Proceedings of the 5th International Conference on Education Innovation and Philosophical Inquiries
DOI: 10.54254/2753-7048/58/20241796

The Effects of Self-regulated Learning Interventions on Primary and Secondary Students Reading Performance: A Meta-analysis

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Abstract: This meta-analysis examines the effects of self-regulated learning (SRL) interventions on reading performance among primary and secondary students from 2001 to 2021. Analyzing 22 studies with 28 effect sizes and involving 2735 participants, the findings indicate that SRL interventions have a moderate positive effect on reading performance (Hedges' g = 0.48). Metacognitive strategies, especially monitoring interventions, were found to be particularly effective. The study highlights significant regional variations, with Western regions showing lower effect sizes compared to regions like Taiwan, Indonesia, Turkey, and Israel. Additionally, the study explored various SRL sub-strategies and found that monitoring, planning, and evaluation were the most beneficial for reading performance, while motivational and cognitive strategies had lesser impacts. The results underscore the importance of tailored metacognitive interventions in improving reading outcomes and provide valuable insights for future research on SRL strategies. Despite potential publication bias, the study confirms the overall effectiveness of SRL interventions in enhancing students' reading performance, offering a comprehensive understanding of their impact across different contexts.

Keywords: reading performance, meta-analysis, metacognitive strategies, monitoring intervention, motivational strategy.

1. Introduction and Literature Review

The factors affecting academic achievement have been highly valued by scholars [1] and [2]. Academic achievement can include a large number of disciplines, subject to research time constraints, this article only explores one of the academic achievements - reading performance. Self-regulating learning is also a topic widely discussed in education [3] and [4]. Assuming that SRL interventions effectively improve students' reading performance: SRL interventions improve students' ability to deal with difficult parts of learning tasks, which can be reflected in improved reading performance. However, there are more empirical studies on the impact of SRL intervention on achievement, and there is a lack of research to understand the problem from a macro perspective [5] and [6]. Therefore, the first goal of this article is to use meta-analysis data for summary analysis to test whether SRL intervention positively impacts students' reading performance. Furthermore, it is assumed that

DOI: 10.54254/2753-7048/58/20241796

specific strategies for SRL intervention will improve students' reading performance. It is not yet known which SRL intervention is most effective in improving student reading performance. Therefore, the second goal of this article is to test which specific SRL interventions are effective. To this end, a further meta-analysis of the impact of SRL interventions on achievement is carried out. The final goal is to explore whether other research factors affect the effectiveness of SRL interventions.

Researchers have proven the effectiveness of self-regulated learning on student performance. The student's academic performance can be reflected in the examination results or tests of different subjects, but this article mainly focuses on the student's reading performance. Reading is defined as a pleasant way to obtain information. Readers need to focus on the reading material and combine existing knowledge to understand the message the author wants to convey.

In addition, the similar research methods and research variables, [7] conducted a meta-analysis of the relationship between reading performance and metacognitive intervention, which examined the effects reported by 43 studies published between 1979 and 199. In the study of the effect of Cohens'd = 0.40 (SE = 0.04), the data show that metacognition on students' reading comprehension performance has a moderate effect, and explores students in different grades, different lengths of intervention, and the intensity of intervention on the effect of intervention differences. Neither of these methods explores the effect of different learning strategies on students' reading performance.

2. Methodology

2.1. Literature search

First, this study used PsycINFO and ERIC databases to conduct a systematic electronic search to determine an intervention study on the impact of self-regulated learning on the reading comprehension of students and excluded research conducted in preschool education. Keywords are set in a wider range to avoid missing relevant literature. The terms related to self-regulated learning is self-reg*, based on the research of [8], the key words also include the following: metacognitive* or manage* or motiv* or monit* or self-efficacy or planning or evaluation or motivation or cogni* or peer or environment or reading strategies or reading comprehension or read or reading achievement or reading outcome or reading performance or peer-reviewed or reading comprehension. A limited period was chosen from January 2001 to June 2021. The study decided to start in 2001 because a few researchers began to conduct a meta-analysis of the effects of learning strategies on student reading performance. This search resulted in 1045 from PsycInfo and 1567 from ERIC. The collected article titles and abstracts can be reduced according to predefined inclusion and exclusion criteria, which can be found in the next paragraph.

