Metacognition and Learning
https://doi.org/10.1007/s11409-024-09377-y

Check for updates

Study strategy use among elementary school students: Is use of specific study strategies related to academic performance?

Yue Yin[1] · Tian Fan[1] · Wenbo Zhao[2] · Jun Zheng[3] · Xiao Hu[4] · Ningxin Su[1] · Chunliang Yang[4,5] · Liang Luo[5,6]

Received: 5 September 2023 / Accepted: 10 February 2024

Abstract

Employment of appropriate study strategies is crucial for academic success. Previous findings on whether use of specific strategies is related to academic performance in real educational settings were inconsistent, and their participant samples were largely restricted to undergraduate students. The current study recruited a large sample (i.e., 4,331 participants) of elementary school students to explore the association between use of specific strategies and academic performance by using multilevel linear regression models, in which two potential confounding variables (i.e., SES and gender) are controlled for. The results showed that after controlling for SES, gender and other study strategies, use of spaced study, rereading and help-seeking positively related to academic performance in elementary school students. However, use of self-testing, highlighting/underlining, note-taking, summarizing, making diagrams, making study plans and studying with friends did not positively correlate with academic performance in elementary school children. Instructors and parents are suggested to encourage children to study by using the effective study strategies, and teach them how to maximize the benefits of these strategies.

Keywords Study strategy usage · Academic performance · Elementary school children · Effective study strategies

How to become a successful learner is always of substantial interests among researchers and practitioners (including learners, instructors and policy-makers). A wealth of laboratory research has established that utilization of appropriate study strategies is crucial for efficient learning, and some strategies (e.g., spaced study and self-testing) have been verified to be more effective than others (e.g., highlighting/underlining and rereading) (Dunlosky et al., 2013; Roediger, 2013; Yang et al., 2021). Several studies investigated whether (and to what extent) students utilize the high- and low-utility strategies in daily learning, and whether use of these strategies is related to academic performance (Anthenien et al., 2018; Geller et al., 2018; Hartwig & Dunlosky, 2012; McAndrew et al., 2016; Morehead et al., 2016; Rodriguez et al., 2021; Tullis & Maddox, 2020; Walck-Shannon et al., 2021). However, the

Extended author information available on the last page of the article

observed findings are rather conflicting (see below for detailed discussion). More importantly, by far no study has explored whether use of specific strategies is related to academic performance in young elementary children – a key stage of study habit development. The current study aims to fill this important gap.

Not all study strategies are equally effective

Numerous laboratory studies in cognitive science and educational psychology have established that some study strategies are more beneficial for durable learning than others (Cepeda et al., 2006; Dunlosky et al., 2013; Roediger, 2013; Yang et al., 2021). A review conducted by Dunlosky et al. (2013) provided a thorough assessment of ten specific strategies' utility, in which the authors evaluated generalizability of those strategies across different dimensions (i.e., material types, learning conditions, student characteristics and criterion tasks). According to the classification of study strategies in the review (Dunlosky et al., 2013), spaced study and testing were identified as high-utility study strategies, and the enhancing effects of spaced study and testing on learning have also been widely documented by many other studies (e.g., Cepeda et al., 2006; Janiszewski et al., 2003; Rowland, 2014; Yang et al., 2021).

Spaced study, which involves dividing the learning process into multiple sessions over time, enhances long-term retention by comparison with massed study or cramming of learning in a single session (Cepeda et al., 2006; Janiszewski et al., 2003). This so-called spacing effect generalizes across different populations (e.g., adults, children), material types (e.g., word lists, word pairs, pictures, trivia facts, texts) and knowledge domains (e.g., biology, mathematics, history) (for a review, see Dunlosky et al., 2013). Testing (i.e., retrieving information from memory), as another effective strategy, has received ample evidence demonstrating that it is superior to other study strategies (e.g., restudying, note-taking) in consolidating long-term retention of studied information and in enhancing learning of new information, a phenomenon known as the testing effect or test-enhanced learning (Dunlosky et al., 2013; Roediger et al., 2006; Rowland, 2014; Yang et al., 2018, 2021).

In contrast to the aforementioned high-utility strategies, Dunlosky et al. (2013) also identified several low-utility study strategies, for which their benefits to learning are relatively limited, such as highlighting/underlining (i.e., marking important contents while reading), rereading (i.e., restudying learning materials after initial reading) and summarizing (i.e., summarizing important knowledge points while or after initial learning). The utility classification of different study strategies mentioned above is repeatedly recognized by previous studies (e.g., Morehead et al., 2016; Rodriguez et al., 2021; Roediger, 2013).

Association between use of specific study strategies and academic performance

An essential question that needs to be investigated is whether use of specific strategies relates to academic performance in real educational settings. Several studies have examined this issue, but the documented findings are rather conflicting (e.g., Anthenien et al., 2018; Geller et al., 2018; Hartwig & Dunlosky, 2012; McAndrew et al., 2016; Morehead et al., 2016; Rodriguez et al., 2021; Tullis & Maddox, 2020; Walck-Shannon et al., 2021). For instance, Hartwig and Dunlosky (2012) and several other studies (McAndrew et al., 2016; Morehead et al., 2016) found that use of spaced study was unrelated to college students' grade point average (i.e., GPA). However, some studies found that undergraduates with higher GPA were more likely to engage in spaced study than those with lower GPA (Anthenien et al., 2018; Geller et al., 2018). In the same way, although some studies observed a positive correlation between use of self-testing and academic performance (Geller et al., 2018; Hartwig & Dunlosky, 2012; Rodriguez et al., 2021; Walck-Shannon et al., 2021), others found no association between these two variables (Morehead et al., 2016; Tullis & Maddox, 2020).

For low-utility study strategies, the results are inconsistent as well. For instance, Hartwig and Dunlosky (2012) observed that use of rereading positively predicted undergraduates' GPA, but Rodriguez et al. (2021) found that rereading was unrelated to final exam scores in a biology course. Additionally, Hartwig and Dunlosky (2012) showed that endorsement of highlighting was unrelated to GPA, but McAndrew et al. (2016) detected a negative correlation between these two variables among dental students. Overall, previous findings about whether use of specific study strategies relates to academic performance are rather conflicting. Further research on this question is called for.

