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Examining the effect of a mobile-assisted self-regulation scheme on primary students' self-regulated vocabulary learning via latent growth modelling

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ABSTRACT: The effect of technology on primary students' self-regulated vocabulary learning (SRVL) over time and its dynamic relationship with vocabulary outcomes have been scarcely studied. This quasi-experimental study reports a longitudinal inquiry into the effect of a mobile-assisted self-regulation scheme on primary students' SRVL and the relationship between the changes in the perceived SRVL skills and vocabulary learning outcome. The study lasted seven months. Participants were 174 Grade 4 students (89 girls) from four classes at a primary school in Mainland China. Two classes were randomly assigned to the experimental and control groups. Students in both groups used the app named Vocab+, the former with and the latter without a mobile-assisted self-regulation scheme. Data collection included questionnaires on students' perceived SRVL skills and vocabulary tests. Latent Growth Modelling (LGM) was used to analyse data. The results showed that perceived SRVL skills and vocabulary learning outcomes increased over time. The findings further revealed that students in the experimental group exhibited a steeper increasing trend in perceived SRVL skills and vocabulary learning outcomes. Besides, the association between the growth rates of students' perception of SRVL skills and vocabulary learning outcomes was stronger with the experimental group than with the control group. Our results provided theoretical implications for understanding the relationship between SRVL skills and vocabulary learning outcomes from a developmental perspective.

Keywords: Self-regulated learning (SRL), Mobile-assisted self-regulation scheme, Self-regulated vocabulary learning (SRVL), Latent growth modelling

1. Introduction

Educators and researchers have recognised self-regulated learning (SRL) as an essential 21st century skill (Eggers et al., 2021). Learners with SRL skills are highly motivated and independent, able to manage learning resources skillfully, exploit the learning environment effectively, and take ownership of their learning (Ho et al., 2022; Sashikala & Chye, 2022). Previous studies have widely supported the positive relationship between perceived SRL skills and learning performance (e.g., Hong et al., 2015; Verstege et al., 2019). However, young learners have very limited ability to regulate their cognitive and metacognitive processes, behaviours, emotions, and motivation (Alvi & Gillies, 2021). Many young learners have indicated that they experience difficulties in effectively self-regulating their learning due to issues such as a lack of prior knowledge (Howard & Melhuish, 2017), inefficient use and adaptation of learning strategies (Li et al., 2018), and trouble monitoring the learning process (Pilegard & Fiorella, 2016). Thus, providing young learners the opportunity to develop SRL skills has been crucial to their academic success.

According to Zimmerman (2008), SRL involves three cyclic phases: forethought, performance, and self-reflection. In the forethought phase, students analyse the learning task, which involves goal setting and strategic planning. In the performance phase, students perform the task while monitoring the learning process. In the self-reflection phase, students assess their learning performance and satisfaction, evaluate the strategies used, and reflect on what they will do in the next round of learning. Research has indicated that learners must participate in effective SRL processes for planning and setting goals, monitoring the learning process, and assessing their overall learning performance to enhance learning outcomes (e.g., Lai et al., 2018).

Although plenty of studies have explored SRL in various discipline areas, one of the areas that have received less attention in the research on self-regulated learning (SRL) is English as a foreign language (EFL) learning (Teng & Zhang, 2022), especially in terms of vocabulary learning (Yang et al., 2023). Therefore, exploring how to support self-regulated vocabulary learning (SRVL) is an important and timely topic in education (Chen et al., 2019). A growing number of studies have been conducted in recent years on the technological interventions of SRVL, demonstrating the efficacy of technology-enhanced SRVL (e.g., Chen et al., 2019). However, few studies have adopted the technology that can support the entire cycle of SRVL, namely, forethought, performance, and self-reflection, especially in mobile learning environments. In addition, even fewer studies have examined whether these technological interventions have a lasting effect on young learners' SRVL or have captured the dynamic relations between SRVL skills and vocabulary learning outcomes.

2. Literature review

2.1. English as a foreign language (EFL) vocabulary learning

Schmitt (2010) stated that vocabulary development is the primary foundation for mastering a second or foreign language. Therefore, learning vocabulary plays an essential role in learning English as a foreign language (EFL). A four-stage method of vocabulary learning has been proposed by Ma (2014), namely (1) discovering a new word, (2) acquiring the word's meaning, (3) mapping the word's meaning with its form, and (4) consolidating the use of the word. However, in China's EFL classes, most teachers often prioritise the meaning of words, neglecting the application of words (Lin, 2015). This makes it difficult for learners to consolidate new words through language use in real-world situations. Numerous studies have shown that repetition or rehearsal is essential to acquire L2 English vocabulary (Jenkins & Dixon, 1983). However, there is a concern about motivating and assisting students to consolidate and apply the words they have learned in real-life learning environments.

2.2. Self-regulated vocabulary learning (SRVL) in mobile-assisted learning environments

In Mainland China, the National English Curriculum Standards advocates student-centred approaches and promotes optimizing learning resources to foster students' learning strategies and promote their SRL skills (MOE, 2011). The recent fast development of mobile technology has given academics new opportunities to explore the possibility of mobile-assisted vocabulary learning (MAVL) to promote second language vocabulary acquisition. Prior research has shown that mobile technology generally benefits English vocabulary learning (Lin & Lin, 2019; Mahdi, 2018). Mobile-assisted vocabulary learning is distinguished by its ability to provide opportunities for spontaneous, informal, customised, and ubiquitous learning (Hwang & Fu, 2019). However, most studies on mobile-assisted vocabulary learning have been limited to decontextualised formal learning settings instead of real-life situations where instructors have prescribed tasks. For example, in some previous studies, learners were only provided with the second language terms and their first language meanings (Chen et al., 2019; Hong et al., 2015) in MAVL, omitting opportunities for students to use and evaluate newly acquired vocabulary in authentic learning environments. Some studies have attempted to enhance students' English vocabulary learning by allowing them to conduct SRL in MAVL environments (Mouri et al., 2018; Wang et al., 2020). Mouri et al. (2018) reported a one-week study on utilising an integrated, ubiquitous learning system to create learning logs to improve university students' English vocabulary learning in a seamless learning environment. Wang et al. (2020) reported a two-week study on the effect of a contribution-oriented self-directed mobile learning ecology (CSDMLE) mode on university students' vocabulary learning. Although the findings of these studies are generally positive, the majority have been carried out in higher education and short-term settings.

Many studies have shown that students' SRL skills improved in online learning systems (Muali et al., 2020; Zheng et al., 2018). However, most students, especially those in primary schools, do not spontaneously regulate their learning in online learning environments (Bai et al., 2022; Lim et al., 2023). Research findings have shown that appropriate SRL support can help improve students' SRL in online learning (Çebi & Güyer, 2020; Huh & Reigeluth, 2018). Although a few studies have developed or adopted online systems for enhancing students' SRVL, most were launched on desktop computers (e.g., Liu et al., 2014). With the increasing popularity and prevalence of mobile technologies in language teaching, there has been a growing interest in developing mobile applications for SRVL (Chen et al., 2019; Hong et al., 2015). Although some mobile applications have been reported to assist primary students' SRVL, the design of these mobile applications failed to meet the theoretical requirements for SRL. For example, Chen et al. (2019) examined the benefits of a mobile-assisted English vocabulary learning application that included an SRL mechanism on primary students' learning performance and motivation. However, the SRL mechanism in Chen et al. (2019) did not reflect self-reflection. Zimmerman's (2002) theoretical model conceptualises SRL as a cyclical process that consists of three phases: forethought, performance, and self-reflection. Prior studies have adopted technologies that can only partially support the SRVL process (Chen et al., 2019; Yang et al., 2023). Thus, there is a need to develop and adopt a mobile app with a full-cycle of self-regulation support scheme to facilitate SRVL (Gambo & Shakir, 2022).

2.3. Latent growth modelling

In the existing literature, the effect of technology on students' SRVL was mainly derived from studies conducted in a short time, for example, two weeks by Chen et al. (2019) or six weeks by Hong et al. (2015). It is worth exploring the potential long-term effect of the newly developed mobile-assisted self-regulation scheme on students' learning performance and SRL skills (Chu et al., 2020).

Although researchers have identified a positive relationship between SRL skills and learning performance (Chang et al., 2022; Lim et al., 2020), they have seldom examined the changes in the perceived SRVL skills and learning performance, not to mention the relationship between these changes across time. The former change refers to the trajectories of individual variables, and the latter refers to the concurrent trajectories of multiple variables. During technology-enhanced SRL, students may adjust their cognition, motivation, and behaviours (Zimmerman, 2002). Students' vocabulary learning and perceived SRVL skills may change over time, and the changes may not be independent but intertwined (Cai & Cheung, 2021; Cai et al., 2022). Therefore, understanding the association between the perceived SRVL skills and vocabulary learning outcomes from a long-term perspective is crucial to provide insightful suggestions on cultivating young learners' mobile-assisted SRVL.

Considering the lack of studies that examine the long-term effects of technology that can support the entire cycle of SRVL on K-12 learners (particularly learners in mobile learning environments), this study conducted Latent Growth Modelling (LGM) to assess the longitudinal effects of a mobile-assisted self-regulation scheme. LGM is a variant of structural equation modelling (SEM) that explains the change and its form across time by identifying two latent growth factors, one representing the initial status (the intercept) and the other representing change over time (the slope) (Duncan et al., 2013). LGM provides several advantages regarding the study of change and development over time. For example, it gives much more flexibility in measuring change than traditional repeated measures analysis of variance. The LGM focuses on describing a single individual's developmental trajectory and capturing individual differences in these trajectories over time. The LGM allows variables to be used as independent and dependent variables in the same model, thereby offering complex growth and change representations (Duncan et al., 2013). Moreover, the LGM method allows for analysing more than one sample within the same model. Participants can be grouped into experimental or control conditions in the context of data collected from various groups. It is possible to examine the existence of multiple subpopulations rather than a single population and multiple growth trajectories rather than a single underlying trajectory for all individuals (Duncan et al., 2013; Weiss et al., 2022).

