Effective strategies for self-regulated learning:

de Boer, Hester; Bergstra, Anouk; Kostons, Danny

Effective Strategies for Self-regulated Learning: A Meta-Analysis

Hester de Boer
Anouk S. Donker-Bergstra
Danny D. N. M. Kostons

In cooperation with:
Hanke Korpershoek
Margaretha P. C. van der Werf

ISBN:

Table of contents

1. Introduction

The past years, the scientific research and literature have paid a great deal of attention to the ability of students to self-regulate their learning, a development clearly demonstrated by the considerable number of NWO-funded studies into metacognitive abilities and self-regulated learning. This focus is hardly surprising, considering the view of the OECD (2004) that in this day and age people need to be able to continue to learn throughout their lives. Until the 1990s, learning mostly entailed memorizing and reproducing information provided by others, whereas nowadays it is regarded far more important to acquire knowledge and skills by oneself. This vision has led curricula at schools to focus increasingly on the teaching of self-regulated learning skills to facilitate the acquisition of knowledge.

Based on the expectation that self-regulated learning will better prepare students for the demands of higher education, secondary education has for some time now put a clear emphasis on this approach. Also in primary education the teaching of self-regulated learning skills has increased, here with the aim of preparing students for secondary education. However, particularly within primary education, students tend to be ill-equipped to deal with the demands of self-regulated learning. Students appear to lack the essential strategies required for this type of learning, such as making proper summaries (Brown & Palincsar, 1989; Cromley, Snyder-Hogan, & Luciw-Dubas, 2010), monitoring and evaluating their own performance (Azevedo & Cromley, 2004; Kostons, Van Gog, & Paas, 2010), or keeping their motivation high (Pintrich, 2004; Zimmerman, 1990). Without strategy instruction, students are unlikely to develop effective learning strategies on their own.

Thus far, many studies have demonstrated the effectiveness of strategy instruction. But although some earlier meta-analyses have tried to summarize the findings of these studies, little concrete knowledge is presently available about which specific strategy or combination of strategies is the most effective in improving student performance in both primary and secondary education. The purpose of this meta-analysis has been to provide further insights into the effectiveness of learning strategies aimed at enhancing studentsô performance in various domains and on different educational levels (primary and secondary education).

First, we will present the theoretical framework used in this meta-analysis, specifically built for self-regulated learning and metacognitive skills. Next, we will provide an overview of prior meta-analyses which have investigated similar issues. After that, a description is given of the method used to perform our meta-analysis, followed by the results. Finally, we will formulate the conclusions of our meta-analysis, together with our recommendations for future research and the educational practice.

2. Theoretical Framework

2.1. What is self-regulated learning?

In attempting to integrate the multitude of definitions available at the time, Pintrich (2000) described self-regulated learning as: ñan active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation and behavior, guided and constrained by their goals and the contextual features in the environmentò (p. 453).

Different elements stand out in this definition. First of all, it conveys an active part: students are actively involved and have clear intentions to be engaged in learning. This component links directly to the second element: goal-orientation, that is, the purposeful focus of learning on the achievement of a goal. The third aspect, the regulation and control of cognition, refers to the use of learning strategies to enhance oneôs learning (Zimmerman, 1990). The fourth element relates to the context of self-regulated learning. A learning environment can both stimulate and hinder learning (e.g. working in a quiet, orderly space instead of in a chaotic and noisy room). The final element integrated in this definition is student motivation: students have to be motivated to adopt this intense form of learning, in which motivational and cognitive aspects are intertwined (Boekaerts, 1996).

In short, self-regulated learning is a complex process, containing cognitive, motivational and contextual elements. Metacognition is the instrument that controls these elements and which forms the basis of the process of self-regulated learning.

2.2. What is metacognition?

Metacognition is a term frequently encountered in the research on self-regulated learning. In fact, the terms metacognition and self-regulated learning are sometimes used interchangeably (Dinsmore, Alexander & Loughlin, 2008). However, although these concepts are strongly related, they refer to different constructs.

Flavell (1979) described metacognition as the knowledge about and cognition of phenomena. He hypothesized that the monitoring of cognitive endeavors takes place through the actions and interactions among metacognitive knowledge, metacognitive experiences, tasks and strategies. Flavell defined metacognitive knowledge as the knowledge or beliefs about the way in which variables act and interact to affect the course and outcome of cognitive undertakings. This type of knowledge is a prerequisite for the independent use of learning strategies. Students who lack metacognitive knowledge do not understand why or when to use learning strategies. Metacognitive knowledge can either refer to oneself (the person), to the task and to the strategies that can be used to successfully fulfill a task. Flavell observed that young students possess less metacognitive knowledge than older students. By metacognitive experience Flavell means the metacognitive knowledge of which a learner has become conscious. This awareness is a necessary step to further develop one's metacognitive knowledge. Flavell stated that it is possible to improve students' metacognition by training; by enhancing their metacognition, students' comprehension and learning are improved.

2.3. Learning strategies

A typical characteristic of self-regulated learners is that they use learning strategies to enhance their learning. Alexander, Graham and Harris (1998) described the learning strategy as a form of procedural knowledge: the 'how to' knowledge. Learning strategies facilitate learning and enhance performance. In other words, they are essential for academic development. Alexander et al. have characterized learning strategies as purposeful, in the sense that they are consciously applied to attain a desired outcome. Learning strategies are different from study skills in that the latter can be automatized, whereas strategies require conscious effort. In order to apply learning strategies, therefore, the learner requires the will and skill to learn to master them (Weinstein, 1994).

Alexander and colleagues (1998) also pointed to the interplay among knowledge, strategy use and motivation. The more one knows about a particular subject, the more complex the strategies which one is able to use. For example, a learner who has less prior knowledge may have to read a text a number of times before grasping its content, whereas an expert will instantly relate the new information to his/her prior knowledge of the subject. The new knowledge enables the learner to apply the proper strategies more effectively. So the learner *can* improve his/her strategy use, but only if he/she is aware of the relationship between the knowledge learnt and its application. Furthermore, as the learning of strategies requires the will to put effort in understanding them, motivated learners are more likely to use these tools. To complete the circle, more knowledge increases motivation.

The literature provides a large number of strategies, ranging from very simple re-reading methods to more complex approaches to synthesizing knowledge or drawing conceptual schemas to depict problems. Based on a combination of commonly used taxonomies and classifications (e.g. Boekaerts, 1997; Mayer, 2008; Pressley, 2002; Weinstein & Mayer, 1986) the following four main categories of strategies have been defined.