It is also worth noting that most (if not all) of the above-discussed studies did not control potential confounding variables when exploring the association between use of specific strategies and academic performance (e.g., Geller et al., 2018; Hartwig & Dunlosky, 2012; McAndrew et al., 2016; Morehead et al., 2016; Rodriguez et al., 2021; Tullis & Maddox, 2020). Some confounding factors may mistakenly exemplify the observed association between these two variables (Credé & Kuncel, 2008; Hartwig & Dunlosky, 2012; Walck-Shannon et al., 2021). For instance, Coleman et al. (1966) found that family socioeconomic status (SES) explained most of the differences in academic performance among the factors affecting students' achievement. Another variable that is commonly controlled for when exploring factors affecting academic performance is gender, which plays an important role in determining academic achievement (Brown & Putwain, 2022; Voyer & Voyer, 2014).

Besides academic performance, SES and gender also affect students' study habits. For instance, Callan et al. (2017) showed that SES was positively related to use of study strategies, and Ekuni et al. (2022) observed significant gender differences in study strategy usage, with female students reporting higher frequency of strategy use overall. Surprisingly, previous studies have largely overlooked the confounding effects of these crucial demographic variables (i.e., SES and gender) when exploring the association between use of specific strategies and academic performance (e.g., Geller et al., 2018; Hartwig & Dunlosky, 2012; McAndrew et al., 2016; Morehead et al., 2016; Rodriguez et al., 2021; Tullis & Maddox, 2020). Going beyond previous studies, the current study targets to measure the relatively "pure" association between use of specific study strategies and academic performance by controlling for the potential confounding effects of SES and gender.

It should also be noted that when investigating the association between use of specific strategies and academic performance, most previous studies restricted their participant samples to undergraduate students (e.g., Geller et al., 2018; Hartwig & Dunlosky, 2012; McAndrew et al., 2016; Morehead et al., 2016; Rodriguez et al., 2021; Walck-Shannon et al., 2021), with one exception which recruited middle and high school students as participants (Tullis & Maddox, 2020). It has never been explored whether use of specific strategies relates to academic performance in elementary school students. It is well-known that study habits vary substantially as a function of educational level, and students at different educational levels employ different study strategies during self-regulated learning (Tullis & Maddox, 2020; Zimmerman & Martinez-Pons, 1990). Hence, it is important to explore the association between use of specific study strategies and academic performance in elementary school children, who are at a critical stage in developing their study habits (Dignath et al., 2008; Dignath & Büttner, 2008).

Furthermore, the sample sizes (ranging from 272 to 931 participants) in previous studies were relatively small (and underpowered), which might be the reason why previous findings were inconsistent (Geller et al., 2018; Hartwig & Dunlosky, 2012; McAndrew et al., 2016; Morehead et al., 2016; Rodriguez et al., 2021; Walck-Shannon et al., 2021). These conflicting findings are of course unhelpful for practitioners. Going beyond previous studies, the current study recruited a larger sample size (i.e., 4,331 participants) to increase statistical power to reach more reliable conclusions.

Lastly, but importantly, previous research largely explored the association among Western samples in developed countries, such as United States (e.g., Geller et al., 2018; Hartwig & Dunlosky, 2012; McAndrew et al., 2016; Morehead et al., 2016; Rodriguez et al., 2021; Walck-Shannon et al., 2021). It is unknown whether previous findings can generalize to non-Western populations in developing countries, where educational outcomes are in dire need of improvement (Ekuni et al., 2022). To fill this gap, the current study explored the association between use of specific strategies and academic performance in a developing country, that is, China.

Overview of the present study

The current study aims to recruit a large sample to explore the association between use of specific strategies and academic performance in Chinese elementary school students by using a multilevel linear regression model, in which two potential confounding variables (i.e., SES and gender) are included as control variables. The main measures in this study were academic performance in two learning domains (i.e., Chinese Language Achievement and Mathematics Achievement) and use of ten specific study strategies. Among the ten strategies, two were high-utility (i.e., spaced study and testing) and another three were low-utility (i.e., highlighting/underlining, rereading and summarizing), as categorized by Dunlosky et al. (2013). Furthermore, another five popular strategies were also assessed, including note-taking (i.e., taking notes while studying), making diagrams, charts or pictures (i.e., making diagrams, charts or pictures to summarize key knowledge points or concepts while studying), making study plans (i.e., making plans and studying according to study plans), studying with friends (i.e., studying in collaboration with others and helping each other), and help-seeking (i.e., seeking help from others, such as friends, teachers and parents). Different from previous studies which measured strategy use in a binary way (i.e., asking participants to report whether or not they use a given strategy) (e.g., Hartwig & Dunlosky, 2012; Tullis & Maddox, 2020), the current study measured strategy use at a higher fine-grained level by using a continuous response scale (see below for details), which might increase statistical power to detect the relation between use of specific study strategies and academic performance (Hartwig & Dunlosky, 2012).

Overall, the research questions explored here are as follows:

RQ1 To what extent do elementary school students utilize different study strategies?

RQ2 Does use of high-utility study strategies (i.e., spaced study and self-testing) positively relate to academic performance in elementary school students after controlling for the potential confounding effects of SES and gender?

RQ3 Does use of low-utility study strategies (i.e., highlighting/underlining, rereading, summarizing) relate to academic performance in elementary school students after controlling for demographic covariates?

RQ4 Does use of other popular study strategies (i.e., note-taking, making diagrams, charts or pictures, making study plans, studying with friends, help-seeking) relate to academic performance in elementary school students after controlling for demographic covariates?

RQ5 Do SES and gender relate to academic performance in elementary school students?

Method

Participants

A total of 4,416 Chinese fourth-grade students were recruited from 7 public elementary schools in Baoding, a city in Hebei province, and 7 public elementary schools in Qinyang, a city in Henan province, China. Data from 85 students were excluded because (1) they did not answer more than 1/3 of questions in the study strategy questionnaire ($n=74$) or (2) they did not take the Chinese Language Achievement Test or the Mathematics Achievement Test ($n=11$). The missing rate was low (1.9%). The final sample consisted of 4,331 fourth-graders (48.3% female) from 14 elementary schools in northern China. Their mean age was 9.77 years old ($SD=.33$).