Against this backdrop, this study aimed to examine the effect of a mobile-assisted self-regulation scheme on primary students' perceived SRVL skills and vocabulary learning outcomes from a longitudinal perspective via LGM. The mobile-assisted self-regulation scheme is embedded in a self-developed mobile vocabulary learning app – Vocab+, to support the entire process of SRVL of primary students. This article explored how primary students' perceived SRVL skills and vocabulary learning outcome change across time (*individual trajectory*); and how the changes in these constructs are associated with each other (*concurrent trajectories*). The following three questions were addressed.

- RQ 1: To what extent does students' perceived self-regulated vocabulary learning (SRVL) change across the experimental and control groups?
- RQ 2: To what extent does students' vocabulary learning outcome change across the experimental and control groups?
- RQ 3: What is the relationship between the change in students' perceived SRVL and the change in their vocabulary learning outcomes across the experimental and control groups?

3. The mobile-assisted vocabulary learning app – Vocab+

This section begins by presenting the design of the Vocab+ app to support vocabulary learning, followed by the design of the mobile-assisted self-regulation scheme embedded in the app.

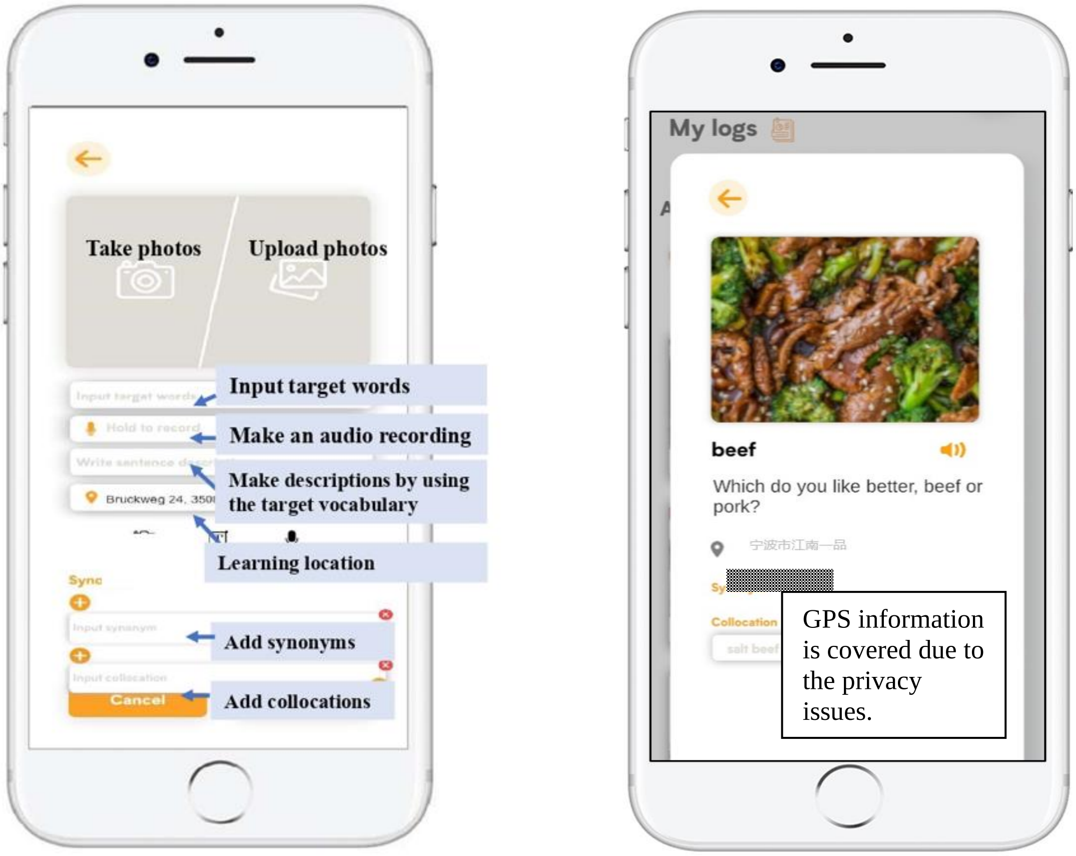
3.1. The Vocab+ app

The Vocab+ app is designed to support students' vocabulary learning after class in this study. The app has three basic modules: (1) "New post"; (2) "My logs"; and (3) "Quiz."

3.1.1. New post

Students can create vocabulary learning logs by using the "New post" module (see Figure 1) by taking pictures of newly learned vocabulary words and tagging them with the GPS-located context information associated with the vocabulary words (see Figure 1(a)). "Creating vocabulary learning logs" was designed to help students use the words they have learned meaningfully. For example, creating logs can support the strategy of elaboration as students reflect on the different ways in which they use the words and how they relate to other concepts. In the case of learning the word "beef" in class, students could use the Vocab+ app to consolidate the word in authentic contexts to reinforce their learning. Students may take a picture of 'beef' encountered in real life, input the word, make an audio recording, and write a sentence like "Which do you like better, beef or pork?" (see Figure 1(b)].

Figure 1. The features of "New Post"



(a) The interface of "New Post" (b) Example of a vocabulary learning log "Beef"

3.1.2. My logs

"My logs" have been designed to increase students' exposure to the target words by reviewing the logs (see Figure 2). "My logs" allows students to view their created vocabulary learning logs in terms of the word lists that are included in the learning units and beyond the learning units. For example, students may categorise the words "beef" and "noodles" into a "food" folder.

3.1.3. Quiz

The system randomly generates quizzes based on students' created vocabulary learning logs (see Figure 3). Four types of quizzes are provided in the "Quiz" module: (1) students need to speak correctly; (2) they need to pick the correct form of the target word; (3) they need to type the correct form of the target word; (4) they need to choose the right meaning.

Figure 2. The interface of "My logs"

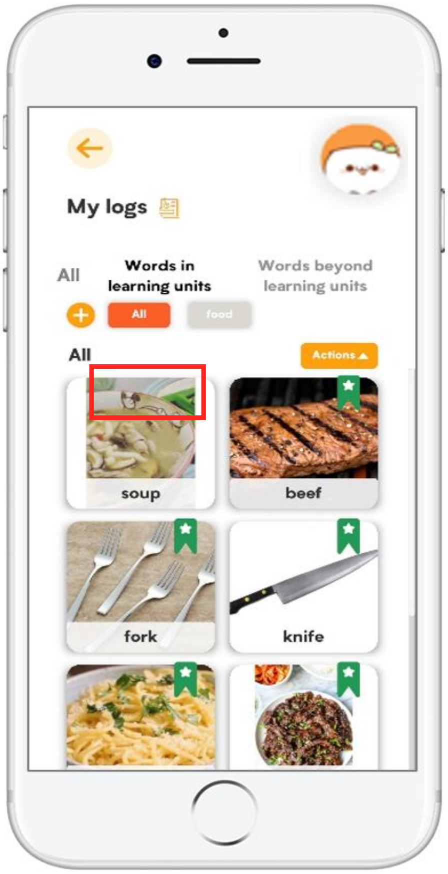
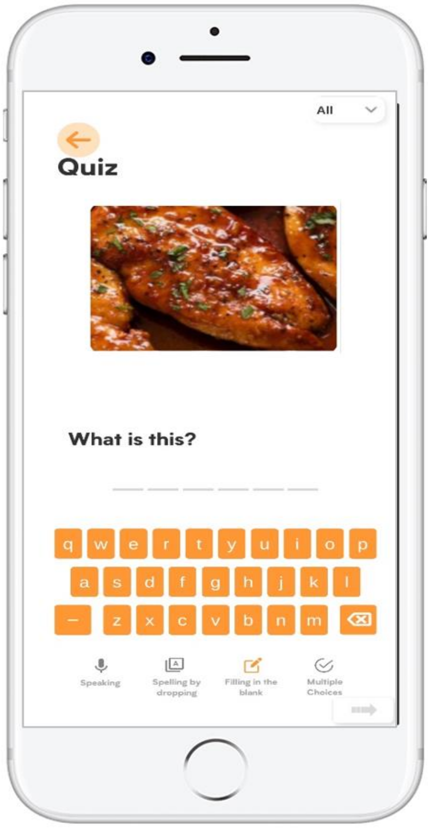


Figure 3. The interface of "Quiz"



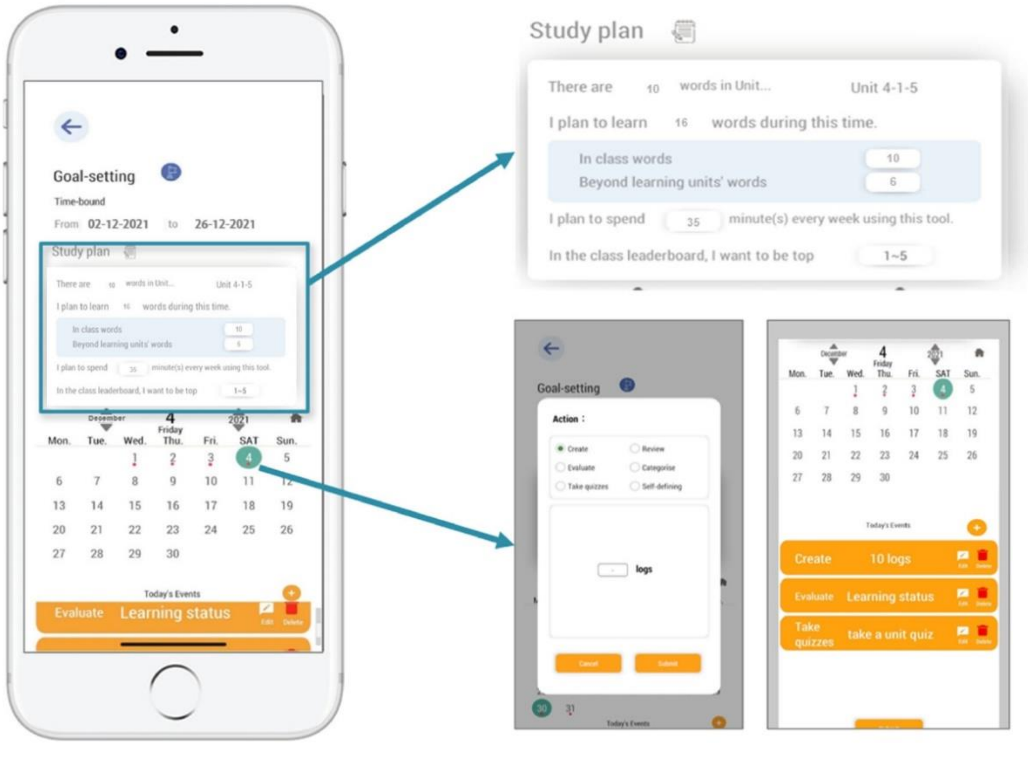
3.2. The mobile-assisted self-regulation scheme

The mobile-assisted self-regulation scheme embedded in the Vocab+ app assists primary students in supporting the entire process of SRVL. The design is grounded in three phases of SRL (forethought, performance, self-reflection) proposed by Zimmerman (2002), including three modules: (1) Goal-setting, (2) My progress, and (3) My reflection. The following presents the functions of three modules.