2.3.1. Cognitive strategies. These are strategies on a lower level than the metacognitive methods. The application of cognitive strategies is domain- and sometimes even task-specific. There are three main types of cognitive strategies: first, elaboration strategies, by which connections are established between new material and what is already known. Second, rehearsal strategies, which help store information in the memory by repeating the material, and third, organization strategies to visualize the material to facilitate learning (Mayer, 2008).

2.3.2. Metacognitive strategies. Metacognitive strategies are used in the various phases of the learning process as described by Zimmerman (2002). He distinguishes three: the forethought phase, which involves the development of planning strategies. An example is the allocation of study time. During the performance phase, the actual learning or task performance takes place. Here the monitoring strategy comes into play; the learner repeatedly checks whether he/she understands the material, e.g. by self-questioning. The last phase is that of self-reflection, during which the learner evaluates the learning process and/or product. Evaluation and reflection techniques are used to support this phase.

2.3.3. Management strategies. Management strategies focus on the learning environment and are used to create the optimal learning conditions. They can be aimed at the learner him/herself (effort management; strategies that help one persist in case of difficulties), at others (help-seeking and/or collaborative learning), or at the physical environment (e.g. using dictionaries and/or going to the library).

2.3.4. Motivational strategies. Motivational strategies aim to enhance specific types of impetus. Examples are the formulation of a learning objective, which enhances the goal orientation: the reason why one undertakes a task, which is either performance or mastery-oriented (Harackiewicz, Barron, Pintrich, Elliot & Thrash, 2002), valuing the task, which enhances the task value beliefs: the degree to which the task is considered as relevant, important and worthwhile (Wigfield & Eccles, 2002), and the development of a positive style of attribution, which enhances the studentôs self-efficacy: the studentôs belief in his or her ability to successfully complete the task (Pintrich, 2003). The enhancement of the motivation element should lead to a higher level of engagement in the task.

3. Prior meta-analyses

A literature search resulted in five meta-analytical studies into the effects of metacognitive and self-regulated learning interventions. We will first discuss their findings with respect to the interventionsô effectiveness in terms of student performance, and then give a brief description of how the meta-analyses were performed. After that, we will address the effectiveness of the self-regulated learning interventions in relation to the influence of particular moderators ï such as student characteristics, manners of implementation, and test characteristics.

3.1. Effects of learning strategies on performance

3.1.1. Haller, Child and Walberg (1988). These authors were the first to perform a quantitative review study on this theme. Their meta-analysis contained 20 studies into the effects of metacognitive instruction on reading comprehension. The studies were published between 1975 and 1987. Their inclusion in the meta-analysis was based on the criterion that they had to report on metacognitive strategy learning. Furthermore, they had to include a control group. The average effect size reported was quite high, namely 0.71 (SD = 0.81; probably Cohenôs d, but this information was not provided). This result showed that metacognitive instruction is very effective in promoting reading comprehension. The authors argued that the more strategies learnt, the more effective the intervention was. However, to compute the average effect size, the authors assigned equally as much weight to studies with a small sample size than to studies with a larger sample size. This approach must have biased the results to some extent, since the effect sizes found in small studies tend to be more extreme than those observed in larger studies (Borenstein, Hedges, Higgins and Rothstein, 2009), as was also reported in this meta-analysis. Despite this methodological flaw, we chose to discuss the results of this meta-analysis, since it still provides some useful insights into the effects of learning strategy instruction interventions.

3.1.2. Hattie, Biggs and Purdie (1996). Hattie, et al. (1996) also performed a meta-analysis of the effects of strategy instruction on student learning. They examined the effects of 51 studies published between 1968 and 1992. Forty-six of these studies provided a measure for performance as outcome. The studies focused on task-related strategies, self-management of learning, or affective components, such as motivation and self-concept. The overall size of the effect on studentsô performance was Cohenôs d = 0.57 (SE = 0.04): a moderate effect. The authors used categorical models to examine if study characteristics and/or student characteristics moderated this effect size. The interventions were grouped according to one moderator variable, or sometimes two, at a time. Unfortunately, the authors did not always report the results of the performance outcome measure separately, but computed the mean effect size based on the three outcome measures performance, study skills and affect. And if the authors did specifically report the results for performance, they omitted to report whether the differences in effect size among the groups of studies were statistically significant. Nevertheless, also this meta-study gave us a good impression of the relationships that might exist between the effectiveness of strategy instruction and the characteristics of the studies and the students.

To examine the differences in the effectiveness of the learning strategies, Hattie et al. categorized the interventions according to their structural complexity and the extent to which they focused on near or far transfer learning (the extent to which the training task and the performance goal overlap). In this respect, simple interventions are directed at teaching one or more strategies, whereas the more structurally complex interventions aim at integrating strategy learning into the educational context and content, and at emphasizing self-regulated learning (for example by providing a metacognitive framework and addressing motivation). The results of this meta-analysis showed that strategy instruction focused on near transfer ï that is, task training and the performance goal are closely related ï is more effective in enhancing academic performance than strategy instruction directed at far transfer. In addition, more complex interventions are more effective in enhancing performance than simple strategy instructions.

3.1.3. Chiu (1998). Chiu (1998) performed a meta-analysis of 43 metacognitive intervention studies into reading comprehension, published between 1979 and 1995. The sample populations of these studies ranged from students of the second up to and including the final grade of college. The average effect size found was Cohenôs d = 0.40 (SE = 0.04). This result indicates that metacognitive interventions are moderately effective in enhancing studentsô reading comprehension. Chiu did not examine the effectiveness of the different learning strategies, but instead analyzed the effects of other training characteristics on the effectiveness of the interventions, such as measurement instrument, implementer of the intervention, research design, random assignment, duration and intensity of the intervention, size of the instructional groups, student ability, grade and school location.

3.1.4. Dignath and Büttner (2008). Dignath and Büttner (2008) performed a meta-analysis of intervention studies into self-regulated learning at the primary and the secondary school levels. They examined the effects reported by 74 studies published between 1992 and

2006. Their meta-analysis can be considered as a sort of follow-up on the meta-analysis of Hattie et al. (1996), as the most recent study in the latterôs analysis was from 1992. The interventions described in the studies in Dignath and Büttnerôs meta-analysis had to include cognitive, metacognitive or motivational strategies. Other selection criteria were that the participants in the studies did not suffer from learning disabilities and that the studies were conducted using a pretest-posttest control group design. Via stepwise backwards meta-regression Dignath and Büttner simultaneously tested the effects of the following study characteristics on academic performance: theoretical background of the study (social-cognitive, motivational or metacognitive), strategy type (cognitive, metacognitive, motivational or metacognitive reflection), cooperative learning, implementation of the intervention by researcher or teacher, and duration of the intervention (number of sessions). The analyses were run separately for the primary and the secondary schools. The authors also tested for differences between the subject categories reading/writing and mathematics.