The protocol was approved by the Ethics Committee at the Collaborative Innovation Center of Assessment for Basic Education Quality at Beijing Normal University (File number: 2021-41). Written informed consent to participate was obtained from children's caregivers.

Procedure

All of the students independently completed the Chinese Language Achievement Test, the Mathematics Achievement Test and the questionnaires in the classroom during regular classes at school under the supervision of well-trained research assistants.

Measures

Academic performance

Academic performance in two subjects was measured using the standardized Chinese Language Achievement Test and Mathematics Achievement Test for fourth-graders. These tests were developed in accordance with the unified curriculum standards of the compulsory education system in the mainland of China. The Chinese Language Achievement Test mainly assessed language knowledge, cultural knowledge, and the ability to understand and interpret information (Dong & Lin, 2011), which reflected students' memory and reading comprehension. The Mathematics Achievement Test mainly measured knowledge of numbers and algebra, statistics and probability, and space and shapes (Dong & Lin, 2011), reflecting students' capacities in understanding, applying and transfering mathematical knowledge.

Students completed each test in class within 45 min and their test scores ranged from 0 to 100. Considering the strong correlation ($r = .67$, $p < .001$) observed between Chinese Language and Mathematical assessment scores, a composite measure of academic performance ranging from 0 to 100 was created by averaging these two scores.[1]

Study strategy survey

Based on existing studies assessing use of specific study strategies (e.g., Dirkx et al., 2019; Hartwig & Dunlosky, 2012; Karpicke et al., 2009; Kornell & Bjork, 2007; Kuhbandner & Emmerdinger, 2019; McAndrew et al., 2016; McCabe, 2018; Morehead et al., 2016; Rodriguez et al., 2021; Tullis & Maddox, 2020; Yan et al., 2014), we developed a study strategy survey according to learning and cognition characteristics of elementary school students.

Ten study strategies were artificially divided into three categories: (1) two high-utility study strategies, including spaced study (i.e., "*I space out my study sessions over multiple days/weeks instead of cramming lots of information the night before the test.*") and self-testing (i.e., "*I test myself when I study, such as retrieving what I have learned, trying to recite and write down ancient poems, or answering practice questions.*"), (2) three low-utility study strategies, including highlighting/underlining (i.e., "*I underline details or important sentences when I read.*"), rereading (i.e., "*I reread learning materials, such as textbooks and notes.*"), summarizing (i.e., "*After reading learning materials or after class, I summarize key knowledge points or concepts.*"), and (3) five other study strategies that are widely used and may be useful for elementary school students, including note-taking (i.e., "*I take notes when I study.*"), making diagrams, charts or tables (i.e., "*I make diagrams, charts or tables to summarize key knowledge points or concepts when I study.*"), making study plans (i.e., "*I make study plans in advance and study according to my plans.*"), studying with friends (i.e., "*I study with other people, such as classmates or friends, in a group, and we help each other.*"), help-seeking (i.e., "*When I encounter difficult problems, I seek help from others, such as teachers, friends and parents.*"). These items were rated on a 6-point Likert scale ranging from 1 (*totally disagree*) to 6 (*totally agree*). A higher rating score represented more frequent use of a given strategy.

[1] We thank an anonymous reviewer for suggesting us to calculate and use a composite score as a more reliable measure of academic performance.

Demographic covariates

Gender information was obtained from school records. Annual household income and parents' educational years were collected from parent surveys. A composite SES score was created by standardizing and then averaging annual household income and parents' educational years.

Statistical analyses

First, bivariate correlation analysis was performed via SPSS 22.0 to preliminarily explore the associations between use of specific strategies and academic performance. Then, given the hierarchical data structure (that is, the sample of students was nested within schools), a multilevel linear regression analysis for measuring within-subjects effects at the student level (Level 1) and between-subjects effects at the school level (Level 2) was conducted using Mplus 8.3. Specifically, to provide a more comprehensive analysis of each strategy's effect while controlling for the influence of other strategies, a two-level hierarchical multiple regression model with random intercepts and fixed slopes was implemented, where use of ten study strategies and control variables (i.e., SES and gender) were entered simultaneously to predict academic performance. Full information maximum likelihood (FIML) estimation was employed to handle missing data (Collins et al., 2001; Enders & Bandalos, 2001; Peters & Enders, 2002), which is less biased and more efficient than traditional missing data approaches.

As an additional note, we assessed multicollinearity among the independent variables (i.e., use of ten strategies, SES and gender) within the two-level hierarchical multiple regression model using Variance Inflation Factors (VIF) and Tolerance. The results indicated that VIF values for all independent variables were well below the commonly accepted threshold of 10, ranging from 1.00 to 1.68. Additionally, Tolerance values, ranging from .60 to 1.00, were all above .10, suggesting a negligible risk of multicollinearity. Given that the multiple regression model is more suited for capturing the "pure effect" of each strategy while controlling for the confounding effects of other strategies, we report results of this multiple regression model in the main text.[2] We also performed separated analyses to evaluate the relation between use of each strategy and academic performance, which showed the same result patterns as the multiple regression analysis. The detailed results of separated analyses are reported in the Online Supplementary Materials (OSM).

Results and discussion

Below we first report descriptive results. Then, the results of the two-level hierarchical multiple regression model with use of ten study strategies and control variables (i.e., SES and gender) predicting academic performance are reported sequentially. That is, we report the results in the order of high-utility study strategies, low-utility study ones, and others. Finally, the roles of SES and gender in predicting academic performance are also reported.

[2] Our gratitude goes to an anonymous reviewer for suggesting us to perform a multiple regression analysis.

Descriptive statistics

Two-tailed bivariate correlations for variables measured in this study are presented in Table 1. According to the results, 7 study strategies (i.e., spaced study, self-testing, highlighting/underlining, rereading, note-taking, studying with friends, and help-seeking) were positively correlated with academic performance, rs = .03 ~ .15, ps < .05. No other statistically significant correlations were detected.