3.2.1. Goal-setting

During the forethought phase, the students analysed the learning task, including goal-setting and strategic planning. "Goal-setting" enables learners to set specific goals in the "Study Plan." Students can track the number of words in their current curriculum units in the study plan (e.g., there are ten words in Unit 4-1-5). Additionally, learners are permitted to internalise their goals in terms of the number of words they want to achieve throughout their learning unit and beyond the learning unit. During each session, learners can choose how much time they think they will spend on learning and how they expect the class to rank at the end of the session. As an example, Figure 4 shows that the student planned to consolidate 10 in-class words and learn six words beyond the learning unit. As part of his/her goal of finishing class in the top five, the student planned to spend 25 minutes weekly. Furthermore, learners can also use the calendar to plan their studies. Instructors and researchers offer learning strategies in various ways (e.g., creating logs, evaluating logs) so that learners can choose the most appropriate learning strategy based on their individual needs or adapt it based on their preferences and learning needs.

Figure 4. The interface of "Goal-setting"



3.2.2. My Progress

"My progress" module facilitates students in monitoring their learning process via dashboards and a leaderboard that allows them to keep track of the process.

- Dashboard: With the help of this dashboard, learners can check their goal progress regarding time spent on the app and the current records of vocabulary learning. Figure 5 shows an example of one student's learning process. Upon checking the record, the student had planned 35 minutes and achieved 26 minutes. The student planned to consolidate ten words in the learning units. However, he/she left behind two words that had yet to be added. Furthermore, the student can label his/her level of knowledge of the words by indicating: "I do not remember," "I need to review," and "well mastered."

- Leaderboard: The app allows students to see a leaderboard that shows them their ranking in the class based on their behaviours on the app. The researchers co-designed the rubrics for grading students' behaviours on the app.

3.2.3. My Reflection

"My Reflection" module enables students to evaluate their strategies and develop plans for improvement. To achieve these goals, an evaluation sheet is provided in "My reflection" to help students (1) evaluate their performance and the efforts; (2) reflect on the vocabulary learning strategies they adopted; and (3) write down the activities in the following learning cycle (Yang & Song, 2022). For example, Figure 5 shows a student's reflection: "In the next stage, I could set more goals."

Figure 5. The interface of "My Progress"

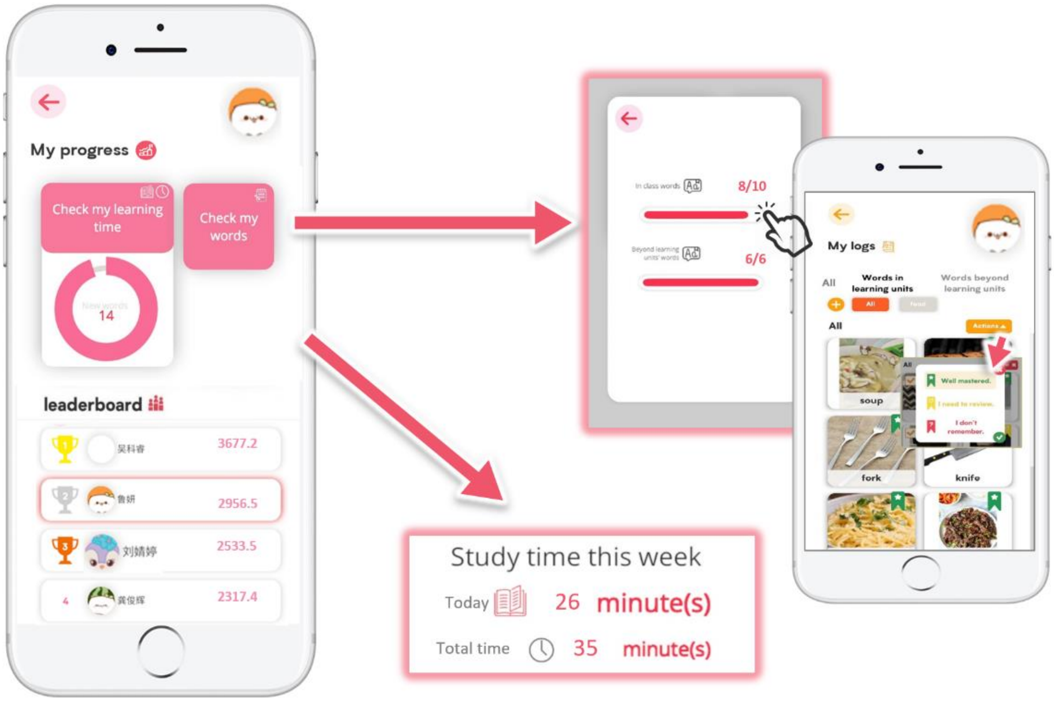
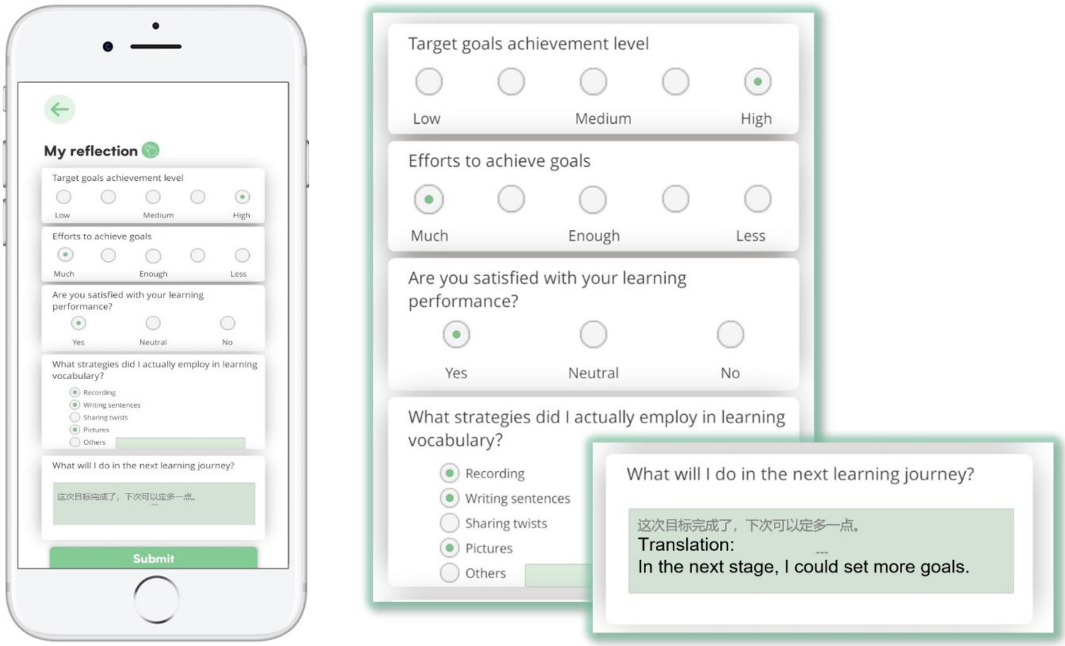


Figure 6. The interface of "My Reflection"



4. Methods

4.1. Participants and context

The study used purposeful sampling. Participants in this study came from a primary school in a metropolitan city (New Tier 1 City) in Eastern China. The income level statistics demonstrated that the city's Gross Domestic Product (GDP) per capita was around US$ 22,604 in 2021, which can be classified into the high-income group by income level 2020–2021 (DataBank, n.d.). The academic performance of the selected school fell in the upper range between the moderate and high performers in its geographical location. The researcher chose samples based on the following criteria: (1) government-aided primary schools; (2) schools that encouraged technology-assisted teaching and learning; (3) classes using People's Education Edition Primary School English published by People's Education Press as textbooks; (4) teachers with a minimum of three years of teaching experience, the ability to adopt new pedagogical methods and overcome the difficulties of technology-enhanced language learning; and (5) participants ranged in age from 10 to 11 years old and had experience utilising mobile devices to assist learning. Based on these criteria, 174 Grade 4 EFL students (89 girls) aged between 10 and 11 from four intact classes from a primary school with two English language teachers participated in this study. It should be noted that primary students begin to learn English in Grade 3. Typically, a 40-minute English class is held three times a week.

Two classes were randomly assigned to the experimental group and the control group. Students in the experimental groups (n = 88, 43 girls) learned vocabulary using Vocab+ with the self-regulation scheme, and students in the control groups (n = 86, 46 girls) learned vocabulary using Vocab+ without the self-regulation scheme. The in-class learning activities in both experimental and control groups were the same. The out-of-class learning activities in the two groups differed in tools: students in the experimental group used Vocab+ with the self-regulation scheme for SRVL by setting learning goals, monitoring learning status, and making self-reflection. However, students in the control group used Vocab+ without the self-regulation scheme for SRVL. They could use basic functions of Vocab+ (e.g., New post, My logs, Quizzes). The six topics from the Grade 4 textbooks were chosen as the learning topics.