The average effect sizes for academic performance in primary and secondary school were Cohenôs d = 0.61 (SE = 0.05) and 0.54 (SE = 0.11), respectively; both moderate effect sizes. In primary school, the effect sizes of mathematics performance were twice as large as those of reading/writing: 0.96 (SE = 0.13) versus 0.44 (SE = 0.06). In contrast, in secondary school the effect sizes were much larger for reading/writing than for mathematics: 0.92 (SE = 0.20) versus 0.23 (SE = 0.08).

Dignath and Büttner found that among the theories on self-regulated learning, strategy instruction based on social-cognitive theory had the largest effects on studentsô academic performance in primary school. In secondary school, strategy instruction based on metacognitive theories yielded the largest effects. Interesting was that the theoretical background on which the strategy instruction was based, did not always directly relate to the same types of strategies that were instructed. The correlations between the theoretical background and the types of strategies instructed showed that interventions with a metacognitive theoretical background indeed mainly focused on metacognitive *reflection* strategies (reasoning, knowledge about strategies, and benefit of strategy use), rather than on other metacognitive strategies (planning, monitoring, and evaluation). Interventions with a social-cognitive theoretical background even had negative correlations with cognitive strategy instruction. Interventions with a motivational theoretical background did emphasize the instruction of motivation strategies, but also that of metacognitive and cognitive strategies. It can therefore be concluded that the effects of the strategies actually instructed are more important than those of the theoretical background of the strategy instruction. The results showed that metacognitive strategy instruction and motivational strategy instruction were more effective in enhancing studentsô academic achievement than cognitive strategy instruction. In secondary school, this finding also applied to metacognitive reflection strategy instruction. When the effects of strategy instruction were separately tested for the subject categories reading/writing and mathematics, the results indicated that in primary school, metacognitive reflection instruction had a significantly lower effect on studentsô mathematics performance than the other types of instruction.

3.1.5. Dignath, Büttner and Langfeldt (2008). In a later meta-analysis of self-regulation training programs in primary schools only, Dignath, et al. (2008) took a closer look at the effectiveness of the different categories of learning strategies. They investigated the same 48 primary school interventions (from 30 articles) which were examined in the prior meta-analysis of Dignath and Büttner (2008). Using ANOVA, the authors tested if there were significant between groups differences in student performance when the interventions were categorized along the use of individual learning strategies. For the cognitive learning strategies, they examined between groups differences when the interventions were categorized based on the individual cognitive strategies elaboration, organization and problem solving. They found that the interventionsô effectiveness depended on the use of these individual learning strategies. Analysis per subject domain of reading/writing and mathematics revealed no significant between groups differences.

An ANOVA performed among metacognitive strategies (including the individual strategies planning, monitoring and evaluation) showed no between groups differences, neither for overall student performance nor for mathematics performance, except for the subject reading/writing, for which the authors did find a significant difference of this kind. With respect to the main category metacognitive reflection, including the individual learning strategies óreasoningô, óknowledge about strategiesô and óbenefit of strategy useô, no significant between groups differences were found.

Finally, the authors tested the effects of a categorization of the interventions according to the following four motivational strategies: resource strategy, causal attribution and self-efficacy beliefs, action control strategy and feedback strategy. This examination indeed showed significant between groups differences with respect to the studentsô overall performance, but not for the subject domains reading/writing and mathematics.

3.1.6. Conclusion. In summary, the results of the meta-analyses presented above tell us that teaching students how to self-regulate their learning enhances their performance. It remains unclear, however, which (combination of) specific learning strategies should be taught to enhance this performance to a maximum. Haller et al. (1988) found that interventions which include multiple metacognitive strategies (which strategies exactly was not further specified) are more effective in enhancing student performance than those which are focused on only a few metacognitive strategies. Hattie et al. (1996) observed that interventions in which strategy learning goes together with self-regulated learning (metacognition and motivation) are more effective than those that only concentrate on learning one or a small number of strategy types. Dignath and Büttner (2008) however, did not find that instructing multiple strategy types (metacognitive, cognitive and motivational) is more effective in promoting student performance than instructing only one type of strategy. The results of Dignath et al. (2008) showed that it matters which individual learning strategies are taught. They reported on significant between groups differences in student performance among the interventions per learning strategy category. Unfortunately, their results did not show which particular learning strategies are significantly more effective than other ones.

The mixed results of the prior meta-analyses leave uncertain which particular learning strategy (i.e. which substrategy within a broader category, such as metacognition, cognition, management or motivation) or which combination of strategies, is the most effective in promoting student performance. In the current meta-analysis we do address this question and examine the effectiveness of different substrategies simultaneously in order to find out which (combinations of) particular strategies are the most effective in enhancing student performance.

3.2. Influence of other moderators on the effectiveness of the strategy instruction interventions

Except for the content of the intervention, also other aspects can influence the effectiveness of a strategy instruction. In the prior meta-analyses, some of these aspects were examined.

3.2.1. Studentsô ability. Hattie et al. (1996) examined if the effectiveness of strategy instruction differed among students with different ability levels. It appeared that the mean effect size of the three outcome measures performance, study skills and affect, was the highest for students with a medium ability, followed by students who were underachieving. Low and high ability students benefited the least from strategy instruction. The difference in effectiveness between strategy instruction for students with medium ability levels on the one hand and that for low or high ability students on the other hand, was quite large.

Unfortunately, however, these results were not specifically presented for the outcome measure óperformanceô.

Chiu (1998) also found a slight difference in effectiveness related to student ability. Interventions focused on low ability students and on students who were diagnosed as remedial pupils were slightly more effective than interventions aimed at other student groups. This result is contradictory to the finding of Hattie and colleagues.

3.2.2. Studentsô age. Haller et al. (1988) found some differences in effectiveness related to the age of students. The effects were the highest for seventh and eighth graders, lower for second and third graders and the lowest for fourth, fifth and sixth graders.

Chiu (1998) reported that interventions aimed at students in the fifth grade or higher were more effective than those meant for younger students.

Hattie et al. (1996) observed that university students and adults benefited the least from strategy instruction. The effect sizes of strategy instruction interventions focused on upper secondary students were the largest, followed by interventions meant for primary and preprimary students and then by those aimed at lower secondary students.