2.2. Eligibility criteria

The inclusion criteria used were that: (a) the study was published in English; (b) the study had been peer-reviewed; (c) the study included empirical results of one of the self-regulated learning interventions concerning learning outcomes; (d) Studies were conducted between 2021-2001; (e) The researches exclude the content related to the treatment of preschool children [9].

A few criteria were not presented by keywords, such as English and education levels. Studies that were frequently excluded focused on non-reading subjects or non-reading performance. Other common reasons for the exclusion of standing were educational levels involving higher education, early childhood education and qualitative studies. The criteria for further excluded papers were whether the statistical information provided in the papers could calculate the effect size.

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2.3. Coding

To review the collected research systematically, we coded multiple characteristics of the intervention: the type of intervention, the duration (in weeks), the characteristics of the students in the sample and the grade of students, the region where the institute is located, the year of publication, effect size and the number of participants. Below, it was described the coding of intervention types and student characteristics.

SRL intervention is first divided into four broad categories: metacognitive intervention, cognitive intervention, management intervention and motivative intervention. For four types of interventions, these interventions were coded whether it was (1) was not (0) included in these interventions. As long as the data mentions any point sub-strategies intervention from four types of intervention, it will be marked as (1). For example, students were asked to plan the time and amount of tasks to complete before the reading task, an intervention that was coded 1 in metacognitive intervention. Interventions have the following treatments: (a) focused on changing student reading behavioural methods, (b) focused on the impact of intervening SRL strategies in reading on student performance, (c) focused on improving students' strategies for reading grades, (d) focusing on other methods, and (e) including a lot the T-test method. When coding the type of intervention, it was followed the first part of the classification of SRL intervention. For detailed classification information, please refer to Chapter 1.

In addition, to explore which sub-strategy intervention has a better effect on students' reading performance, the sub-strategy intervention was coded. Sub-strategies interventions included monitoring, planning, evaluation, elaboration, organization, rehearsal, efforts, peers, environment, and self-efficacy. When researchers or teachers specifically interfered with students' reading behaviour, the proposed intervention methods were included in these ten sub-strategies interventions. The sub-strategy intervention mentioned was marked as (1), whereas that not mentioned was marked as (0).

This study collected data across different regions. The geographical span between regions is large and the cultural differences are large. Regions are classified into two broad categories based on a combination of factors. The first category was coded as (1) including USA, UK, Australia, Germany, and Belgium, represented by the United States because of 13 studies from the USA. The second category for other regions is coded as (0) including Taiwan, Indonesia, Turkey, and Israel. There are relatively different cultural and economic backgrounds between other regions and the first category.

This study included primary students, secondary students, and different types of students. The education level of students was easily shown through their grades from 3 to 12. This study has not excluded students with special needs, so the characteristics of student types should differentiate. The type of students was divided into two categories. The first is a sample of the general students who represent the student population in the country, which was coded as (1). The second category of students includes special needs students in several different aspects, which was coded as (0). Students come from low socioeconomic status families. Students themselves have learning disabilities such as dyslexia and attention-deficit hyperactivity disorder (ADHD).

2.4. Effect size extraction

Effect size extraction is an essential component of the outcome of empirical studies and collecting data. The effect sizes were collected to measure the strength of the relations between SRL intervention and reading performance. There are many ways to measure the effect size, and it was often seen in Hedges' g and Cohen's d in the meta-analysis. This study uses Hedges' g because a smaller sample was collected more than a large sample.

There are several ways to collect Hedges'g but three methods were adopted to calculate the effect size in this study. First of all, the easiest way is that the paper has presented the effect size of Hedges'g,

DOI: 10.54254/2753-7048/58/20241796

which is rare. A more common way was to calculate Hedges'g by formula [10] that was used to caliphate the edge of the s g: g=$\sqrt{[(n1+n2-2/n1+n2)d]}$.

The meaning of d is Cohens'd that was calculated by following formula: Cohens'd: d=(M2-M1)/$\sqrt{(SD12+SD22)/2}$.

According to the formula, in order to work out Hedges' g, it was needed to find the mean, standard deviation and sample size of sample 1 and sample 2 in papers. If the original study reported only the population sample size but did not provide a clear division of the treatment group, the total sample size was divided equally with the number of groups contained in the study. The last way is to convert the different measures of the effect size (eg. a correlation coefficient) to Hedges'g.

Some studies had multiple effect sizes, such as the effect size of reading comprehension and the SRL effect size. However, this paper only considered the variables related to its topic, namely reading performance results variables. These results are often evaluated using multiple tests. These evaluations resulted in numerous effect sizes in research (for example, [11] reflected four effect sizes for kids' reading ability in their meta-analysis). By calculating, these impact sizes are averaged to get a typical effect size for each research.