The most to the least frequently used study strategies were as follows: help-seeking (M=5.11, SD=1.12), studying with friends (M=5.03, SD=1.22), spaced study (M=4.86, SD=1.23), rereading (M=4.77, SD=1.23), note-taking (M=4.76, SD=1.28), highlighting/underlining (M=4.72, SD=1.18), self-testing (M=4.62, SD=1.31), making study plans (M=4.43, SD=1.40), making diagrams, charts or pictures (M=4.30, SD=1.41), and summarizing (M=4.01, SD=1.45).

Relation between use of high-utility strategies and academic performance

An unconditional (or "empty") multi-level model, in which no predictors were included, showed that the school level explained 9.54% of variations of academic performance, and that the variation at the school level was statistically significant, p=.001, confirming the necessity to adopt a multilevel model to handle the nested data.

As shown in Table 2, the results of the conditional (or "full") multi-level model demonstrated that after controlling for SES, gender and other study strategies, spaced study positively predicted academic performance, β = .10 [.07, .13], SE=.02, p<.001. In other words, the present results indicate that elementary school students who frequently engage in spaced study tend to exhibit superior academic performance. However, self-testing did not predict academic achievement after controlling for SES, gender and other study strategies, β = 0 [-.05, .05], SE=.02, p=.995. In brief, even though self-testing frequency positively relates to academic performance in bivariate correlation analysis (see Table 1), this positive correlation disappears when the confounding effects of SES, gender and other study strategies are controlled for (see Table 2).

Relation between use of low-utility strategies and academic performance

Among the three low-utility study strategies, the results showed that after controlling for SES, gender and other study strategies, highlighting/underlining did not predict academic achievement, β = .01 [-.04, .06], SE=.02, p=.620. Rereading positively predicted academic achievement, β = .11 [.08, .14], SE=.02, p<.001. By contrast, summarizing negatively predicted academic achievement, β = -.05 [-.10, -.01], SE=.02, p=.026.

In a nutshell, the current findings suggest that elementary school students who frequently engage in rereading are associated with better academic performance. However, those who frequently use highlighting/underlining and summarizing strategies do not exhibit better academic achievement.

Table 1 Descriptive statistics and correlation matrix among variables

	M	*SD*	1	2	3	4	5	6	7	8	9	10
1. Academic performance	65.15	15.14	—									
2. Spaced study	4.86	1.23	.13**	—								
3. Self-testing	4.62	1.31	.04*	.40**	—							
4. Highlighting/underlining	4.72	1.18	.08**	.37**	.39**	—						
5. Rereading	4.77	1.23	.15**	.38**	.38**	.40**	—					
6. Summarizing	4.01	1.45	0	.38**	.44**	.42**	.40**	—				
7. Note-Taking	4.76	1.28	.03*	.35**	.38**	.49**	.39**	.43**	—			
8. Making diagrams	4.30	1.41	-.02	.30**	.39**	.36**	.33**	.43**	.33**	—		
9. Making study plans	4.43	1.40	-.02	.41**	.39**	.41**	.38**	.51**	.41**	.38**	—	
10. Studying with friends	5.03	1.22	.07**	.28**	.28**	.27**	.28**	.34**	.29**	.27**	.28**	—
11. Help-seeking	5.11	1.12	.12**	.24**	.23**	.23**	.27**	.20**	.26**	.19**	.22**	.28**

Note: *$p < .05$; **$p < .01$

Relation between use of other study strategies and academic performance

The results showed that after controlling for SES, gender and other study strategies, help-seeking positively predicted academic achievement, β = .10 [.05, .13], SE=.02, p<.001 (see Table 2). However, making diagrams, charts or pictures, β = -.10 [-.14, -.07], SE=.02, p<.001, and making study plans, $\beta = -.10$ [-.13, -.07], SE=.02, p<.001, negatively predicted academic achievement. Note-taking, β = -.01 [-.06, .04], SE=.03, p=.688, and studying with friends, β = .01 [-.03, .05], SE=.02, p=.590, did not statistically predict academic achievement.

In brief, the above results showed that elementary school students who are more inclined to seek help from others are associated with better academic performance. However, those who frequently make diagrams and those who frequently make study plans do not achieve better academic performance, and in some cases, even worse.

Relation between demographic covariates and academic performance

As shown in Table 2, the results of the conditional multi-level model demonstrated that when use of ten study strategies and demographic covariates were entered simultaneously, SES positively predicted academic performance, β = .20 [.17, .24], SE=.02, p<.001, with students from higher SES families demonstrating superior academic performance. Additionally, gender significantly predicted academic performance, β = .04 [.02, .07], SE=.01, p=.002, with girls outperforming boys.

General discussion

Employment of appropriate study strategies is crucial for academic success (Dunlosky et al., 2013; Hartwig & Dunlosky, 2012; Roediger, 2013). The current study is the first to investigate the association between use of specific strategies and academic performance in a large sample (i.e., 4,331 participants) of elementary school students in a developing country (i.e., China). More importantly, we controlled for the confounding effects of SES and gender when assessing the associations.

The current study documented that use of spaced study, rereading and help-seeking positively related to academic performance in elementary school children when the confounding effects of SES, gender and other strategies were controlled for. However, the results showed that use of self-testing, highlighting/underlining, note-taking and studying with friends tended not to correlate with academic performance in elementary school students. Additionally, summarizing, making diagrams and making study plans even tended to negatively relate to learning outcomes. In line with previous studies (Brown & Putwain, 2022; Coleman et al., 1966; Liu et al., 2020; Voyer & Voyer, 2014), the current study also revealed that students from higher SES families performed better on academic assessment, and that girls outperformed boys.