With respect to overall academic performance, Dignath and Büttner (2008) found no significant differences in effectiveness between strategy instruction for primary school students and strategy instruction for secondary school students. However, when looking at the strategy instruction in mathematics and reading/writing separetely, they did find large differences. In primary school the strategy instruction was more effective in mathematics, whereas in secondary school it was more effective in reading/writing.

All in all, the meta-analyses reported mixed results as regards the influence of age on the effectiveness of strategy instruction. In most studies however, the age effects were quite small.

3.2.3. School location. Haller et al. (1988) and Chiu (1998) investigated whether the school location had an influence on the effectiveness of strategy instruction interventions. Haller et al. (1988) found that students in urban areas benefited more from metacognitive interventions than those in suburban or rural areas. Chiu, however, reported no significant differences in effectiveness in this respect. Chiu hypothesized that there was a relationship between the school location and studentsô socioeconomic status, and that analyzing the school location as a moderator of the effect size would give an indication of the effect of socioeconomic status on the effectiveness of the intervention. It is unclear, however, to what extent the urbanization degree of the school location is related to studentsô socioeconomic status.

***3.2.4. Subject domain*.** Haller et al. (1988) and Chiu (1998) only selected studies focused on reading comprehension for their meta-analyses. Hattie et al. (1996), Dignath and Büttner (2008) and Dignath et al. (2008) on the other hand, did not select studies on the basis of a specific subject. The average effect size found in the meta-analysis of Haller and colleagues was Cohenõs d = 0.71, but this outcome may have been positively biased due to a wrong analysis method. We did therefore not attach much weight to this result. The average effect sizes found in the other meta-analyses were Cohenõs d = 0.40 for Chiu, 0.57 for Hattie and colleagues, and 0.61 and 0.54 for Dignath and Büttner (primary school and secondary school, respectively). These last authors also separately reported the average effect sizes for the subject domains reading/writing and mathematics, which for reading/writing were 0.44 and 0.92 (primary school and secondary school, respectively), and for mathematics 0.96 and 0.23 (primary school and secondary school, respectively).

The conflicting results of Dignath and Büttner for primary and secondary school do not give much information on differences in strategy instruction effectiveness related to subject domain. The lower effect size found in Chiuõs study, however, might suggest that metacognitive training interventions in reading comprehension are less effective than this type of training in other subject domains, since the average effect sizes reported in the other studies are higher. More research is needed to determine whether the effectiveness of self-regulated learning strategies indeed differs per domain.

3.2.5. Implementer of the intervention. Haller et al. (1988) argued that it does not matter whether the intervention is implemented by the researcher or the teacher. Chiu (1998), however, reported on higher effect sizes of interventions implemented by the researcher than of those introduced by the regular teacher. Dignath and Büttner (2008) found a similar result for interventions implemented in secondary schools, but observed no significant differences for interventions in primary schools.

3.2.6. Research design. Hattie et al. (1996) examined whether the effect sizes of the interventions depended on the research design. They found that studies using a control group or a pre- and posttest showed slightly lower effect sizes on the outcome measures óperformanceõ, óstudy skillsô and óaffectô than studies based on other designs. These differences were, however, not significant.

Chiu (1998) investigated if the effect size was related to whether or not the participants or classrooms in the primary studies were randomly assigned to the control group and the experimental group. When the random assignment was the only variable in the regression analysis, no significant relationship was found, but after correction for other training characteristics it appeared that studies based on random assignment produced lower effect sizes than those using other methods.

Haller et al. (1988) tested whether the impact of the intervention could be explained by the Hawthorne effect. The Hawthorne effect implies that participants in a study improve or modify their behavior because they know that they are being monitored. The authors, however, found no indication of this phenomenon. Chiu (1998) also tried to check for Hawthorne effects. The coders had to indicate whether they thought if the control group did or did not believe that it was receiving training. Unfortunately, the inter-rater reliability as regards this issue was too low to use this information in the meta-analysis.

3.2.7. Measurement instrument. Two of the prior meta-analyses reported on whether the measurement instrument influenced the intervention effect estimated. Haller et al. (1988) suggested on the basis of their results that the effect size does not depend on whether the intervention was tested using a self-developed or a standardized test. It is not clear, however, if they had directly tested this relationship or inferred their conclusion from other analyses in their study.

Chiu (1998) also examined if the type of measurement instrument matters. He first reviewed prior reading comprehension studies and concluded that positive effects were the most frequently associated with non-standardized tests. Chiuǿs meta-analysis presented 32 effect sizes measured using a standardized test and 91 using a non-standardized test. Of the 43 studies included in the meta-analysis, 19 applied a standardized test to estimate the effect of the intervention. Chiu also found that the effects of metacognitive instruction interventions for reading comprehension were higher using a non-standardized test than a standardized test. The non-standardized tests resulted in an average effect size of Cohenǿs d = 0.61, whereas the standardized tests produced an effect size of only 0.24. Moreover, after correction for other training characteristics, this difference even increased.

Because Haller and colleaguesǿ method of analysis was not so solid, whereas that of Chiu was, we attached more weight to the findings of Chiu than to those of Haller and colleagues.

3.2.8. Duration of the intervention. Hattie et al. (1996) found that the duration of the intervention matters to a small extent. Short programs (one or two days) appeared to be more effective than interventions of three or four days, but even longer trajectories proved the most effective (between four and 30 days). Unfortunately, the authors did not present the results of the outcome measure ŏperformanceǿ separately, but for ŏperformanceǿ, ŏstudy skillsǿ and

ʻaffectʼ together. It is therefore not certain whether this finding also holds for performance alone.

Dignath and Büttner (2008) observed that the duration of the intervention had a small effect on studentsʼ mathematics performance in both primary and secondary school. Interventions including more sessions had higher effects. However, with respect to reading/writing, the duration of the intervention did not have a significant influence on the effect size. Moreover, when the interventions for reading/writing and mathematics were merged into a single analysis, no significant effect whatsoever was visible of the duration of the intervention.

Chiu (1998) indicated that duration, operationalized as the total number of intervention days, had no significant effect on the effectiveness of reading comprehension interventions. On the other hand, the intensity of the intervention, operationalized as the number of session days per week, did matter to a small extent. Less intensive interventions were slightly more effective than more intensive interventions.

In summary, the duration of the intervention has at the most a small influence on the effectiveness of strategy instruction interventions, whereby longer but less intensive interventions are more effective.

3.2.9. Cooperative learning. Chiu (1998) reported that reading comprehension interventions in which the instruction was given in small groups (between two and ten students) were more effective than those on an individual basis or those in which the groups contained more than ten students. He suggested that small group instruction is the most effective because in this context students are the most likely to work collaboratively.