2.5. Meta-analysis

Valid samples extracted from relevant literature were imported into Excel for organizing data first. Although the study has changed the effect size measurement used, for this analysis, all effects are converted to Hedges' g, which is easy to explain and has good statistical properties. This study used the software Stata for meta-analysis, after collecting and coding data.

3. Results

3.1. Descriptive and effect of SRL intervention in general

A total of 22 articles in terms of the correlations between reading performance and self-regulated learning strategies met our screening criteria, which coded 28 effect sizes and involved 2735 participants. The SRL interventions (e.g., cognitive and management) are generated in the context of reading. Table 1 summarizes some of the characteristics of all included studies. Among the 28 interventions on student reading performance, 20 focused on reading comprehension, 5 focused on vocabulary, 4 focused on grammar, and 3 focused on other subjects. The SRL of intervention is divided into four categories of strategies: metacognitive strategies, cognitive strategies, motivation and management strategies, these strategies are further divided into more specific sub-strategies, and these sub-strategies are respectively coded with data. Planning and monitoring in the metacognitive strategy is the most frequent intervention strategy, which has appeared 25 times in total. Secondly, elaboration in cognitive strategies is also a very common intervention strategy, which has appeared 16 times in total. The organization in Management strategies has appeared 8 times, followed by the peer appeared six times, and effort has only appeared twice. The least visible strategy is motivation. The most of research tests (16) were standardized tests such as published tests or general measurements, and 9 tests were self-developed. A pre-test-post-test control group method is used in the research design of most articles. Methods to assess students' reading performance include self-developed and independent tests. A total of 16 studies used the independent test, so it is the main test method. Table 1 shows the characteristics of the data.

DOI: 10.54254/2753-7048/58/20241796

Table 1: Key characteristics of the studies included in the meta-analysis

ID	Authors	Pub. Year	n	Region	student characteristics	Duration (weeks)	Type instrument	Effect size
1	Muhid, A	2020	50	Indonesia	general	8.5	self-developed	1.285
2	Lubliner and Smetana	2005	77	USA	special	5	self-developed	0.6
3	Erkan Çer	2016	65	Turkey	general	8	self-developed	3.064
4	Lisa R. Hoyt Chair	2011	10	Washington	Special	10	Independent	1.762
5	Mei mei Chang	2010	90	Taiwan	general	16	self-developed	0.36
6	The fund, Z.	2007	473	Israel	general	26	self-developed	0.51
7	O. Pesout, J. Nietfeld	2021	84	USA	general	6	self-developed	-0.023
8	McCarthy, Kathryn S.	2017	234	USA	general	3	self-developed	0.201
9	Mason	2004	32	USA	special	9	self-developed	0.94
10	McCarthy, Kathryn S.	2018	234	USA	general	3	self-developed	0.177
11	Yea-Ru Tsai	2014	114	Taiwan	general	18	self-developed	0.797
12	Allen and Hancock	2008	112	USA	special	16	self-developed	0.64
13	Boulware-Gooden et al.	2007	112	USA	regular	5	Independent	0.5
14	Bruce	2001	46	Australia	special	28	Independent	0.37
15	Cantrell, Almasi, and Carter	2010	47	USA	special	34	Independent	0.25
16	Cantrell, Almasi, and Carter	2010	47	USA	Special	34	Independent	0.09
17	Guterman	2003	109	USA	special	13	self-developed	0.83
18	Huff and Nietfeld	2009	73	USA	regular	2	Independent	0.42
19	Kaniel,Licht, and Peled	2000	79	Israel	Special.	5	Independent	0.66
20	E. Souvignier, J. Mokhlesgerami	2006	65	Germany	regular	8	Independent	0.24

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Table 1: (continued)

21	E. Souvignier, J. Mokhlesgerami	2006	65	Germany	regular	8	Independent	0.427
22	E. Souvignier, J. Mokhlesgerami	2006	43	Germany	regular	8	Independent	0.52
23	E. Souvignier, J. Mokhlesgerami	2006	40	Germany	regular	8	Independent	-0.034
24	E. Souvignier, J. Mokhlesgerami	2006	198	Germany	regular	8	Independent	0.00
25	Van Keer and Vanderlinde	2010	59	Belgium	regular	13	Independent	0.05
26	Van Keer and Vanderlinde	2010	59	Belgium	regular	13	Independent	0.03
27	S. Vaughn, J. Klinger, and Swanson	2011	59	USA	regular	18	Independent	0.06
28	Wright and Jacobs	2010	59	UK	special	26	Independent	0.68