4.2. Procedure

The project lasted seven months, including the orientation and the implementation phase. During the orientation, research aims were introduced to the teachers and students. Informed consent forms were obtained from the principal of the school, the students, and the legal guardians of the students. In addition, students were offered three one-hour orientation sessions to familiarise themselves with the mobile learning app - Vocab+. The implementation phase of the project was when the students were learning new words (e.g., discovered new words, obtained the words' meaning) in class, and then they consolidated those words and used them in their daily lives after class with the help of Vocab+. The formal in-class learning activities of the two groups were the same. Several measures were taken to ensure that teachers across all classes consistently taught the material. These measures included regular teacher training sessions (twice a month), classroom observations by the researcher, and frequent communication between teachers and researchers to ensure that the material was taught the same way across classes. Students in the experimental group used the Vocab+ app with the self-regulation scheme in informal learning settings; students in the control group used the Vocab+ app without the self-regulation scheme in informal learning settings. The pedagogical framework that guided this study is depicted in Figure 7. The first two phases were conducted in the classroom, where students were introduced to a new word and learned its meaning. Subsequently, they connected the word's meaning to its form and reinforced their understanding of the target word by utilising the Vocab+ app for SRVL outside of the classroom. Students were encouraged to use the tool for at least one hour per week during the implementation (Yang et al., 2023). Figure 8 shows the three waves of data collection (T1 = Time 1; T2 = Time 2; T3 = Time 3). The surveys containing the perceived SRVL questionnaires and vocabulary tests were completed at three-time points across two academic semesters during the implementation. The first surveys were conducted during the first week of November 2021. The second survey was completed in February 2022. Finally, the third survey was completed in May 2022.

Figure 7. The pedagogical design framework

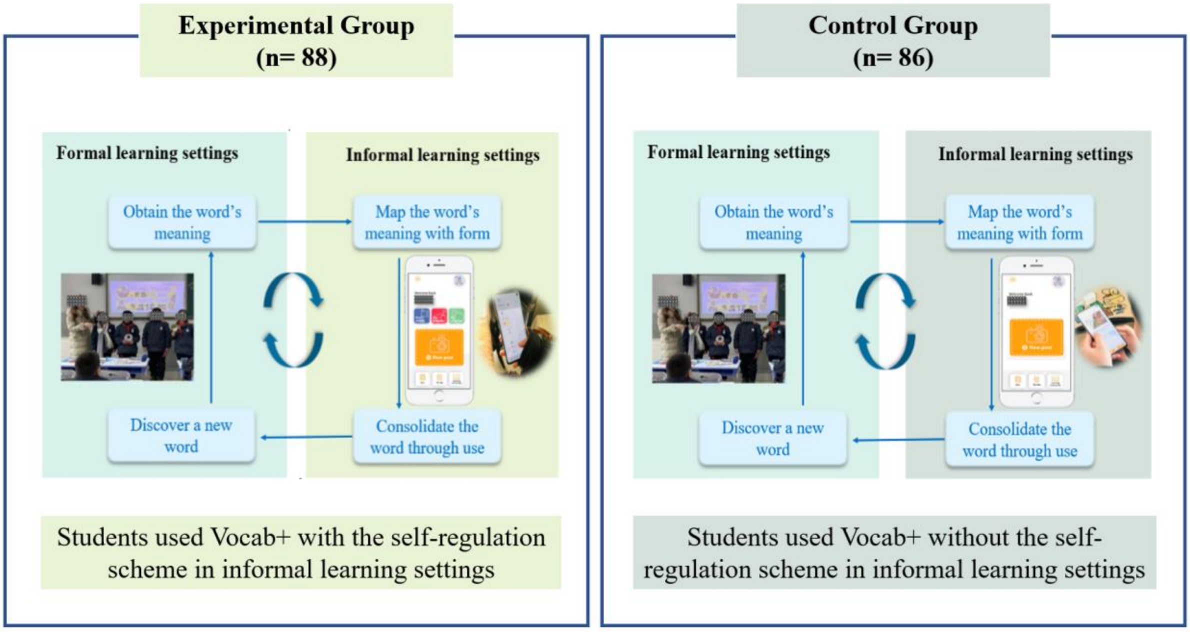
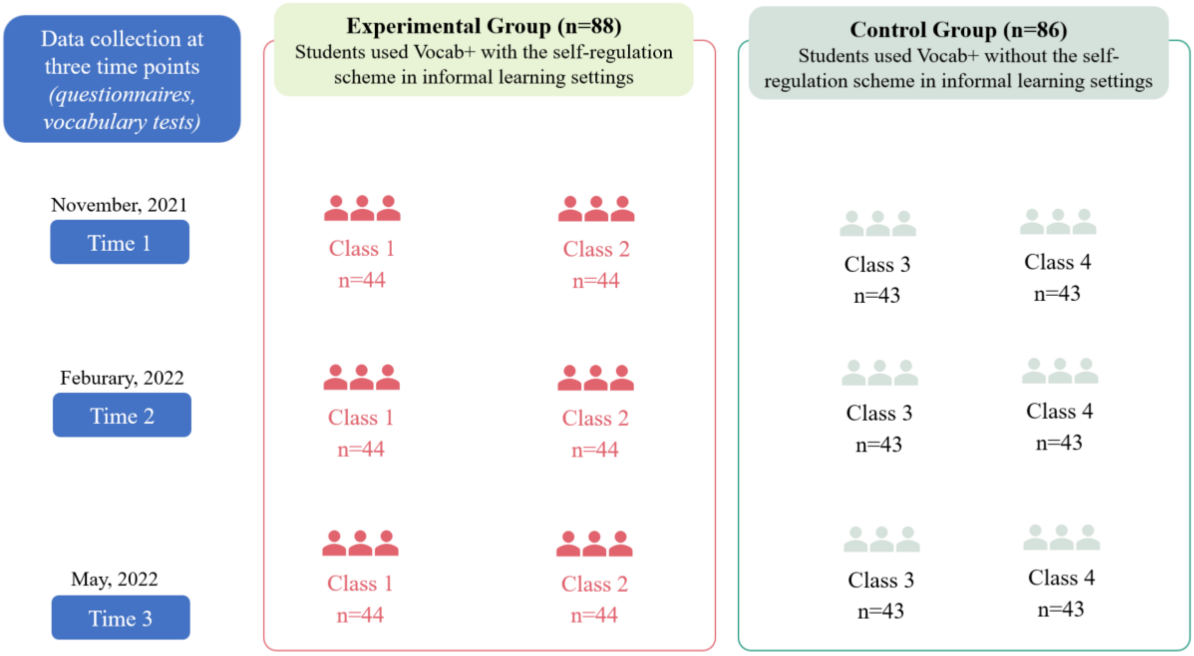


Figure 8. Research procedure



4.3. Data collection

Students' perceived SRVL skills questionnaires and vocabulary tests were collected at three time points.

4.3.1. The perceived SRVL questionnaires

The perceived SRVL questionnaires contained 20 items adapted from Şahin Kızıl and Savran (2018) and Tseng et al. (2006), using a 7-point Likert-scale ranging from 1 (strongly disagree) to 7 (strongly agree) (Joshi et al., 2015). Unlike other SRL instruments, Şahin Kızıl and Savran (2018) provide a comprehensive examination of vocabulary learning in digital environments and the role of learners' innate SRL capacity in the acquisition of L2 vocabulary learning. It contains five dimensions, including commitment regulation (four items), metacognitive regulation (five items), affective regulation (six items), resources (five items), and social regulation (three items).

The items in social regulation in Şahin Kızıl and Savran's (2018) did not fit the context of the present study. Thus, four items of environmental regulation in Tseng et al. (2006) were used in our adapted questionnaire (e.g., When I am studying vocabulary and the learning environment becomes unsuitable, I try to sort out the problem). The content and construct validity of the perceived SRVL questionnaires were assessed.

Content validity was assessed using back-translation (Brislin, 1986). Three bilingual researchers were involved. The instrument was first translated into Chinese by two researchers independently. The differences between the two transcripts were discussed and modified. The third translator was responsible for translating the Chinese version into English. The translated document was compared with the original instrument for accuracy and quality. After that, twelve Grade 4 students in the selected school were randomly chosen to try out the questionnaires. The students could ask questions when they encountered difficulties filling in the questionnaire. Based on their feedback, slight amendments were made. Finally, the questionnaire was confirmed by three experts in the field.

Construct validity was assessed using confirmatory factor analysis (CFA). CFA is a theory-driven approach for testing how well a model explains the covariance among items. According to Byrne (2013), CFA is most efficient when applied to measures that have been fully developed. As the SRVL has long been available in the literature (Şahin Kızıl & Savran, 2018; Tseng et al., 2006), we consider it appropriate to incorporate CFA to evaluate the factor structures identified in the literature. The instrument validation procedures followed the two-step method adopted by Anderson and Gerbing (1988). First, the five factors were proposed in the present study (commitment regulation, metacognition regulation, emotional regulation, resource regulation, and environmental regulation). Items with loading estimates higher than 0.6 were accepted (Hair et al., 2010). The loading estimates showed that three items in the commitment regulation (When learning vocabulary, I believe Vocab+ can help me achieve my goals more quickly than expected), emotional regulation (I feel Vocab+ effectively maintain my interest and enthusiasm in learning vocabulary), and resource regulation (I believe Vocab+ is effective in expanding my resources for vocabulary learning) subscale remained below the acceptable value. Therefore, these three items were excluded from further analysis. In addition, the model fit indices for metacognition were not satisfactory (RMSEA = 0.11). Based on the modification index, an item using Vocab+ to plan tasks and relevant materials to learn vocabulary outside of school was removed from the model for its low loading and high error correlation with another item relating to adjusting Vocab+ to their learning styles. This deletion led to the model fit indices for the construct of metacognition: TLI = 1.005, CFI = 1.000, RMSEA = 0.000, and χ^2/df = 1.447/2. To sum up, four items were removed, leaving a 20-item perceived SRVL skills questionnaire. Apart from the GFI value (0.876), the other fit indices showed that the first-order five-factor model formed a good overall model fit with TLI = 0.925, CFI = 0.937, RMSEA = 0.064, and χ^2/df = 301.557/160, showing good construct validity (Hair et al., 2010). Second, second-order factor analysis was used to determine the relationship between the five first-order factors and one second-order factor — perceived SRVL skills. The model fit results were: TLI = 0.924, CFI = 0.873, RMSEA = 0.064, and χ^2/df = 313.856/165. It is concluded that the model had an acceptable fit for the 20 items. We decided that the measurement validity of the questionnaire was established.