Dignath and Büttner (2008) argued that interventions based on cooperative learning produced lower effects in primary school and higher effects in secondary school compared to interventions in which students were not stimulated to cooperate.

3.2.10. Conclusion. The effectiveness of self-regulated learning and metacognitive strategy instruction interventions appears not only to depend on the category of learning strategies instructed, but also on other training characteristics and on student characteristics. Student ability seems to matter, but because of the mixed findings of the prior research, the influence of this item on the effectiveness of strategy instruction remains unclear, which also applies to age and subject domain. The influence of age on the effectiveness of strategy instruction interventions is probably quite small. Furthermore, there is also not much evidence that the school location is a significant moderator of the effectiveness of strategy instruction. Chiu suggested that the school location is an indication of studentsʼ socioeconomic status, but we are not sure of this. It is an interesting question, however, to what extent studentsô socioeconomic status moderates the effects of strategy instruction. What is widely known is that performance is related to studentsô socioeconomic status (Sammons, 1995; Dekkers, Bosker & Driessen, 2000; Van der Werf, Lubbers & Kuyper, 2002). The school performance of students with a higher socioeconomic status is on average better than that of students with a lower socioeconomic background. It therefore seems not unreasonable to suggest that the effects of strategy instruction might differ based on studentsô socioeconomic status.

With respect to the other characteristics it can be assumed that interventions are probably more effective when implemented by the researcher than by the teacher. Next, the research design has little or no impact on the effect size, but the measurement instrument, by which the effectiveness is estimated, probably has. The duration of the intervention does not seem to be a very important moderator of the effect size. Finally, it has as yet remained undecided if interventions in which students can cooperate are more effective.

4. Research questions

The prior meta-analyses have not clearly shown which particular learning strategies (substrategies), or combinations of substrategies, are the most effective in enhancing student performance. The current study, therefore, has been particularly aimed at this topic. Our research question has been formulated as follows:

1. *Which (combination of) learning strategies (particular strategies or substrategies within the broad spectrum of cognitive, metacognitive, management and motivational strategies) should be instructed to enhance student performance the most effectively?*

We hypothesize that the most effective (combinations of) learning strategies vary depending on the subject domain. Writing a text for example, requires other skills than reading comprehension or mathematics. We therefore expect that the effectiveness of learning strategies will differ per subject domain. In the current meta-analysis, we will examine if this is true. The research questions representing this hypothesis are:

2a. Which (combination of) learning strategies should be instructed to enhance student performance the most effectively in reading comprehension?

2b. Which (combination of) learning strategies should be instructed to enhance student performance the most effectively in writing a text?

2c. Which (combination of) learning strategies should be instructed to enhance student performance the most effectively in mathematics?

2d. Which (combination of) learning strategies should be instructed to enhance student performance the most effectively in science?

The prior meta-analyses demonstrated that the effects of self-regulated learning and metacognitive training interventions were also moderated by aspects other than the strategies instructed. However, the studies often revealed mixed results for the same moderator variables. In our meta-analysis, we will examine whether the effectiveness of the strategy instruction differs per student group. We will analyze the effects of studentsô ability, socioeconomic status and grade and investigate if the intervention characteristics moderate the effectiveness of the strategy instruction. We will include the following aspects in our analysis:

implementer of the intervention, measurement instrument, duration and intensity of the intervention, computer use during the intervention and cooperative learning.

The research questions concerning the moderator variables have been formulated as follows:

3a. Do the effects of strategy instruction on student performance differ per student group?

3b. Do the effects of strategy instruction on student performance depend on characteristics other than the learning strategies instructed?

We are also interested in the question if strategy instruction has a sustaining effect on student performance. Hence the final research question:

4. Do the effects of the learning strategies on student performance sustain once the strategy instruction has ended?

5. Method

In this paragraph, we describe our search criteria for the initial study retrieval and the eligibility criteria for the final inclusion of studies in or their exclusion from the meta-analysis. In addition, we explain the study coding procedure and how we analyzed the data.

5.1. Literature search

We started by searching the internet databases *ERIC* and *PsychInfo*. We decided to use a limited time span, concentrating on the most recent research. We assumed that important findings from studies conducted longer ago would have been replicated, whereby solely focusing on the more recent research would still enable us to demonstrate the most important results. The period selected ranges from 2000 to 2011. The search terms we entered were ómetacognit*ô and óself-reg*ô, which had to form part of the titles of the articles. With respect to advanced search options, we limited our search to articles written in English and published in peer-reviewed journals (so books and book-chapters were excluded from our analysis). These searches produced an overwhelming amount of articles.

Next to using search engines, the following journals were selected for hand-search: Metacognition & Learning, Learning & Instruction, British Journal of Educational Psychology and Journal of Instructional Psychology. We selected them because of their frequent appearance in our literature list, which indicated both the willingness of these journals to publish articles on self-regulated learning and metacognition on the one hand, and that of the authors of these articles to publish in these journals on the other hand. We selected the journals to be completely searched using the same criteria as applied to our internet search; journals from 2000 to 2011 were screened for the terms óself-reg*ô and ómetacognit*ô as appearing in the title.

5.2. Eligibility criteria

Our principles for inclusion were all based on our main criterion: empirical studies focused on the instruction of self-regulated learning (or metacognition) to improve academic achievement. This criterion meant that we only selected articles which included the dependent variable óacademic achievementô (operationalized as performance on one or more school subject domains). Studies exclusively aimed at fostering self-regulated learning, which did not measure any other construct besides self-regulation and/or metacognition, were excluded, as it was our goal to analyze gains in academic performance by improving self-regulated learning.

So, studies with self-regulated learning or a related construct as the only dependent variable were excluded, since they did not provide any information on possible effects on academic achievement, and were therefore not relevant to our analysis. Finally we excluded correlation studies which only examined the relationship between self-regulated learning and student achievement. In these studies, self-regulated learning was not implemented as training, whereby it was not possible to analyze the possible causal relationship between self-regulated learning and student achievement. The other eligibility criteria were:

- The research has to include a control group. If the research design lacks a control group, it is unclear whether the results of the experimental group are due to the intervention or to normal developments.
- The research has to provide pre- en posttest measures. Studies which only provided posttest scores were only included if it was indicated that there were no initial differences between the control and experimental group.
- With respect to the subject domain, the research may include all regular academic subjects with the exception of music, arts and physical education. In practice, the majority of the studies focused on reading comprehension, writing a text or mathematics. Studies about foreign language learning were included as long as they were conducted in regular schools and the foreign language was a subject for all students; special (extra-curricular) education for second language learners was not being considered part of the ‘regular academic achievement’, and therefore these studies were left out.
- To be able to generalize the results to school learning, the research sample has to consist of primary school or secondary school students up to and including the twelfth grade, following most European and the American School Systems. The grade numbers used in the different countries were standardized; grade 1 including students from age 5 to 6, grade 6 students from age 11 to 12 (end of primary school) and grade 12 students around the age of 16, 17 years old.
- The participants have to be representative of the average school community. Therefore, studies based on children with learning difficulties or disabilities were also included in our sample. By coding the student characteristics, we made sure that the studies with these specific student samples were recognizable.
- The study samples have to include at least ten students per group in order to assure that the effect size Cohen’s *d* is approximately normally distributed (Hedges and

Olkin, 1985). Studies with less than ten students per group were therefore excluded from the meta-analysis.