Consistent with prior laboratory findings (Cepeda et al., 2006; Janiszewski et al., 2003), the current study confirms that elementary school students who frequently engage in spaced study, one of the high-utility study strategies, exhibit superior academic performance. Additionally, spaced study is among the top three study strategies frequently used by elementary

Table 2 Standardized parameter estimates for the two-level regression model

	Estimate	*SE*	*Est/SE*	*p*-value	95% CI
Fixed effects					
Intercept	15.96	1.94	8.24	<.001	[12.17, 19.76]
Slope					
SES	.20	.02	10.97	<.001	[.17, .24]
Gender	.04	.01	3.11	.002	[.02, .07]
Spaced study	.10	.02	5.95	<.001	[.07, .13]
Self-testing	0	.02	-.01	.995	[-.05, .05]
Highlighting	.01	.02	.50	.620	[-.04, .06]
Rereading	.11	.02	7.25	<.001	[.08, .14]
Summarizing	-.05	.02	-2.23	.026	[-.10, -.01]
Note-Taking	-.01	.03	-.40	.688	[-.06, .04]
Making diagrams	-.10	.02	-5.42	<.001	[-.14, -.07]
Making study plans	-.10	.02	-6.62	<.001	[-.13, -.07]
Studying with friends	.01	.02	.54	.590	[-.03, .05]
Help-seeking	.10	.02	4.59	<.001	[.05, .13]
Random effects					
Level 1 (Student)	.91	.01	109.49	<.001	[.89, .93]
Level 2 (School)	1				
Deviance	30,263				

Note: (1) *$p<.05$; **$p<.01$. (2) This table displays the standardized coefficients (i.e., β) of the conditional (or "full") two-level regression model in which ten study strategies and control variables (i.e., SES and gender) were entered to predict academic performance. (3) Deviance = (-2) * loglikelihood

school children. These findings are encouraging to both researchers and practitioners (i.e., students, instructors and policy-makers). Future research should develop potential interventions to facilitate use of spaced study and to guide the generalization of this strategy in real educational settings. Furthermore, instructors can teach students about the advantages of spaced study based on scientific evidence so that more elementary students can benefit from it and, more importantly, use it consistently even at higher levels of education, such as when they become college students and have no instructors to supervise their learning all the time (Sun et al., 2022).

In line with prior studies (Geller et al., 2018; Hartwig & Dunlosky, 2012; Rodriguez et al., 2021; Walck-Shannon et al., 2021), the current study observed a positive bivariate correlation between use of self-testing and academic performance. However, it is unexpected that use of self-testing did not relate to academic performance when the confounding effects of SES, gender and other strategies were controlled for. These findings highlight the necessity to control for confounding variables when exploring the pure association between use of specific strategies and academic performance, which has been largely overlooked in previous studies (Ekuni et al., 2022; Hartwig & Dunlosky, 2012). The absence of "pure" association between usage of self-testing and academic performance is inconsistent with the lab findings that self-testing is an effective approach to improving learning outcomes (Dunlosky et al., 2013; Rowland, 2014; Yang et al., 2021), and inconsistent with survey studies conducted by Hartwig and Dunlosky (2012) and several other studies (Geller et al., 2018; Rodriguez et al., 2021; Walck-Shannon et al., 2021) which observed a positive correlation between use of self-testing and academic performance in undergraduates.

A plausible source for the inconsistent findings regarding self-testing derives from the difference in participant samples between the present study (namely, elementary school children) and previous studies (i.e., university/college students). On the one hand, any strategy, including self-testing, can be used properly or inappropriately, and the effectiveness of a given strategy is discounted if it is used in an inappropriate manner (Dunlosky et al., 2013; Hartwig & Dunlosky, 2012; Karpicke et al., 2014). For instance, given that children are often overconfident when monitoring their learning (Finn & Metcalfe, 2014; van Loon et al., 2017), they might stop self-testing prematurely or without checking the correctness of their answers (i.e., no feedback), leading to the ineffectiveness of self-testing in improving learning performance. On the other hand, children generally have poorer memory ability than adults (Cycowicz et al., 2001) and may therefore frequently suffer from retrieval failures when testing themselves, which reduces re-exposure to learning materials. Indeed, it has been shown that test-enhanced learning is more likely to be observed when retrieval attempts are successful (Jang et al., 2012; Rowland & DeLosh, 2015). Results from a meta-analysis conducted by Rowland (2014) showed no reliable testing effect when retrieval rate during the practice phase was below 50%. Hence, the association between self-testing use and academic performance in elementary school children may be obscured by retrieval failures.

Although it should be acknowledged that the aforementioned conjectures are not tested in the current study, the null relation between usage of self-testing and academic performance underscores the necessity to investigate the effectiveness of self-testing with young children in educational settings. Despite certain studies confirming the mnemonic testing effects for elementary school children (Marsh et al., 2012; Goossens et al., 2014), some researchers emphasize the importance of providing guidance and support for retrieval practices in young children. For instance, Karpicke et al. (2014) found that retrieval practice did not enhance learning of educational texts among elementary school children when they were not instructed on how to utilize this strategy. Intriguingly, when elementary school children received additional guidance and support for successful retrieval practice, they excelled in the retrieval task, resulting in a positive impact on final test performance. These findings highlight that self-testing can be an effective strategy for young children, particularly when accompanied by appropriate scaffolding. Given the substantial benefits of self-testing documented in previous studies (Dunlosky et al., 2013; Rowland, 2014; Yang et al., 2021), it is essential for future research to explore the developmental trends of the testing effect, and to investigate effective methods for scaffolding self-testing in self-regulated learning settings for elementary school children.

The current study showed that frequency of rereading, a type of low-utility strategies for adults, positively related to academic performance in elementary school children in real educational settings. A possible reason is that simple re-exposing (i.e., rereading) compensates for elementary school children's poor memory ability. In addition, a positive correlation was observed between use of help-seeking and academic performance among elementary school students. Given that children are complete beginners in learning and typically need social support more than adults (Belle, 1989), direct instructions are essential, especially if experienced teachers or parents help them solve challenging problems they are encountering. A bulk of literature has established that appropriate supports from parents, teachers and peers contribute to the all-round development of children, including academic performance (Ahmed et al., 2010), cognition (Kang et al., 2016) and well-being (Chu et al., 2010). For instance, it has been shown that parental involvement positively relates to academic attainment in elementary school students (Boonk et al., 2018; Englund et al., 2004). Therefore, it is necessary to provide adequate support for children and encourage them to seek help from others.