This is the effect of SRL intervention on reading performance, aimed at students with different characteristics. Table 2 presents a forest plot that visually summarizes the effect sizes (Hedges' g) of self-regulated learning (SRL) interventions on reading performance across different studies. The average mean of effect size and weighted effect size is Hedges' g= 0.53 and Hedges' g=0.47 (with a confidence interval from 0.25 to 0.74), which means it was a moderate and significant effect. This data shows that the overall intervention is effective. Answered the first question of this study, is SRL intervention effective for students' reading performance?

Each square represents the effect size of an individual study, with the size of the square indicating the weight of the study in the meta-analysis, and the horizontal lines representing the 95% confidence intervals (CI) for the effect sizes. The diamond shape at the bottom represents the overall effect size, combining individual effect sizes using a random-effects model, with the diamond's width indicating the confidence interval for the combined effect size. The plot includes 28 studies with varying effect sizes; some show substantial positive effects (e.g., Study 3 with an effect size of 3.06), while others have smaller or negative effects (e.g., Study 7 with an effect size of -0.02). The statistics at the bottom indicate significant heterogeneity among the studies ($I^2 = 99.77\%$, $\tau^2 = 0.33$, $Q(27) = 204.23$, $p = 0.00$), suggesting variability in the effectiveness of SRL interventions. Many studies have confidence intervals that cross the zero line, indicating non-significant results. However, the overall effect size (0.48 [0.25, 0.71]) is positive and significant, suggesting a moderate beneficial effect of SRL interventions on reading performance. The percentages on the right indicate each study's contribution to the overall effect size, with larger and more precise studies contributing more. In summary, the forest plot indicates that SRL interventions generally have a positive impact on reading performance, with an overall moderate effect size, but the significant heterogeneity suggests variability in effectiveness depending on specific study factors.

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Table 2: Forest plot for reading performance research.

Study	Effect Size (with 95% CI)	Weight (%)
Study 1	1.28 (0.67, 1.90)	3.26
Study 2	0.60 (0.05, 1.16)	3.41
Study 3	3.06 (2.37, 3.76)	3.06
Study 4	1.76 (0.04, 3.48)	1.27
Study 5	0.36 (-0.05, 0.77)	3.73
Study 6	0.51 (0.18, 0.84)	3.91
Study 7	-0.02 (-0.55, 0.50)	3.48
Study 8	0.20 (-0.06, 0.46)	4.03
Study 9	0.94 (0.04, 1.84)	2.59
Study 10	0.18 (-0.08, 0.43)	4.03
Study 11	0.80 (0.42, 1.18)	3.81
Study 12	0.64 (-0.43, 1.71)	2.22
Study 13	0.50 (0.06, 0.94)	3.67
Study 14	0.37 (-0.06, 0.80)	3.69
Study 15	0.25 (0.04, 0.46)	4.1
Study 16	0.09 (0.05, 0.14)	4.23
Study 17	0.83 (0.55, 1.11)	4.00
Study 18	0.43 (-0.15, 1.00)	3.35
Study 19	0.66 (-0.08, 1.40)	2.95
Study 20	0.24 (-0.05, 0.53)	3.97
Study 21	0.13 (0.03, 0.72)	3.97
Study 22	0.52 (0.23, 0.81)	3.97
Study 23	-0.03 (-0.33, 0.26)	3.97
Study 24	0.00 (-0.29, 0.29)	3.97
Study 25	0.05 (0.05, 0.05)	4.24
Study 26	0.03 (0.01, 0.05)	4.24
Study 27	0.03 (-0.48, 0.54)	3.51
Study 28	0.68 (0.11, 1.25)	3.38

3.2. Effects of self-regulated learning on reading performance

We first provide the effect size of the results about the effects of the strategies interventions on student reading achievement in a regression model, then we present all effect sizes found in the studies, as displayed in forest plots. therefore, it also created sub-groups with different intervention strategies which were compared with each other. Even within these sub-strategies, there was wide variation in terms of the effect of the intervention.