4.3.2. Vocabulary tests

Vocabulary tests included the Vocabulary Levels Test (VLT) and self-developed vocabulary learning outcomes tests based on the curriculum. Vocabulary tests were designed to examine the breadth and depth of students' word knowledge.

For the breadth of vocabulary knowledge, the Vocabulary Levels Test (VLT) has been widely considered the most appropriate assessment of vocabulary size and vocabulary understanding for low-proficiency EFL learners (Webb et al., 2017). According to the Chinese National English curriculum standards (2011), primary students are required to master 600-700 words (p. 49). The bilingual version of VLT was used to test the first 1,000 and second 1,000 words of English (West, 1953). The test consisted of 60 items.

For the depth of vocabulary knowledge, we developed a curriculum-based vocabulary learning outcomes test with 290 items. This test considered word form, meaning, and use and adopted Nation's (2001) framework of word knowledge. The target words were selected from six units of the English textbooks. The test format used multiple-choice or fill-in-blanks to assess word forms and meaning. To assess the use of the target words, learners were required to write a sentence. According to the scoring rubric, a score of 1 was assigned if the sentence was semantically and grammatically accurate using the target term. A score of 0.5 was assigned if the sentence understood the term but misused the word. A score of zero was given for semantically and grammatically incorrect sentences using the target term (Wesche & Paribakht, 1996; Zou, 2017).

The original pool of 350 items was piloted among 252 primary students from Grades 3, Grade 4, and Grade 5. Finally, according to the difficulty levels of the words, the items were divided into three tests with similar difficulty and used in the implementation. The tests were paper-and-pencil based. All students received the same test in each session. The three tests with similar difficulty were assigned to students each time. For each test, the total grade was 108, including 18 items assessing the breadth of vocabulary knowledge and 90 items assessing the depth of vocabulary knowledge.

4.4. Data analysis

For the first research question (RQ1), an LGM was used to analyse the change in students' perceived SRVL over time. The overall fit indices of the models were assessed using model chi-square statistics ($\chi 2$), the Incremental Fit Index (IFI), Comparative Fit Index (CFI), Tucker–Lewis index (TLI), and the Root Mean Square Error of Approximation (RMSEA). The following criteria were used: IFI > 0.9 (Bollen, 1989), CFI > 0.95 (Hu & Bentler, 1999), and RMSEA < 0.08 (Browne & Cudeck, 1992). Data were analysed using SPSS 27 and AMOS 24.0. Firstly, unconditional LGM was conducted. The unconditional LGM investigates the variance in the initial perceived SRVL skills (the intercept) and changes over time (slope). Once the growth shape was determined, the treatment (experimental and control groups) as covariance was assessed in the conditional LGM to explore the differences in perceived SRVL across the control and experimental groups.

For the second research question, the LGM was used to explore the change in vocabulary learning outcomes over time. First, unconditional LGM was conducted. The unconditional LGM investigated the variance in the initial vocabulary learning outcomes status (the intercept) and the change over time (slope). Once the growth shape was determined, the treatment (experimental and control groups) as the covariance was assessed in the conditional LGM to explore the effect of the intervention on the change in students' vocabulary learning outcomes over time.

The third research question examined the within-individual change in perceived SRVL skills over time and if this change was related to their change in vocabulary learning outcomes. To investigate the relationship between the changes in vocabulary performance and perceived SRVL skills (slope-slope relationship), multivariate LGM (Duncan et al., 2013) was used by combing the previous two LGMs. Then, the two-group multivariate LGM was used to examine the concurrent changes in students' perceived SRVL skills and vocabulary learning outcomes across the groups.

5. Results

5.1. Descriptive data analysis

The descriptive statistics of perceived SRVL skills and vocabulary learning outcomes of experimental and control groups in three time points are shown in Table 1. The skewness (-0.35 to 0.50) and kurtosis (-0.89 to -0.06) of the perceived SRVL skills and vocabulary learning outcomes satisfied the assumption of normal distribution (Kline, 2015).

Table 1. Descriptive statistics for observed variables

	Experimental Group					Control Group				
	M	*SD*	*N*	Skewness	Kurtosis	*M*	*SD*	*N*	Skewness	Kurtosis
Perceived SRVL skills										
T1	90.25	13.93	88	0.33	-0.319	89.71	14.35	86	-0.23	-0.75
T2	99.80	12.98	88	0.10	-0.880	93.87	13.26	86	0.08	-0.45
T3	112.56	11.81	88	0.15	-0.300	101.57	12.41	86	-0.31	-0.18
Vocabulary learning outcomes										
T1	60.00	5.70	88	-0.35	-0.204	60.00	5.28	86	-0.11	-0.39
T2	66.00	7.08	88	-0.10	-0.505	63.02	6.04	86	0.05	-0.06
T3	74.01	9.49	88	0.50	-0.414	66.98	8.47	86	-0.11	-0.17

Note. T1 = Time 1; T2 = Time 2; T3 = Time 3; *M* = Means; *SD* = Standard deviation; *N* = Sample size.

5.2. Trajectories of students' perceived SRVL skills change

To address the question "To what extent does students' perceived SRVL change across the experimental and control groups?" the unconditional LGM was conducted first. Table 2 shows the estimates of the intercept and slope factors of the perceived SRVL skills**.** The intercept is a constant representing the initial status of individuals' SRVL. The factor loadings for the first, second, and third data points were all fixed at 1. The slope factor represented the speed of growth, and the factor loadings were fixed tat0, 0.5, and 1 for the three data points, respectively. For perceived SRVL skills, the unconditional model had an acceptable model fit: TLI = 0.970, CFI = 0.970, RMSEA = 0.086, and χ^2/df = 6.883/3. This indicates that the linear growth model was appropriate for the data. The LGM parameter estimates (factor means, variances, and covariance) were examined to understand the growth trajectory within the sample.

As shown in Table 2, the intercept factor had a mean of 89.42 ($p < .001$), suggesting the starting level of students' perceived SRVL skills. In addition, the intercept factor had a variance of 129.64 ($p < .001$), suggesting systematic individual differences in perceived SRVL skills at initial status (some students had higher mean levels than others at T1). The slope factor of SRVL had a mean of 17.14 ($p < .001$), suggesting that students' perceived SRVL skills increased over time. Further, the slope factor had a variance of 94.74 ($p < .01$), indicating that not all students grew at the same rate and that some students' perceived SRVL skills increased much faster than others over the same period. In addition, the results showed a negative relationship between the intercept and slope factors ($r = -0.49$, $p < .05$), indicating that children with higher SRL at the beginning had a slower growth rate.

Once the shape of growth was determined, treatment as the covariance was added to the unconditional LGM to explore the differences in perceived SRVL across groups. The conditional model has a good model fit: TLI = 0.990, CFI = 0.990, and RMSEA = 0.035, and χ^2/df = 7. 249/6. In each model, the factor loadings and residual variances of the repeated measures were specified to be equal across groups. To determine intervention effects on the growth process for each model, the means of the slope for experimental and control conditions were compared. The growth rates shown by the slopes (S) for the two groups were positive and significant ($S_{experimental}$ = 22.31, $SE_{\text{experimental}}$ = 1.52, $S_{control}$ = 11.86, SE_{control} = 1.59). This finding demonstrated that both groups experienced a significant increase in perceived SRVL skills over time, with the intervention group experiencing a steeper increase.

5.3. Trajectories of students' vocabulary learning outcomes change

To address the question "To what extent does students' vocabulary learning outcome change across the experimental and control groups?" the unconditional LGM was conducted first. The unconditional model produced a good model fit for students' vocabulary learning outcomes: TLI = 0.939, CFI = 0.939, RMSEA = 0.090, χ^2/df = 7.164/3, indicating a good model-data fit. Table 2 shows that the intercept factor had a mean of 59.75 ($p < .001$), indicating the vocabulary knowledge levels at the beginning of data collection. The intercept factor had a variance of 5.67 ($p > .05$), revealing nonsignificant individual differences in students' vocabulary knowledge at initial status. The slope factor of vocabulary learning outcomes had a mean of 10.54 ($p < .001$), indicating that students' vocabulary learning outcomes increased over time. Further, the slope factor had a variance of 43.85 ($p < .001$). This indicates that not all students grew at the same rate, and some students' vocabulary learning outcomes increased faster than others over the same period.

The results also showed a positive relationship between the intercept of the students' vocabulary learning outcomes and the slope of students ($r = 0.39$, $p > .05$), indicating that students with better vocabulary learning outcomes at the beginning had a faster growth rate.

Once the growth shape was determined, treatment group was added as the covariance to form the conditional LGM to explore the differences in learning outcomes across the control and experimental groups. The conditional model had a good model fit: TLI = 0.979, CFI = 0.979, RMSEA = 0.035, and χ^2/df = 7. 238/6. In each model, the factor loadings and residual variances of the repeated measures were specified to be equal across groups. The growth rates shown by the slopes (S) for the two groups were positive and significant ($S_{experimental}$ = 14.01, $SE_{\text{experimental}}$ = 1.01, $S_{control}$ = 6.99, SE_{control} = 0.96). This finding demonstrated that both groups had a significantly increasing trend in vocabulary learning outcomes over time, with the intervention group experiencing a steeper increase.