- The type of intervention has to be properly described. For studies in which the exact type of intervention was not sufficiently explained, it was impossible to code the learning strategies taught to the students. These studies were therefore also excluded from the meta-analysis.
- The research should include an intervention independent test, such as a standardized or published test, as opposed to a self-developed test. We considered tests specially developed for assessing the effect of the intervention as less informative than intervention independent tests. Self-developed tests are generally aimed at measuring the (very) near transfer of the task learnt, whereas independent tests focus on the further transfer of the task learnt, which is preferable. In practice however, many studies only used self-developed tests to estimate the effect of the intervention. If we had restricted the meta-analysis to studies based on tests independent of the intervention, we would have lost a great deal of research material. We therefore decided to also include studies using only self-developed tests. In the analyses we will examine if there is a difference in effect size between the interventions assessed via self-developed tests and those tested using intervention independent tests. Later on, we will then correct for the differences in the effect size measures of the strategy instruction interventions related to the measurement instrument.
- The research has to provide a sufficient amount of quantitative figures. Studies that did not present enough quantitative figures to calculate an effect size were excluded from the meta-analysis.
- The study has to be published in peer-reviewed journals in the years 2000 to 2011 and written in English. Studies that did not meet this criterion were excluded from the analysis.

5.3. Coding

Following Lipsey and Wilson (2001), we designed a coding scheme to integrate the multiple hierarchical levels. As we believed that the effectiveness of the trainings with respect to student performance might be influenced by a broad spectrum of variables, we coded many of them. Because our coding scheme was so extensive, outcome differentiation was allowed.

The coding scheme was based on an example used in earlier meta-analysis (Dignath, Büttner & Langfeldt, 2008). After testing this scheme it was refined by considering all coding categories until the authors reached full agreement. Finally, they coded the articles independently and calculated the inter-rater reliability, which yielded a Cronbachǿs alpha of 0.90, and after that the remaining articles were divided between the authors. If necessary, they discussed their questions and concerns. Next, we highlight the variables relevant to the current meta-analysis:

5.3.1. Learning strategies. In line with our theoretical framework, we distinguished four main categories of learning strategies. However, because some studies particularly focused on stimulating metacognitive knowledge rather than on the teaching of specific strategies, a category pertaining to metacognitive knowledge was added. In total, we coded for fourteen substrategies. These were defined as follows:

Metacognitive knowledge.

1. *Personal metacognitive knowledge.* A personǿs knowledge of his/her own learning. This knowledge includes no general information about strategies but particularly relates to oneǿs personal strengths and weaknesses, and how they can compensate one another. It particularly concerns information on how óyouô learn best.
2. *General metacognitive knowledge.* Knowledge of learning and cognition in general, including knowledge of how, when and why to use learning strategies.

Cognitive strategies. The following types of cognitive strategies were coded:

3. *Rehearsal.* Repeating and re-reading words and text passages (also with respect to metacognitive knowledge) in order to learn to remember their content and be able to apply them.
4. *Elaboration.* Actively making connections between new and already existing material and structuring this information in order to facilitate the storage of this knowledge in the long-term memory.
5. *Organization.* Reducing the information to the relevant issues to enhance oneǿs comprehension.

   Examples: categorizing information, structuring a text, transforming text into a graph.

Metacognitive strategies. We distinguished three types of metacognitive strategies related to the phases of the learning process:

6. Strategies for *planning and prediction.* An explicit focus on planning and the use of time, based on which the students have to determine how they are going to perform and what they will need to perform well.

Examples: making a plan, starting from the most important aspect, and determining how much time you will need to spend on it.

7. Strategies for *monitoring and control*. Monitoring the learning process by checking if you are still óon the right trackô and adjusting your learning approach if so required. Examples: formulating questions to check your understanding, checking information.
8. Strategies for *evaluation and reflection*. After completing a task, reconsidering either the process or the product. Examples: checking answers before handing in an assignment, comparing the outcome to the goal.

Management strategies. Three categories of management were distinguished:

9. *Management of the self*, or *effort management*. This concept is related to motivation. It reflects the commitment to completing oneôs study goals even when there are problems or distractions. Examples are goal-directed behavior and perseverance despite difficulties.
10. *Management of the environment.* Looking for possibilities in the environment to create the best circumstances for learning, for instance finding a quiet place to study, but also using dictionaries and going to the library ï or the internet ï to look for information.
11. *Management of others.* Help-seeking or collaborative learning.

Motivation strategies. Regarding motivation we distinguished the next three categories:

12. *Self-efficacy.* Belief of a student in his or her ability to successfully complete a task. Includes judgments about oneôs ability to accomplish a task as well as oneôs confidence in oneôs skills to perform the task.
13. *Task value.* Belief in the relevance and importance of a task.
14. *Goal orientation*. The degree to which the student perceives him/herself to be participating in a task for reasons such as seeking a challenge, curiosity, wanting to master a skill (intrinsic),obtaining high grades, getting rewards, achieving a good performance and/or evaluation by others, and competition (extrinsic).

5.3.2. Other characteristics of strategy instruction interventions. The other eight characteristics of the interventions coded were:

Subject domain. We coded the subject domain in which the training was integrated. We distinguished (comprehensive) reading, writing, mathematics, science and a category labeled óotherô. We excluded studies focused on strategy use in less academic subjects, such as music or arts.

Student characteristics. We distinguished óregular studentsô (when trainings were aimed at students who had none of the characteristics mentioned below, or when no specific information was provided, in which case we assumed that the students were representative of the majority of the population, which was the focus of our research), ólow SES studentsõ, óhigh SES studentsõ, óstudents with special needsõ, and ógifted studentsõ. We based these categories on the information provided by the authors of the primary articles.

Grade. The studentsô school year.