First, Table 3 presents the results of the four major types of learning strategies. The results show coefficients from different learning strategies interventions. metacognitive knowledge significantly improved student performance. The coefficient of metacognitive is 0.50 higher than that of other strategies. Metacognitive intervention compared with others shows positive effects, which means that metacognitive intervention has the largest positive influence on interventions effectiveness of the intervention. In contrast, the analyses also indicate negative effects of the inclusion of cognitive (-0.25), motivational (-0.02), and management intervention (-0.02), which strategies have a negative influence on the effectiveness of the intervention. However, negative effects do not mean that the last three intervention strategies have negative influences on student reading performance and

DOI: 10.54254/2753-7048/58/20241796

metacognitive intervention has a positive effect on reading performance, yet these influences are significantly lower than other strategies.

Table 3: The Effect of four sub-group strategies intervention on reading performance: mean effect size and regression results.

	Effect size	B	SE
metacognitive	0.496**	0.470588	0.508512
cognitive	0.296**	0.1455514	-0.2535478
management	0.317*	0.08543	-0.0274617
motivation	0.38*	0.1118443	0.0120027

In the next step, in order to figure out the second research question (which sub-strategy is more effective for students' reading performance), a regression analysis of sub-strategies was run. Table 4 presents the results of this regression. Specifically, evaluation improved students' reading performance because the regression coefficient of monitoring is 0.206 (Hedges' g = 0.648) relatively higher than the rest of the sub-strategies. Second, the interventions based on evaluation had a positive influence on effectiveness, which of coefficients is 0.194. It was noted that its mean effect size is not significant. Similarly, planning showed significant positive effects. Interventions based on the sub-strategies effort and environment management showed slightly better outcomes, but their impact was not significant when compared to other interventions. Because these results are based on a limited number of treatments, they should be taken with care. However, the half of sub-strategies had lower levels of effectiveness. Sub-strategies focused on monitoring, planning, evaluation and effort are beneficial, whereas the inclusion of rehearsal, peer, organization and monitoring appears to be less so.

Table 4: The Effect of ten sub-strategies intervention on reading performance: mean effect size and regression results.

	Effect size	B	SE
Monitoring	0.497**	0.206	.334
Planning	0.648*	0.134	.093
Evaluation	1.037	0.194	.174
Elaboration	0.296**	-.028	.061
Organization	0.207	-.041	.071
Rehearsal	0.302*	-.065	.100
Effort	0.679**	.020	.052
Peers	0.198	-.037	.069
Environment	0.210	.033	.038
Self-efficacy	0.380	-.006	.049

3.3. Effects of other interventions on reading performance

The following section investigates whether the effectiveness of strategic interventions depends on other influencing factors, which will respond to a third question about the effects of other factors.

Table 5 and Table 6 depict the results of meta-regression of the influence of other aspects on the intervention's effectiveness. Reading performance was strongly affected by region, which was significantly greater than in other treatments. Even though a meta-analysis of variance indicated no significant differences in efficacy across different interventions based on the P value, the coefficient

DOI: 10.54254/2753-7048/58/20241796

of students' characteristics type showed a positive connection. We extensively analyzed the different factors using meta-regression. In this approach, rather than examining the differences between variables as a whole, the two variables may be compared to each other. The effect of SRL strategy teaching on reading performance and the instrument did not correlate. Only B=-.236 (SE=.279; p=0.369) was found in a meta-regression with the instrument as a predictor. The effectiveness of the intervention was unaffected by the student's grade or the duration of the session. However, this discovery was faint evidence of a trend, indicating that for every extra week of length, the predicted number of impact sizes fell by.013 on average, while all other factors remained constant. Similarly, an intervention with a student grade of 6 had a.070 smaller impact size on average than an intervention with a student grade of 5.

Table 5: Effect of each other characteristics on student reading performance: meta-regression results.

	B (SE)
Region	0.907 (0.314)
Student grade	-0.070 (0.051)
Characteristics	0.354 (0.286)
Duration	-0.013 (0.014)
Instrument	-0.236 (0.279)

The table presents the average SRL strategy instruction effect sizes estimated for different characteristics. Furthermore, using meta-regression, the study examined the effect of other characteristic interventions on effect size separately. With the aid of mean effect size, it was found that other regions with a Hedges'g of 0.957 had the largest effect on reading performance, and the average effect is very high. Other regions include several regions, such as Iran, Taiwan, Turkey and Indonesia. For the western region, the effect sizes are much lower (0.413) compared to other regions, although the smallest effect size was the self-developed instrument. Independent testing, on the other hand, yielded an average effect size of Hedges'=0.781. SRL methods benefitted special needs students somewhat more than general students, according to average effect sizes. The rest of the treatments had a medium impact on average.