Table 2. Means and variances of intercepts and slopes

Parameters		Perceived SRVL skills	Vocabulary learning outcomes
Unconditional (unstandardised)			
Intercept with slope		$-.49^{**}$	0.39
Intercept means		89.42^{***}	59.76^{***}
Slope mean		17.14^{***}	10.54^{***}
Intercept variance		129.64^{***}	5.67
Slope variance		94.74^{**}	43.85^{***}
Conditional (unstandardised)			
Slope mean	Experimental Group	22.31^{***}	14.01^{***}
	Control Group	11.86^{***}	6.99^{***}

Note. $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

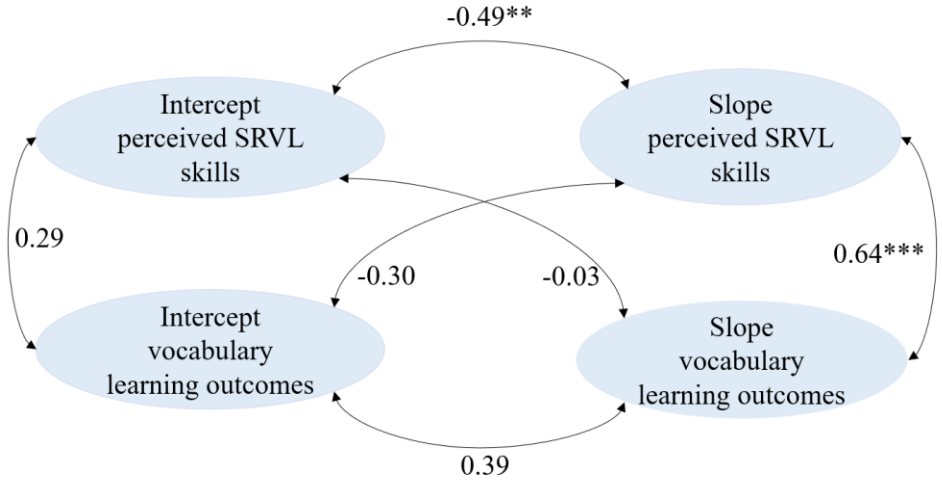
5.4. Relationship between the changes in students' perceived SRVL skills and vocabulary learning outcomes

Multivariate LGM was conducted to address the relationship between the change in students' perceived SRVL skills and vocabulary learning outcomes. The multivariate LGM included multiple measures (e.g., perceived SRVL skills, vocabulary learning outcomes) and multiple occasions (three-time points) at the same time, providing a more dynamic view of the correlates of change "as development in one variable can be associated with development in another variable" (Duncan et al., 2013, p. 63).

The multivariate LGM depicted in Figure 9 describes the relationship among the intercepts and slopes for perceived SRVL skills and vocabulary learning outcomes. The model-data fit results were: TLI = 0.913, CFI = 0.936, RMSEA = 0.087, and χ^2/df = 25.292/11, indicating an acceptable fit.

The results showed that the initial level of students' perceived SRVL skills and the initial level of vocabulary learning outcomes were positively correlated but not statistically significant ($\beta = 0.29$, $p > .05$). In addition, the slope of students' perceived SRVL skills had a significant relationship with the slope of vocabulary learning outcomes ($\beta = 0.64$, $p < .001$). The implication is that the faster students' perceived SRVL skills grow, the faster their vocabulary learning outcomes increase. However, there was a negative relationship between the SRVL intercept and the vocabulary learning outcomes slope ($\beta = -0.03$, $p > .05$), indicating that children with higher SRL at the beginning had a slower growth rate in vocabulary learning outcomes.

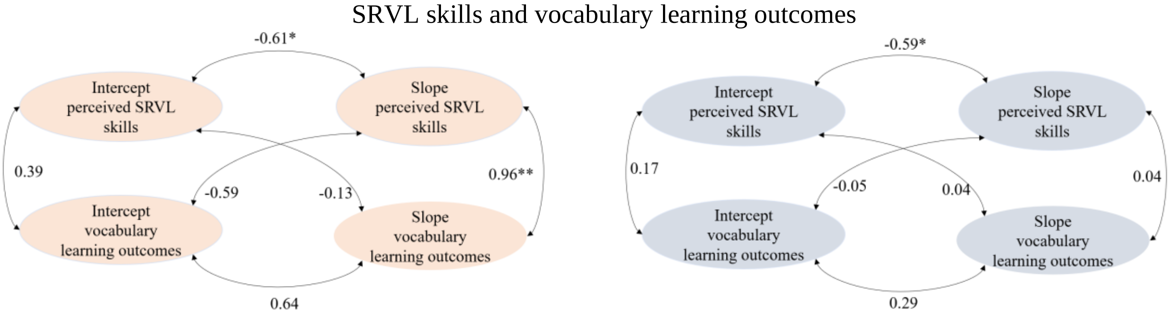
Figure 9. The multivariate LGM depicting the relationship among the intercepts and slopes for perceived SRVL skills and vocabulary learning outcomes (standardised)



Note. For brevity, covariates and relevant estimates are omitted. $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

Next, a two-group multivariate LGM was conducted to examine the concurrent changes in students' perceived SRVL skills and vocabulary learning outcomes across the experimental and control groups (see Figure 10). According to Figure 10, the slope of students' perceived SRVL skills was significantly related to the slope of vocabulary learning outcomes ($\beta = 0.96$, $p < .05$) in the experimental group but not in the control group ($\beta = 0.04$, $p > .05$). This indicates that a faster increase in students' perceived SRVL skills was associated with a faster increase in vocabulary learning outcomes. In addition, the positive relationship between the growth rates of students' perceived SRVL skills and the vocabulary learning outcomes was stronger in the experimental group than their corresponding factors in the control group.

Figure 10. Two-group multivariate LGM assessing the relationship between the growth trajectories for perceived SRVL skills and vocabulary learning outcomes



(a). Multivariate LGM for the experimental group (b) Multivariate LGM for the control group

Note. For brevity, covariates and relevant estimates are omitted. $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

6. Discussion

This study examined the long-term effect of mobile-assisted self-regulation schemes on students' perceived SRVL skills and their vocabulary learning outcomes in informal learning contexts. It also examined the dynamic relationships between the changes in students' perceived SRVL skills and vocabulary learning outcomes.

Our results show that students' perceived SRVL skills and vocabulary learning outcomes increased over time. However, students supported during the whole process of the mobile-assisted self-regulation scheme experienced a steeper increase in perceived SRVL skills and vocabulary learning outcomes than those without the self-regulation scheme on the app. These results extend current understandings of SRVL by suggesting that technology-assisted learning with an SRL scheme can significantly improve learning performance (Su, 2020; Yang et al., 2018; Chen et al., 2014) and vocabulary learning (Chen et al., 2019) from a longitudinal perspective. These findings support the view that technologies optimise SRL when aligned with learning theories (Lai & Gu, 2011; Molenaar, 2022). In this study, the mobile-assisted self-regulation scheme was guided by the theory of Zimmerman's SRL, which was featured in enabling goal-setting, real-time monitoring, and making self-reflection. In addition, our findings suggest that the mobile-assisted self-regulation scheme can effectively cultivate primary students' SRVL skills and enhance learning performance in the long run. These findings support the view that young learners can benefit from technological interventions that support and guide their SRL. This is consistent with existing research by Stebner et al. (2022) and Paris and Paris (2003), who suggest that SRL can be taught and learned. Thus, technological interventions aimed to facilitate SRL can be a valuable tool for educators to support young learners' academic success (Carter Jr et al., 2020).

The results also showed a negative relationship between the initial perceived SRVL skills and the growth rate of the perceived SRVL skills slope, indicating that children with lower SRL initially had a faster growth rate. This finding suggests that primary students with higher perceived SRVL skills at the beginning might not be able to benefit from the mobile-assisted self-regulation scheme as much as their peers with lower perceived SRVL skills. The reason may be that students who had high perceived SRVL skills at the beginning had already developed effective strategies for monitoring, regulating, and evaluating (Pintrich & De Groot, 1990). As a result, the mobile-assisted self-regulation scheme that focused on the three phases of SRVL (i.e., forethought, performance, and self-reflection) might not have provided them with additional support or guidance they did not possess. Instead, they relied on their existing knowledge and skills to engage in SRVL without technological interventions (Yang et al., 2018). This finding is in accordance with a recent study by Chu et al. (2020), who also found a negative relationship between the intercept and slope factors of SRL. However, Chu et al. (2020) did not discuss the reasons behind the finding. This finding highlights the importance of considering individual differences in students' perceived SRVL skills when designing and implementing interventions. Teachers and researchers need to tailor interventions to meet the needs of students with different levels of SRVL skills, such as by providing additional guidance or scaffolding for students who are less confident in their SRL abilities.

For the relationship between the change in students' perceived SRVL skills and vocabulary learning outcomes, the growth rate of students' perceived SRVL skills is positively related to the growth rate of their vocabulary learning outcomes. The results are consistent with previous studies (Jackson et al., 2014; Teng, 2022).

Furthermore, there was a stronger correlation between the slope factor of students' perceived SRVL skills and the slope factor of their vocabulary learning outcomes among the group supported by a mobile-assisted self-regulation scheme than the correlation among the no-support group. This difference could be possibly explained as that students supported by the mobile-assisted self-regulation scheme were more able to set clear goals, check learning processes, and make reflections to adjust learning performance in the next round. As these students' SRVL was continuously guided, they were more likely to be engaged in learning, leading to faster growth of vocabulary learning outcomes.

7. Conclusions

The present study showed the benefits of embedding a self-regulation scheme in mobile-assisted vocabulary learning to support the whole process of SRVL. Regardless, our study bore at least three limitations. First, the present study focused on young learners from a primary school in Mainland China. This focus could potentially limit the generalisability of the results to other populations. Second, the measurement of SRVL skills relied on students' subjective self-reports. Future studies could consider using multimodal data (e.g., think-aloud, facial expressions) (Lajoie et al., 2021) or students' trace data on the learning applications (e.g., log data, mouse movement) (Bernacki, 2017) to provide a more rigorous solution to getting a comprehensive understanding of SRVL. Furthermore, we did not assess the out-of-class learning time for the two groups. It is possible that students in one group had more out-of-class learning time than students in the other. This absence could have influenced the results. For example, more out-of-class learning time may have led to more vocabulary acquisition and retention. Therefore, future research should take out-of-class learning time into consideration to better understand its impact on primary students' SRVL. Third, the current study was not able to obtain student background information such as their socio-economic status (SES) (Caughy et al., 2022) or their parents' beliefs about SRL (Stern & Hertel, 2020), which were also believed to influence students' SRL. Future research could collect such background information to gain a more in-depth understanding of primary students' SRVL.