Discussing the magnitude and reliability of the effect sizes documented in the current study is critically important, especially given the large sample size involved here. Dent and Koenka (2016) conducted a meta-analysis to explore the relationship between academic achievement and self-regulated learning, including metacognitive processes and use of cognitive strategies among elementary and secondary school students. Their results showed weak-to-medium correlations, with $r=.20$ for metacognitive processes and $r=.11$ for cognitive strategies. Notably, these effect sizes demonstrated a comparable magnitude of the corrections observed here (e.g., spaced study: $\beta = .10$, rereading: $\beta = .11$, and help-seeking: $\beta = .10$). Considering that the present results were obtained from real educational settings, rather than from laboratory settings in which all other irrelevant variables are strictly controlled for, it is plausible to infer that the effect sizes observed in this study are practically meaningful.

Intriguingly, the current study found that use of summarizing, making diagrams and making study plans negatively related to elementary school children's academic performance. A possible explanation for these counterintuitive results is that children use these strategies inappropriately and excessively, thereby hindering rather than enhancing learning. Taking summarizing as an example, it can be effective for students who are skilled at summarizing, but it is less feasible for other learners who lack knowledge about how to make a knowledge summary, such as children (for a review, see Dunlosky et al., 2013). Similarly, children may not be good at planning and have trouble carrying out learning activities as planned due to poor action execution (Anderson, 2002), so frequently making study plans does not improve their learning performance. Furthermore, when students spend more time using relatively ineffective strategies (e.g., summarizing) rather than effective ones (e.g., spaced study), it is possible that too much time is wasted in inefficient learning, which then impairs their academic achievement. Future research is encouraged to further investigate the robustness and underlying mechanisms of these findings.

A limitation of the current study lies in whether elementary school students' self-reported use of study strategies can unbiasedly reflect the strategies they actually use in their daily learning. It is plausible that elementary school students may simply be unable to accurately remember the strategies they actually use in daily learning. Additionally, it should be acknowledged that self-report results always suffer from response bias, such as bias induced by socially desirable responses, commonly observed in survey studies (Furnham, 1986). By comparison with self-reports, a more suitable approach to measure students' strategy usage is to directly observe their daily study activities. Another limitation of the current study is that the observed relational results cannot be used to infer the causal relationship between use of specific study strategies and academic performance. In other words, it is challenging to ascertain whether use of specific study strategies directly influences students' academic performance or whether students are more likely to use specific study strategies because they possess higher levels of academic achievement. Future research is recommended to explore the bidirectional relation between use of specific study strategies and academic performance through conducting longitudinal research and performing cross-lagged analysis.

Overall, the current study contributes to the literature on use of specific strategies and academic performance by controlling for SES and gender in a large sample of Chinese elementary students. While the current study did not find a reliable relationship between self-testing and academic performance, it did detect a positive correlation between use of many other strategies (e.g., spaced study, rereading and help-seeking) and academic achievement in elementary school students. These results have important practical implications. Instructors and parents should encourage children to study by using these effective study strategies, and teach them how to maximize the benefits of these strategies. Future research should explore why usage of some other strategies (e.g., self-testing) does not relate to academic performance in elementary school students.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11409-024-09377-y.

Funding This study was funded by the Natural Science Foundation of China (32171045; 32000742; 32371116; 32200841), the Fundamental Research Funds for the Central Universities (1233200008), the Tang Scholar Foundation, the Research Program Funds of the Collaborative Innovation Center of Assessment for Basic Education Quality at Beijing Normal University (2022-01-132-BZK01), and the China Postdoctoral Science Foundation (2023M740300).

Data availability The data presented in this study are available from the corresponding authors upon request at Liang Luo (luoliang@bnu.edu.cn) or Chunliang Yang (chunliang.yang@bnu.edu.cn).

Declarations

Ethical approval Ethical approval was obtained from the Institutional Review Board of the Collaborative Innovation Center of Assessment for Basic Education Quality at Beijing Normal University (File number: 2021-41).

Consent to participant Written informed consent to participate was obtained from children's caregivers.

Consent for publication All authors agreed with the content and gave explicit consent to publish this study.

Conflict of interest The authors declare that they have no conflict of interest.

References

Ahmed, W., Minnaert, A., van der Werf, G., & Kuyper, H. (2010). Perceived social support and early adolescents' achievement: The mediational roles of motivational beliefs and emotions. *Journal of Youth and Adolescence*, *39*(1), 36–46. https://doi.org/10.1007/s10964-008-9367-7.

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology*, *8*(2), 71–82. https://doi.org/10.1076/chin.8.2.71.8724.

Anthenien, A. M., DeLozier, S. J., Neighbors, C., & Rhodes, M. G. (2018). College student normative misperceptions of peer study habit use. *Social Psychology of Education*, *21*. https://doi.org/10.1007/s11218-017-9412-z

Belle, D. (1989). *Children's social networks and social supports* (Vol. 136). Wiley.

Boonk, L., Gijselaers, H. J., Ritzen, H., & Brand-Gruwel, S. (2018). A review of the relationship between parental involvement indicators and academic achievement. *Educational Research Review*, *24*, 10–30. https://doi.org/10.1016/j.edurev.2018.02.001.

Brown, C., & Putwain, D. W. (2022). Socio-economic status, gender and achievement: The mediating role of expectancy and subjective task value. *Educational Psychology*, *42*(6), 730–748. https://doi.org/10.1080/01443410.2021.1985083.

Callan, G. L., Marchant, G. J., Finch, W. H., & Flegge, L. (2017). Student and school SES, gender, strategy use, and achievement. *Psychology in the Schools*, *54*(9), 1106–1122. https://doi.org/10.1002/pits.22049.

Cepeda, N. J., Pashler, H., Vul, E., Wixted, J. T., & Rohrer, D. (2006). Distributed practice in verbal recall tasks: A review and quantitative synthesis. *Psychological Bulletin*, *132*(3), 354–380. https://doi.org/10.1037/0033-2909.132.3.354.

Chu, P. S., Saucier, D. A., & Hafner, E. (2010). Meta-analysis of the relationships between social support and well-being in children and adolescents. *Journal of Social and Clinical Psychology*, *29*(6), 624–645. https://doi.org/10.1521/jscp.2010.29.6.624.

Coleman, J. S., Campbell, E. Q., Hobson, C. J., McPartland, J., Mood, A. M., Weinfeld, F. D., & York, R. L. (1966). *Equality of educational opportunity*. Government Printing Office.