Implementer of the training. In our study search we came across several publications in which trainings were provided by student assistants and computers. So in contrast with earlier analyses, we used four categories: researcher, teacher, other person (e.g., student assistants specifically trained for the program) and computer.

PC Use by the students during the training.

Cooperation in terms of whether the training focused on cooperative learning or on individual learning.

Duration of the intervention, coded in weeks.

Intensity of the intervention, coded as number of sessions per week.

5.4. Analysis

Meta-analysis is a statistical technique by which the quantitative results of multiple studies focusing on one particular research question are combined. As opposed to primary studies, in a meta-study the unit of analysis is not the individual participant, but the effect size found based on the primary studies. A meta-analysis enables one to systematically review multiple studies on the same subject. The summary effect can be calculated based on all studies included in the meta-analysis. Furthermore, it can be examined if there are moderators that influence the size of the effect. Compared to the conventional methods of reviewing, by which the reviewer only focuses on the statistical significance of the findings, another advantage of a meta-analysis is the possibility to take both the magnitude of the effects and the sampling errors into account. Especially in a review of small studies these options can make a difference. In small studies, the effect found might be of considerable magnitude, whereas due to its low statistical power (as a consequence of the small sample size) it is not significant. Using statistical significance as only criterion, the conclusion would be that there is no significant effect. However, investigating a number of small samples via meta-analysis might produce different results, because by pooling the effects estimated in the different studies, the statistical power increases (Lipsey & Wilson, 2001; Raudenbush & Bryk, 2002; Borenstein, et al., 2009; Denson, & Seltzer, 2011).

When performing a meta-analysis, each primary study is assigned a different weight, depending on the precision with which the effect size has been measured. With respect to computing a summary effect, effect sizes measured with greater precision are therefore given more weight. That is, primary studies in which the variance of the estimated effect size is smaller, obtain more weight. In general, studies with larger sample sizes are measured with more precision. The exact weight assigned to each study is the inverse of the variance (1/variance).

Generally, the effect sizes calculated in primary studies are not identical. This circumstance might be due to random error, but might also be the manifestation of real differences in effect size. Real differences in effect size arise when studies of the same topic are not identical. In the current meta-analysis, differences in effect size may have occurred because the interventions were not exactly the same. They differed, for example, in terms of the specific learning strategies implemented, the subject, or the participantsô student characteristics. Meta-analysis can be used to examine if the variance found in the effect sizes is mainly due to random error or the result of real variance. If there is real variance, also called heterogeneity, meta-analysis enables one to identify the moderators which explain these heterogeneous effect sizes.

5.4.1. Comprehensive Meta-Analysis (CMA). óComprehensive Meta-Analysisô version 2, developed by Biostat (see: www.meta-analysis.com), is a statistical package designed to perform meta-analyses and examine the influence of a single moderator on the summary effect. The moderator can either be a variable measured on an interval scale (such as age), or a categorical variable with multiple categories (for example ethnicity). In the case of a categorical variable, CMA executes an analysis of variance, adapted to meta-analytical data, which could be called a meta-ANOVA. CMA also has the option to check for publication bias. A study is more likely to be published if the effects found are significant. Therefore, studies with no significant effects might be underrepresented in the meta-analysis. CMA shows if this is the case, and estimates to what extent the results of the meta-analysis are biased.

We used CMA to compute the effect size and its variance, in this case the effect on student performance, for each intervention. The effects of most interventions were measured based on a pretest-posttest control group design. We used the means, standard deviations and sample size of the control group and the experimental group in the pretest and the posttest to compute the effect size. The effect size Cohenôs *d* was calculated as the mean change between the posttest and the pretest of the experimental group minus the mean change of the control group, divided by the pooled standard deviation of the posttests. To calculate the pooled standard deviation of the posttest, we had to know the correlation between the pretest and the posttest scores for the experimental and control groups. Unfortunately, none of the studies provided these measures. Only one study (the study of Tajika, Nakatsu, Nozaki, Neumann & Maruno, 2007) presented this correlation for the experimental and the control groups together ($r = 0.54$). We therefore estimated the pretest-posttest correlation in the studies at $r = 0.5$. Since Cohenôs *d* tends to be slightly overestimated in small samples, we converted Cohenôs *d* into Hedgesô *g* by applying a correction factor (J). Positive effect sizes indicated that the experimental group outperformed the control group. The interventions without information about the means, standard deviation and the sample sizes of the pretest and the posttest provided either F-test values, difference scores, or only posttest measures of the control group and the experimental group. In CMA these measures were also used to compute Hedgesô *g* and its variance.

If the effects of two or more interventions are tested and compared to a single control group, the computed effect sizes of these interventions are statistically not independent. This is because they share the same control group. If we did not correct for this dependency, the weight assigned to the experimental groups would be too high in the meta-analysis. To correct for this dependency, we therefore divided the number of students in the control group by the number of experimental groups. For example, if a study examined the effects of three experimental groups and compared the results to a control group of 90 students, we used the same mean and standard deviation of the control group test scores, but adjusted the sample size to 30. This correction resulted in a higher variance, and thus in a lower study weight.

To prevent extreme effect sizes to influence the results in an unrepresentative way, we adjusted these values by Windsorizing (Lipsey & Wilson, 2001). Outliers were recoded to the general unweighted mean of the effect sizes plus or minus two times the standard deviation.

5.4.2. Hierarchical Linear Modeling (HLM). For additional analyses, we used the statistical package óHierarchical Linear Modelingô, version 6, of Raudenbush, Bryk and Congdon. The data for our meta-analysis were hierarchically structured by nesting the subjects within the interventions. Using HLM, we could take the variation on both levels into account. This option of HLM makes it an appropriate statistical package for meta-analysis. The level 1 variable served as the effect size estimate of each intervention. Its variance was already known (a V-known model). The level 2 model included the estimation of the summary effect and its variance. Characteristic of HLM is its point of departure that the variability among effect sizes is not only due to random error, but can also be the reflection of real differences in effect sizes among the interventions (this is called a random effects model).

Unlike CMA, HLM has the option to perform a meta-regression with multiple predictors. A meta-regression is like a normal regression-analysis, except that in a meta-regression the predictors, or moderators, are at the level of the intervention and the dependent variable is the size of the effect of the interventions. We used this analysis method to simultaneously test the effects of the multiple learning strategies on the summary effect.

