111/bjep.12413

Teng, M. F., & Zhang, L. J. (2022). Development of metacognitive knowledge and morphological awareness: A longitudinal study of ethnic minority multilingual young learners in China. *Journal of Multilingual and Multicultural Development.* https://doi.org/10.1080/01434632.2022.2052301

Teng, M. F., & Zhang, L. J. (2024a). Ethnic minority multilingual young learners' longitudinal development of metacognitive knowledge and breadth of vocabulary knowledge. *Metacognition and Learning*, *19*(1), 123-146. https://doi.org/10.1007/s11409-023-09360-z

Teng, M. F., & Zhang, L. J. (2024b). Validating a new method for assessing young foreign language learners' metacognitive knowledge. *Research Methods in Applied Linguistics, 3*(2), 100121. https://doi.org/10.1016/j.rmal.2024.100121

Uttl, B. (2002). North American adult reading test: Age norms, reliability, and validity. *Journal of Clinical and Experimental Neuropsychology, 24*(8), 1123-1137. https://doi.org/10.1076/jcen.24.8.1123.8375

Webb, S., & Nation, P. (2017). *How vocabulary is learned*. Oxford University Press.

Wenden, A. L. (1998). Metacognitive knowledge and language learning. *Applied Linguistics, 19*(4), 515-537. https://doi.org/10.1093/applin/19.4.515

White, B., & Frederiksen, J. (2005). A theoretical framework and approach for fostering metacognitive development. *Educational Psychologist, 40*(4), 211-223. https://doi.org/10.1207/s15326985ep4004_3

Zargar, E., Adams, A. M., & Connor, C. M. (2020). The relations between children's comprehension monitoring and their reading comprehension and vocabulary knowledge: An eye-movement study. *Reading and Writing, 33*(3), 511-545. https://doi.org/10.1007/s11145-019-09966-3

Zhang, L. J. (2010). A dynamic metacognitive systems account of Chinese university students' knowledge about EFL reading. *TESOL Quarterly, 44*(2), 320-353. https://doi.org/10.5054/tq.2010.223352

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory Into Practice, 41*(2), 64-70. https://doi.org/10.1207/s15430421tip4102_2