Collins, L. M., Schafer, J. L., & Kam, C. M. (2001). A comparison of inclusive and restrictive strategies in modern missing data procedures. *Psychological Methods*, *6*(4), 330–351. https://doi.org/10.1037/1082-989X.6.4.330.

Credé, M., & Kuncel, N. R. (2008). Study habits, skills, and attitudes: The third pillar supporting collegiate academic performance. *Perspectives on Psychological Science*, *3*(6), 425–453. https://doi.org/10.1111/j.1745-6924.2008.00089.x.

Cycowicz, Y. M., Friedman, D., Snodgrass, J. G., & Duff, M. (2001). Recognition and source memory for pictures in children and adults. *Neuropsychologia*, *39*(3), 255–267. https://doi.org/10.1016/S0028-3932(00)00108-1.

Dent, A. L., & Koenka, A. C. (2016). The relation between self-regulated learning and academic achievement across childhood and adolescence: A meta-analysis. *Educational Psychology Review*, *28*, 425–474. https://doi.org/10.1007/s10648-015-9320-8.

Dignath, C., & Büttner, G. (2008). Components of fostering self-regulated learning among students. A meta-analysis on intervention studies at primary and secondary school level. *Metacognition and Learning*, *3*(3), 231–264. https://doi.org/10.1007/s11409-008-9029-x.

Dignath, C., Buettner, G., & Langfeldt, H. P. (2008). How can primary school students learn self-regulated learning strategies most effectively? A meta-analysis on self-regulation training programmes. *Educational Research Review*, *3*(2), 101–129. https://doi.org/10.1016/j.edurev.2008.02.003.

Dirkx, K. J. H., Camp, G., Kester, L., & Kirschner, P. A. (2019). Do secondary school students make use of effective study strategies when they study on their own? *Applied Cognitive Psychology*, *33*(5), 952–957. https://doi.org/10.1002/acp.358.

Dong, Q., & Lin, C. (2011). *National Children's Study of China (NCSC) technical report (in Chinese)*. Science Press.

Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychological Science in the Public Interest*, *14*(1), 4–58. https://doi.org/10.1177/1529100612453266.

Ekuni, R., de Souza, B. M. N., Agarwal, P. K., & Pompeia, S. (2022). A conceptual replication of survey research on study strategies in a diverse, non-WEIRD student population. *Scholarship of Teaching and Learning in Psychology*, *8*(1), 1–14. https://doi.org/10.1037/stl0000191.

Enders, C. K., & Bandalos, D. L. (2001). The relative performance of full information maximum likelihood estimation for missing data in structural equation models. *Structural Equation Modeling*, *8*(3), 430–457. https://doi.org/10.1207/S15328007SEM0803_5.

Englund, M. M., Luckner, A. E., Whaley, G. J., & Egeland, B. (2004). Children's achievement in early elementary school: Longitudinal effects of parental involvement, expectations, and quality of assistance. *Journal of Educational Psychology*, *96*(4), 723–730. https://doi.org/10.1037/0022-0663.96.4.723.

Finn, B., & Metcalfe, J. (2014). Overconfidence in children's multi-trial judgments of learning. *Learning and Instruction*, *32*, 1–9. https://doi.org/10.1016/j.learninstruc.2014.01.001.

Furnham, A. (1986). Response bias, social desirability and dissimulation. *Personality and Individual Differences*, *7*(3), 385–400. https://doi.org/10.1016/0191-8869(86)90014-0.

Geller, J., Toftness, A. R., Armstrong, P. I., Carpenter, S. K., Manz, C. L., Coffman, C. R., & Lamm, M. H. (2018). Study strategies and beliefs about learning as a function of academic achievement and achievement goals. *Memory*, *26*(5), 683–690. https://doi.org/10.1080/09658211.2017.1397175

Goossens, N. A., Camp, G., Verkoeijen, P. P., & Tabbers, H. K. (2014). The effect of retrieval practice in primary school vocabulary learning. *Applied Cognitive Psychology*, *28*(1), 135–142. https://doi.org/10.1002/acp.2956.

Hartwig, M. K., & Dunlosky, J. (2012). Study strategies of college students: Are self-testing and scheduling related to achievement? *Psychonomic Bulletin & Review*, *19*(1), 126–134. https://doi.org/10.3758/s13423-011-0181-y.

Jang, Y., Wixted, J. T., Pecher, D., Zeelenberg, R., & Huber, D. E. (2012). Decomposing the interaction between retention interval and study/test practice: The role of retrievability. *Quarterly Journal of Experimental Psychology*, *65*(5), 962–975. https://doi.org/10.1080/17470218.2011.638079.

Janiszewski, C., Noel, H., & Sawyer, A. G. (2003). A meta-analysis of the spacing effect in verbal learning: Implications for research on advertising repetition and consumer memory. *Journal of Consumer Research*, *30*(1), 138–149. https://doi.org/10.1086/374692.

Kang, D. H., Boss, L., & Clowtis, L. (2016). Social support and cognition: Early childhood versus older adulthood. *Western Journal of Nursing Research*, *38*(12), 1639–1659. https://doi.org/10.1177/0193945916655796.

Karpicke, J. D., Butler, A. C., & Roediger, I. I. I., H. L (2009). Metacognitive strategies in student learning: Do students practise retrieval when they study on their own? *Memory*, *17*(4), 471–479. https://doi.org/10.1080/09658210802647009

Karpicke, J. D., Blunt, J. R., Smith, M. A., & Karpicke, S. S. (2014). Retrieval-based learning: The need for guided retrieval in elementary school children. *Journal of Applied Research in Memory and Cognition*, *3*(3), 198–206. https://doi.org/10.1016/j.jarmac.2014.07.008.

Kornell, N., & Bjork, R. A. (2007). The promise and perils of self-regulated study. *Psychonomic Bulletin & Review*, *14*(2), 219–224. https://doi.org/10.3758/BF03194055.