The study has theoretical implications in at least two ways. First, although SRL has long been regarded as a powerful facilitator of language learning, whether and to what extent SRL works in technology-based environments lacks evidence. This is mainly because technology has been frequently reported to be negatively related to learning outcomes (Cavus & Ibrahim, 2017; Huang et al., 2012). Our study showed that if implemented appropriately, SRL could be a powerful facilitator of L2 learning for young L2 learners. Second, this study should be able to shed new light on the interaction between SRL and technology-based L2 learning environments from an epistemological perspective. Conventionally, researchers are used to understanding a static relationship between a predictor variable and an outcome variable. For instance, if the variation of an outcome variable (e.g., L2 vocabulary learning) is positively related to the variation of a predictor variable (e.g., SRL skills), the conclusion is made that the predictor facilitates the outcome variable. While this static approach provides a general perception of the learning outcome, it does not allow a more subtle understanding of the learning process (Cai et al., 2022). In the era of progression-oriented learning, it is more important to reveal to what extent students can achieve than to merely tell where they are now (Cai & Cheung, 2021). From this perspective, the longitudinal evidence regarding the dynamic relationship between the trajectories of SRL skills and L2 vocabulary not only helps us to understand the static relationship between variables indicating where students are through the association between the intercepts but also to understand how far they can develop through the variance of the slope factors. More importantly, the association between the slope factors can also help us to understand how and the extent to which the development of a contributing variable can speed up the magnitude of the increase in an outcome variable.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Alvi, E., & Gillies, R. M. (2021). Self-regulated learning (SRL) perspectives and strategies of Australian primary school students: a qualitative exploration at different year levels. *Educational Review*, 1-23. https://doi.org/10.1080/00131911.2021.1948390

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin*, *103*(3), 411. https://doi.org/10.1037/0033-2909.103.3.411

Bai, B., Wang, J., & Zhou, H. (2022). An intervention study to improve primary school students' self-regulated strategy use in English writing through e-learning in Hong Kong. *Computer Assisted Language Learning*, *35*(9), 2265-2290. https://doi.org/https://doi.org/10.1080/09588221.2020.1871030

Bernacki, M. L. (2018). Examining the cyclical, loosely sequenced, and contingent features of self-regulated learning: Trace data and their analysis. In D. H. Schunk & J. A. Greene (Eds.), *Handbook of self-regulation of learning and performance* (2 ed., pp. 370-387). Routledge. https://doi.org/10.4324/9781315697048-24

Browne, M. W., & Cudeck, R. (1992). Alternative ways of assessing model fit. *Sociological Methods & Research*, *21*(2), 230-258. https://doi.org/10.1177/0049124192021002005

Bollen, K. A. (1989). A new incremental fit index for general structural equation models. *Sociological Methods & Research*, *17*(3), 303-316. https://doi.org/10.1177/0049124189017003004

Brislin, R. W. (1986). The wording and translation of research instruments. In W. J. Lonner & J. W. Berry (Eds.), *Field methods in cross-cultural research* (pp. 137–164). Sage. https://psycnet.apa.org/record/1987-97046-005

Byrne, B. M. (2013). *Structural equation modeling with Mplus: Basic concepts, applications, and programming*. Routledge.

Cai, Y., & Cheung, H. (2021). A dynamic language ability system framework for diagnosing EMI students' readiness of English language ability. In *Rethinking EMI* (1 ed., Vol. 1, pp. 141-160). Routledge. https://doi.org/10.4324/9780429352362-8

Cai, Y., King, R. B., & McInerney, D. M. (2022). The concurrent trajectories of utility value, metacognitive strategy use, and achievement. *The Journal of Experimental Education*, 1-22. https://doi.org/10.1080/00220973.2022.2053496

Cavus, N., & Ibrahim, D. (2017). Learning English using children's stories in mobile devices. *British Journal of Educational Technology*, *48*(2), 625-641. https://doi.org/10.1111/bjet.12427

Carter Jr, R. A., Rice, M., Yang, S., & Jackson, H. A. (2020). Self-regulated learning in online learning environments: strategies for remote learning. *Information and Learning Sciences*, *121*(5/6), 321-329. https://doi.org/10.1108/ILS-04-2020-0114

Caughy, M. O. B., Brinkley, D. Y., Pacheco, D., Rojas, R., Miao, A., Contreras, M. M., ... & McClelland, M. (2022). Self-regulation development among young Spanish-English dual language learners. *Early Childhood Research Quarterly*, *60*, 226-236. https://doi.org/10.1016/j.ecresq.2022.02.004

Çebi, A., & Güyer, T. (2020). Students' interaction patterns in different online learning activities and their relationship with motivation, self-regulated learning strategy and learning performance. *Education and Information Technologies, 25*, 3975-3993.

Chang, C.-Y., Panjaburee, P., Lin, H.-C., Lai, C.-L., & Hwang, G.-H. (2022). Effects of online strategies on students' learning performance, self-efficacy, self-regulation and critical thinking in university online courses. *Educational Technology Research and Development*, 1-20. https://doi.org/10.1007/s11423-021-10071-y

Chen, C. M., Chen, L. C., & Yang, S. M. (2019). An English vocabulary learning app with self-regulated learning mechanism to improve learning performance and motivation. *Computer Assisted Language Learning*, *32*(3), 237-260. https://doi.org/10.1080/09588221.2018.1485708

Chen, C. M., Wang, J. Y., & Chen, Y. C. (2014). Facilitating English-language reading performance by a digital reading annotation system with self-regulated learning mechanisms. *Educational Technology & Society*, *17*(1), 102-114.

Chu, L., Li, P.-H., & Yu, M.-N. (2020). The longitudinal effect of children's self-regulated learning on reading habits and well-being. *International Journal of Educational Research*, *104*, 101673. https://doi.org/10.1016/j.ijer.2020.101673

DataBank. (n.d.) *GDP per capita (Current US$).* https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?most_recent_value_desc=true

Duncan, T. E., Duncan, S. C., & Strycker, L. A. (2013). *An introduction to latent variable growth curve modeling: Concepts, issues, and applications*. Routledge.

Eggers, J. H., Oostdam, R., & Voogt, J. (2021). Self-regulation strategies in blended learning environments in higher education: A systematic review. *Australasian Journal of Educational Technology*, 175-192. https://doi.org/10.14742/ajet.6453

Gambo, Y., & Shakir, M. Z. (2023). Evaluating students' experiences in self-regulated smart learning environment. *Education and Information Technologies*, *28*(1), 547-580. https://doi.org/10.1007/s10639-022-11126-0

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis* (7th ed.). Prentice Hall.

Ho, H. N. J., Liang, J. C., & Tsai, C. C. (2022). The interrelationship among high school students' conceptions of learning science, self-regulated learning science, and science learning self-efficacy. *International Journal of Science and Mathematics Education*, *20*(5), 943-962. https://doi.org/10.1007/s10763-021-10205-x

Hong, J. C., Hwang, M. Y., Chang, H. W., Tai, K. H., Kuo, Y. C., & Tsai, Y. H. (2015). Internet cognitive failure and fatigue relevant to learners' self-regulation and learning progress in English vocabulary with a calibration scheme. *Journal of Computer Assisted Learning*, *31*(5), 450-461. https://doi.org/10.1111/jcal.12103

Howard, S. J., & Melhuish, E. (2017). An early years toolbox for assessing early executive function, language, self-regulation, and social development: Validity, reliability, and preliminary norms. *Journal of Psychoeducational Assessment*, *35*(3), 255-275. https://doi.org/10.1177/0734282916633009

Hu, L. T., & 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

Huang, R. T., Jang, S. J., Machtmes, K., & Deggs, D. (2012). Investigating the roles of perceived playfulness, resistance to change and self-management of learning in mobile English learning outcome. *British Journal of Educational Technology*, *43*(6), 1004-1015. https://doi.org/10.1111/j.1467-8535.2011.01239.x

Huh, Y., & Reigeluth, C. M. (2018). Online K-12 teachers' perceptions and practices of supporting self-regulated Learning. *Journal of Educational Computing Research*, *55*(8), 1129–1153. https://doi.org/10.1177/0735633117699231

Hwang, G.-J., & Fu, Q.-K. (2019). Trends in the research design and application of mobile language learning: A review of 2007–2016 publications in selected SSCI journals. *Interactive Learning Environments*, *27*(4), 567-581. https://doi.org/10.1080/10494820.2018.1486861

Jackson, C. W., Schatschneider, C., & Leacox, L. (2014). Longitudinal analysis of receptive vocabulary growth in young Spanish English–speaking children from migrant families. *Language, Speech, and Hearing Services in Schools*, *45*(1), 40-51. https://doi.org/10.1044/2013_LSHSS-12-0104

Jenkins, J. R., & Dixon, R. (1983). Vocabulary learning. *Contemporary Educational Psychology*, *8*(3), 237-260. https://doi.org/10.1016/0361-476X(83)90016-4

Joshi, A., Kale, S., Chandel, S., & Pal, D. K. (2015). Likert scale: Explored and explained. *British Journal of Applied Science & Technology*, *7*(4), 396. https://doi.org/10.9734/BJAST/2015/14975

Kline, R. B. (2015). *Principles and practice of structural equation modeling*. Guilford publications.

Li, J., Ye, H., Tang, Y., Zhou, Z., & Hu, X. (2018). What are the effects of self-regulation phases and strategies for Chinese students? A meta-analysis of two decades research of the association between self-regulation and academic performance. *Frontiers in Psychology*, *9*, 2434. https://doi.org/10.3389/fpsyg.2018.02434

Lim, C., Ab Jalil, H., Ma'rof, A., & Saad, W. (2020). Peer learning, self-regulated learning and academic achievement in blended learning courses: A structural equation modeling approach. *International Journal of Emerging Technologies in Learning (iJET)*, *15*(3), 110-125. https://doi.org/10.3991/ijet.v15i03.12031

Lim, L., Bannert, M., van der Graaf, J., Singh, S., Fan, Y., Surendrannair, S., Rakovic, M., Molenaar, I., Moore, J., & Gašević, D. (2023). Effects of real-time analytics-based personalized scaffolds on students' self-regulated learning. *Computers in Human Behavior*, *139*, 107547. https://doi.org/10.1016/j.chb.2022.107547

Lai, C., & Gu, M. (2011). Self-regulated out-of-class language learning with technology. *Computer Assisted Language Learning*, *24*(4), 317-335. https://doi.org/10.1080/09588221.2011.568417

Lai, C.-L., Hwang, G.-J., & Tu, Y.-H. (2018). The effects of computer-supported self-regulation in science inquiry on learning outcomes, learning processes, and self-efficacy. *Educational Technology Research and Development*, *66*(4), 863-892. https://doi.org/10.1007/s11423-018-9585-y

Lajoie, S. P., Zheng, J., Li, S., Jarrell, A., & Gube, M. (2021). Examining the interplay of affect and self-regulation in the context of clinical reasoning. *Learning and Instruction*, *72*, 101219. https://doi.org/10.1016/j.learninstruc.2019.101219

Lim, L., Bannert, M., van der Graaf, J., Singh, S., Fan, Y., Surendrannair, S., Rakovic, M., Molenaar, I., Moore, J., & Gašević, D. (2023). Effects of real-time analytics-based personalized scaffolds on students' self-regulated learning. *Computers in Human Behavior*, *139*, 107547. https://doi.org/10.1016/j.chb.2022.107547

Lin, L. F. (2015). The impact of problem-based learning on Chinese-speaking elementary school students' English vocabulary learning and use. *System*, *55*, 30-42. https://doi.org/10.1016/j.system.2015.08.004

Lin, J.-J., & Lin, H. (2019). Mobile-assisted ESL/EFL vocabulary learning: a systematic review and meta-analysis. *Computer Assisted Language Learning*, *32*(8), 878-919. https://doi.org/10.1080/09588221.2018.1541359

Liu, S. H.-J., Lan, Y.-J., & Ho, C. Y.-Y. (2014). Exploring the relationship between self-regulated vocabulary learning and web-based collaboration. *Educational Technology & Society*, *17*(4), 404-419.