Table 6: Effect of ten sub-strategies intervention on reading performance: mean effect size and regression results.

	Mean Hedges' g	B(SE)
west	0.302**	-.5607456 (.2592026) *
other	1.090	.7204107 (.7204107)
special	0.468**	.0727479 (.1276561)
general	0.446	-.145495861 (.2553123)
self-developed	0.263	-.2185046 (.1152109)
independent	0.754*	.4370092 (.2304219)

3.4. Publication bias

In the last part, we discuss publication bias related to meta-analysis. The funnel plot in Figure 1 illustrates the presence of publication bias in the meta-analysis of self-regulated learning (SRL) interventions on reading performance. A funnel plot is used to check for bias by plotting the effect size of individual studies against a measure of study precision, typically the standard error. In an

DOI: 10.54254/2753-7048/58/20241796

unbiased scenario, studies should be symmetrically distributed around the mean effect size. However, the plot shows asymmetry, indicating publication bias [12]. The left side of the funnel plot appears to be missing studies, suggesting that smaller studies with non-significant or negative results are underrepresented because they are less likely to be published. The plot includes a method to adjust for this bias called the "Trim and Fill" method. It estimates the number of missing studies and adjusts the plot accordingly, with the missing studies imputed and shown by the adjusted effect size (red line). These signs indicate that publication bias may have inflated the observed effect sizes in the meta-analysis, suggesting that the true effect of SRL interventions might be smaller than reported.

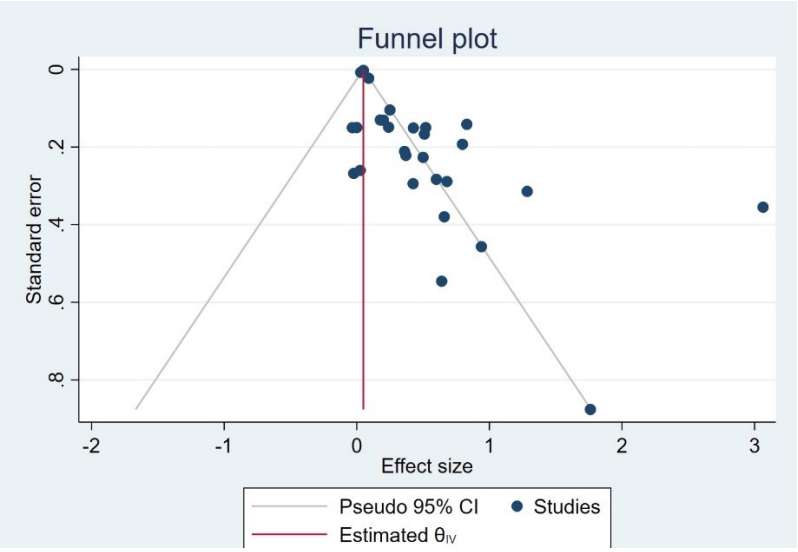

Figure 1: The funnel plot for reading performance research.

4. Conclusion

To conclude, this study has conducted an advanced statistical method (meta-analysis) of the effect of self-regulated learning interventions on students reading performance to answer three research questions. The first research question in terms of the effect of SRL intervention in general on reading performance is moderate, which means that using SRL intervention can improve students' reading performance. However, due to the existence of publicity bias, SRL intervention may have less effective in improving student reading performance. Moreover, this study provided insight into that most of the effectiveness of SRL interventions for enhancing students' reading performance is thus due to metacognitive intervention. Specifically, monitoring and planning among the metacognitive interventions contribute the most to improving student reading achievement. The performance of evaluation among metacognitive interventions has a positive effect but the effect is not significant. The exploration of the last research question found that the characteristics of this study affected the effect of SRL intervention. Student achievement and self-regulated learning have more room for investigation, and this meta-analysis study provides a systematic insight into the performance of adolescents in the field of reading while providing new ideas for future research in this direction.

Acknowledgements

We are grateful to our colleagues at the Universiti Malaya and The National University of Malaysia, for their constructive feedback and stimulating discussions that greatly enhanced the quality of this work.

DOI: 10.54254/2753-7048/58/20241796

Lastly, we would like to thank our families for their understanding and support during the demanding periods of this research.

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