Kuhbandner, C., & Emmerdinger, K. J. (2019). Do students really prefer repeated rereading over testing when studying textbooks? A reexamination. *Memory*, *27*(7), 952–961. https://doi.org/10.1080/09658211.2019.1610177

Liu, J., Peng, P., & Luo, L. (2020). The relation between family socioeconomic status and academic achievement in China: A meta-analysis. *Educational Psychology Review*, *32*(1), 49–76. https://doi.org/10.1007/s10648-019-09494-0.

Marsh, E. J., Fazio, L. K., & Goswick, A. E. (2012). Memorial consequences of testing school-aged children. *Memory*, *20*(8), 899–906. https://doi.org/10.1080/09658211.2012.708757

McAndrew, M., Morrow, C. S., Atiyeh, L., & Pierre, G. C. (2016). Dental student study strategies: Are self-testing and scheduling related to academic performance? *Journal of Dental Education*, *80*(5), 542–552. https://doi.org/10.1002/j.0022-0337.2016.80.5.tb06114.x.

McCabe, J. A. (2018). What learning strategies do academic support centers recommend to undergraduates? *Journal of Applied Research in Memory and Cognition*, *7*(1), 143–153. https://doi.org/10.1016/j.jarmac.2017.10.002.

Morehead, K., Rhodes, M. G., & DeLozier, S. (2016). Instructor and student knowledge of study strategies. *Memory*, *24*(2), 257–271. https://doi.org/10.1080/09658211.2014.1001992

Peters, C. L. O., & Enders, C. (2002). A primer for the estimation of structural equation models in the presence of missing data: Maximum likelihood algorithms. *Journal of Targeting Measurement and Analysis for Marketing*, *11*(1), 81–95. https://doi.org/10.1057/palgrave.jt.5740069.

Rodriguez, F., Kataoka, S., Janet Rivas, M., Kadandale, P., Nili, A., & Warschauer, M. (2021). Do spacing and self-testing predict learning outcomes? *Active Learning in Higher Education*, *22*(1), 77–91. https://doi.org/10.1177/1469787418774185.

Roediger, H. L. (2013). Applying cognitive psychology to education: Translational educational science. *Psychological Science in the Public Interest*, *14*(1), 1–3. https://doi.org/10.1177/1529100612454415.

Roediger, I., Henry, L., & Karpicke, J. D. (2006). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science*, *17*(3), 249–255. https://doi.org/10.1111/j.1467-9280.2006.01693.x.

Rowland, C. A. (2014). The effect of testing versus restudy on retention: A meta-analytic review of the testing effect. *Psychological Bulletin*, *140*(6), 1432–1463. https://doi.org/10.1037/a0037559

Rowland, C. A., & DeLosh, E. L. (2015). Mnemonic benefits of retrieval practice at short retention intervals. *Memory*, *23*(3), 403–419. https://doi.org/10.1080/09658211.2014.889710.

Sun, Y., Shi, A., Zhao, W., Yang, Y., Li, B., Hu, X., & Luo, L. (2022). Long-lasting effects of an instructional intervention on interleaving preference in inductive learning and transfer. *Educational Psychology Review*, *34*(3), 1679–1707. https://doi.org/10.1007/s10648-022-09666-5.

Tullis, J. G., & Maddox, G. B. (2020). Self-reported use of retrieval practice varies across age and domain. *Metacognition and Learning*, *15*(2), 129–154. https://doi.org/10.1007/s11409-020-09223-x.

van Loon, M., de Bruin, A., Leppink, J., & Roebers, C. (2017). Why are children overconfident? Developmental differences in the implementation of accessibility cues when judging concept learning. *Journal of Experimental Child Psychology*, *158*, 77–94. https://doi.org/10.1016/j.jecp.2017.01.008.

Voyer, D., & Voyer, S. D. (2014). Gender differences in scholastic achievement: A meta-analysis. *Psychological Bulletin*, *140*(4), 1174–1204. https://doi.org/10.1037/a0036620.

Walck-Shannon, E. M., Rowell, S. F., & Frey, R. F. (2021). To what extent do study habits relate to performance? *CBE—Life Sciences Education*, *20*(1), ar6. https://doi.org/10.1187/cbe.20-05-0091.

Yan, V. X., Thai, K. P., & Bjork, R. A. (2014). Habits and beliefs that guide self-regulated learning: Do they vary with mindset? *Journal of Applied Research in Memory and Cognition*, *3*(3), 140–152. https://doi.org/10.1016/j.jarmac.2014.04.003.

Yang, C., Potts, R., & Shanks, D. R. (2018). Enhancing learning and retrieval of new information: A review of the forward testing effect. *NPJ Science of Learning*, *3*(1), 8. https://doi.org/10.1038/s41539-018-0024-y

Yang, C., Luo, L., Vadillo, M. A., Yu, R., & Shanks, D. R. (2021). Testing (quizzing) boosts classroom learning: A systematic and meta-analytic review. *Psychological Bulletin*, *147*(4), 399–435. https://doi.org/10.1037/bul0000309.

Zimmerman, B. J., & Martinez-Pons, M. (1990). Student differences in self-regulated learning: Relating grade, sex, and giftedness to self-efficacy and strategy use. *Journal of Educational Psychology*, *82*(1), 51–59. https://doi.org/10.1037/0022-0663.82.1.51.

Authors and Affiliations

Yue Yin[1] · Tian Fan[1] · Wenbo Zhao[2] · Jun Zheng[3] · Xiao Hu[4] · Ningxin Su[1] · Chunliang Yang[4,5] · Liang Luo[5,6]

✉ Chunliang Yang
chunliang.yang@bnu.edu.cn

✉ Liang Luo
luoliang@bnu.edu.cn

1 Collaborative Innovation Center of Assessment for Basic Education Quality, Beijing Normal University, Beijing, China

2 School of Social Development and Public Policy, Beijing Normal University, Beijing, China

3 Center for Teacher Education Research, Faculty of Education, Beijing Normal University, Beijing, China

4 Beijing Key Laboratory of Applied Experimental Psychology, National Demonstration Center for Experimental Psychology Education, Faculty of Psychology, Beijing Normal University, Beijing, China

5 Institute of Developmental Psychology, Faculty of Psychology, Beijing Normal University, Beijing 100875, China

6 State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing 100875, China