Ma, Q. (2014). A contextualised study of EFL learners' vocabulary learning approaches: Framework, learner approach and degree of success. *Journal of Asia TEFL, 11*(3), 33-71.

Mahdi, H. S. (2018). Effectiveness of mobile devices on vocabulary learning: A meta-analysis. *Journal of Educational Computing Research*, *56*(1), 134-154. https://doi.org/10.1177/0735633117698826

Molenaar, I. (2022). The concept of hybrid human-AI regulation: Exemplifying how to support young learners' self-regulated learning. *Computers and Education: Artificial Intelligence*, *3*, 100070. https://doi.org/10.1016/j.caeai.2022.100070

Mouri, K., Uosaki, N., & Ogata, H. (2018). Learning analytics for supporting seamless language learning using e-book with ubiquitous learning system. *Educational Technology & Society, 21*(2), 150-163.

Muali, C., Setyosari, P., Purnomo, P., & Yuliati, L. (2020). Effects of mobile augmented reality and self-regulated learning on students' concept understanding. *International Journal of Emerging Technologies in Learning (iJET)*, *15*(22), 218-229. https://doi.org/10.1016/j.caeai.2022.100070

Nation, I. S. (2001). *Learning vocabulary in another language*. Ernst Klett Sprachen.

Paris, S. G., & Paris, A. H. (2003). Classroom applications of research on self-regulated learning. In *Educational psychologist* (pp. 89-101). Routledge. https://doi.org/10.1207/S15326985EP3602_4

Pintrich, P. R., & De Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, *82*(1), 33-40. https://doi.org/10.1037/0022-0663.82.1.33

Pilegard, C., & Fiorella, L. (2016). Helping students help themselves: Generative learning strategies improve middle school students' self-regulation in a cognitive tutor. *Computers in Human Behavior, 65*, 121-126. https://doi.org/10.1016/j.chb.2016.08.020

Şahin Kızıl, A., & Savran, Z. (2018). Assessing self-regulated learning: The case of vocabulary learning through information and communication technologies. *Computer Assisted Language Learning, 31*(5-6), 599–616. https://doi.org/10.1080/09588221.2018.1428201

Sashikala, J. P., & Chye, S. Y. (2022). Self-regulated reading: Insights from a phenomenological study of primary 6 students in Singapore. *Reading Psychology*, 1-36. https://doi.org/10.48550/arXiv.2205.11487

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

Stebner, F., Schuster, C., Weber, X. L., Greiff, S., Leutner, D., & Wirth, J. (2022). Transfer of metacognitive skills in self-regulated learning: effects on strategy application and content knowledge acquisition. *Metacognition and Learning*, *17*(3), 715-744. https://doi.org/10.1007/s11409-020-09237-5

Stern, M., & Hertel, S. (2020). Profiles of parents' beliefs about their child's intelligence and self-regulation: a latent profile analysis. *Frontiers in Psychology*, *11*, 610262. https://doi.org/10.3389/fpsyg.2020.610262

Su, J. M. (2020). A rule-based self-regulated learning assistance scheme to facilitate personalized learning with adaptive scaffoldings: A case study for learning computer software. *Computer Applications in Engineering Education, 28*(3), 536-555. https://doi.org/10.1002/cae.22222

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, L. S., & Zhang, L. J. (2022). Can self-regulation be transferred to second/foreign language learning and teaching? Current status, controversies, and future directions. *Applied Linguistics, 43*(3), 587-595. https://doi.org/10.1093/applin/amab032

The Ministry of Education of the People's Republic of China (MOE). (2011). *English curriculum standards for compulsory education (2011 version)*. http://www.moe.gov.cn/srcsite/A26/s8001/201112/W020220418401378728645.pdf

Tseng, W.-T., Dörnyei, Z., & Schmitt, N. (2006). A new approach to assessing strategic learning: The case of self-regulation in vocabulary acquisition. *Applied Linguistics*, *27*(1), 78-102. https://doi.org/10.1093/applin/ami046

Verstege, S., Pijeira-Díaz, H. J., Noroozi, O., Biemans, H., & Diederen, J. (2019). Relations between students' perceived levels of self-regulation and their corresponding learning behavior and outcomes in a virtual experiment environment. *Computers in Human Behavior*, *100*, 325-334. https://doi.org/10.1016/j.chb.2019.02.020

Wang, Z., Hwang, G.-J., Yin, Z., & Ma, Y. (2020). A contribution-oriented self-directed mobile learning ecology approach to improving EFL students' vocabulary retention and second language motivation. *Educational Technology & Society*, *23*(1), 16-29.

Webb, S., Sasao, Y., & Ballance, O. (2017). The updated Vocabulary Levels Test: Developing and validating two new forms of the VLT. *ITL-International Journal of Applied Linguistics, 168*(1), 33-69. https://doi.org/10.1075/itl.168.1.02web

Wesche, M., & Paribakht, T. S. (1996). Assessing second language vocabulary knowledge: Depth versus breadth. *Canadian Modern Language Review, 53*(1), 13-40. https://doi.org/10.3138/cmlr.53.1.13

Weiss, E. M., McDermott, P. A., Rovine, M. J., & Oh, J. (2022). Latent growth trajectories of peer context behavior problems across preschool, kindergarten and first grade. *Early Education and Development*, *33*(6), 939-957. https://doi.org/10.1080/10409289.2021.1928445

West, M. (1953). *A general service list of English words.* Longman.

Yang, K.-H., Chu, H.-C., & Chiang, L.-Y. (2018). Effects of a progressive prompting-based educational game on second graders' mathematics learning performance and behavioral patterns. *Educational Technology & Society, 21*(2), 322-334.

Yang, Y., Wen, Y., & Song, Y. (2023). A systematic review of technology-enhanced self-regulated language learning. *Educational Technology & Society, 26*(1), 31-44.

Yang, Y., & Song, Y. (2022). Understanding primary students' self-regulated vocabulary learning behaviours on a mobile app via learning analytics and their associated outcomes: A case study. *Journal of Computers in Education*, 1-30. https://doi.org/10.1007/s40692-022-00251-x

Zheng, L., Li, X., & Chen, F. (2018). Effects of a mobile self-regulated learning approach on students' learning achievements and self-regulated learning skills. *Innovations in Education and Teaching International*, *55*(6), 616-624. https://doi.org/10.1080/14703297.2016.1259080

Zou, D. (2017). Vocabulary acquisition through cloze exercises, sentence-writing and composition-writing: Extending the evaluation component of the involvement load hypothesis. *Language Teaching Research*, *21*(1), 54-75. https://doi.org/10.1177/1362168816652418

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

Zimmerman, B. J. (2008). Investigating self-regulation and motivation: Historical background, methodological developments, and future prospects. *American Educational Research Journal*, *45*(1), 166-183. https://doi.org/10.3102/0002831207312909

Appendix I

Questionnaire on the perceived SRVL skills

Commitment

1. When learning vocabulary, I believe Vocab+ can help me persist until I reach the goals that I make for myself.
2. Vocab+ is an important tool to maintain my interest in achieving my vocabulary learning goals.
3. I believe Vocab+ is effective in boosting willpower for learning vocabulary.

Metacognitive

4. I know how to use Vocab+ to effectively monitor myself to achieve my vocabulary learning goals.
5. I adjust my vocabulary learning goals in response to the information resources and communication venues I have access to via the Vocab+.
6. I believe Vocab+ could help me monitor my progress in learning vocabulary.
7. I know how to adjust Vocab+ according to my learning styles.

Affective

8. During the process of learning vocabulary, I believe that Vocab+ can help me overcome any sense of boredom.
9. When feeling bored with learning vocabulary, I use Vocab+ to regulate my mood in order to regain the interest and enthusiasm in learning.
10. When I feel stressed about vocabulary learning, I feel Vocab+ help to reduce this stress.
11. I feel satisfied with the way I use Vocab+ to reduce the stress of vocabulary learning.
12. I feel Vocab+ can make the task of vocabulary learning more attractive to me.
13. I feel Vocab+ effectively maintain my interest and enthusiasm in learning vocabulary.

Resource

14. I use Vocab+ to create and increase opportunities to learn and use vocabulary.

15. I use Vocab+ to seek learning resources and opportunities to help achieve my vocabulary learning goals.
16. I seek engaging vocabulary learning materials and experience delivered via Vocab+.

Environment

17. When I am studying vocabulary and the learning environment becomes unsuitable, I try to sort out the problem.
18. When learning vocabulary, I know how to arrange the environment to make learning more efficient.
19. When learning vocabulary, I am aware that the learning environment matters.
20. When I study vocabulary, I look for a good learning environment.

Appendix II

Sample vocabulary test

https://drive.google.com/file/d/1hGtqF3jee0MQXeGIVckMGo992c6MGT0v/view?usp=share_link