We generally used multiple tests for measuring the effects of an intervention on academic performance. CMA could automatically calculate the mean of these outcomes, which formed an adequate approach to the use of this statistical package in our analyses. In HLM however, we wanted to use all effect size measures separately. In this way, it was possible to correct for the effects related to the measurement instrument when regressing the multiple predictors of the effect size. But in order to be able to add all effect sizes separately in the HLM-analyses, we had to adjust the weights. If we would not do this, the interventions measured via multiple tests would have a larger weight than the interventions examined via a single test. We therefore adjusted the weights by dividing them by the number of tests by which the effectiveness of the intervention was measured (actually, we multiplied the variance by the number of tests, so that the weight ï which was the inverse of the variance ï was divided by the number of tests).

6. Results

We will first present some descriptive characteristics of the strategy instruction interventions coded. Then, we will report the summary effect and describe if there was any publication bias. Next, it is examined whether any other intervention characteristics rather than the learning strategies influenced the effectiveness of the strategy instruction. After that, we will proceed with the core question of this study: Which (combinations of) learning strategies are the most effective in enhancing student performance? In investigating this question, we will separately provide the results for the subjects reading comprehension, writing, math and science. Finally, we will present the follow-up effects of the strategy instruction interventions.

6.1. Descriptives

The literature search resulted in 55 studies with in total 95 interventions that met our eligibility criteria. Of these 95 interventions, 23 focused on reading comprehension, 16 on writing, 44 on math, nine on science and three on other subjects. The effectiveness of the 95 interventions on student performance was measured by executing in total 180 tests. Thus on average, approximately two tests were done per intervention. The majority of these tests (122) were self-developed, whereas 50 tests were independent of the intervention. These were standardized tests, published tests or more general measures of student performance (for example report grades). Of eight tests it was unknown whether or not they were self-developed. In almost all cases the research design was a pretest-posttest control group approach. Only five interventions used a posttest only control group design and four interventions applied both designs.

Before describing the learning strategies taught, we will list some other characteristics of the interventions. As Table 1 shows, most interventions were directed at regular students. A minority of the interventions focused on students with special needs because of learning difficulties, students with a low socioeconomic status, or gifted students. Only one intervention program was provided to students characterized as having a high socioeconomic status. Furthermore, the interventions were implemented in the grades two up to eleven, of which the mean grade was 6.4.

Table 1 also indicates that most interventions were implemented by the teacher. In 15 cases, the strategy instruction was fully delivered via the computer. In other cases, the researcher or another person (a research assistant) offered the strategy instruction. In 27 interventions the students (also) worked on a computer and in 37 programs the students cooperated with one another. On average the instructions took 13 weeks, although there was a large variety in duration, with 2.3 sessions a week. Unfortunately, some studies did not report the duration and/or intensity of the intervention.

Table 1

Characteristics of the strategy instruction interventions

	N interventions	M	SD	Min	Max
Subject domain					
Reading	23				
Writing	16				
Math	44				
Science	9				
Other subjects	3				
Student characteristics					
Regular	67				
Low SES	7				
Special needs	14				
High SES	1				
Gifted	6				
Grade		6.41	2.16	2	11
Implementer					
Researcher	9				
Teacher	58				
Pc	15				
Other person	12				
Unknown	1				
PC-use	27				
Cooperation	37				
Duration in weeks	Valid 73	13.14	10.72	1	40
Intensity (days per week)	Valid 66	2.31	1.59	0.3	5

We coded 14 learning strategies. Table 2 indicates how often the strategies were present in the interventions. The table shows that the metacognitive strategies óplanning and predictionô and ómonitoring and controlô were most common strategy instructions. The metacognitive strategy óevaluation and reflectionô and the cognitive strategy óelaborationô formed part of about half of the strategy instruction interventions. Other learning strategies were less prevalent. óManaging the environmentô and the motivational strategies ótask valueô and ógoal orientationô were taught the least often.

Table 2

Frequency of the learning strategies in the interventions

Learning strategies	N	%
1. Metacognitive knowledge personal	13	13.7
2. Metacognitive knowledge general	35	36.8
3. Cognitive strategy rehearsal	10	10.5
4. Cognitive strategy elaboration	50	52.6
5. Cognitive strategy organization	32	33.7
6. Metacognitive strategy planning and prediction	68	71.6
7. Metacognitive strategy monitoring and control	81	85.3
8. Metacognitive strategy evaluation and reflection	54	56.8
9. Management strategy effort	15	15.8
10. Management strategy environment	6	6.3
11. Management strategy peers/others	21	22.1
12. Motivation strategy self-efficacy	13	13.7
13. Motivation strategy task value	6	6.3
14. Motivation strategy goal orientation	6	6.3

Table 3 presents the correlations between the learning strategies. The numbers 1 to 14 in the first row represent the learning strategies. The first column of Table 2 shows the numbers that correspond to the learning strategies. If in an intervention a certain learning strategy was taught, it was coded ó1ô and if not it was coded ó0ö. Table 3 shows which learning strategies were often combined in the interventions. A positive correlation indicates that teaching the one strategy is related to teaching the other strategy and a negative correlation that the presence of one of both strategies often excludes that of the other.

Table 3 shows that there are several significant correlations between the learning strategies. According to Cohen (1988), a correlation of 0.1 is weak, one of 0.3 moderate and one of 0.5 and higher strong. When looking at the correlations of 0.25 and higher, we see that teaching personal metacognitive knowledge is related to teaching the motivation strategy óself-efficacyö. Furthermore, teaching the metacognitive strategy óplanning and predictionô is related to teaching the metacognitive strategies ómonitoring and controlô and óevaluation and reflectionô and the management strategy óeffortö. The metacognitive strategy óevaluation and reflectionô is also related to the management strategy óeffortö. The cognitive strategy órehearsalô is associated with the management strategies óeffortô and ópeers/othersô and the motivation strategies óself-efficacyô and ótask valueö. The relationship with task value is strong. Teaching the cognitive strategy óorganizationô is connected to teaching the management strategy ópeers/othersô and the motivation strategy ótask valueö. The management strategy óeffortô is also related to the management strategy ópeers/othersô and ï strongly ï to the motivation strategies óself-efficacyô and ótask valueö. Managing the environment is also associated with the management strategy ópeers/othersö, and with the motivation strategy óself-efficacyö. Finally, the management strategy ópeers/othersô is also connected with the motivation strategies ótask valueô and ógoal orientationö. The relationship with task value is strong.

Table 3

Correlations between the learning strategies

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.00													
2	-.18	1.00												
3	.06	.16	1.00											
4	-.05	.03	-.02	1.00										
5	-.09	-.13	.19	.19	1.00									
6	.18	.09	.22*	.06	-.04	1.00								
7	.17	.01	.14	.20	-.08	.27**	1.00							
8	.16	-.04	.16	-.19	.13	.25*	-.06	1.00						
9	.08	.03	.42**	-.17	.24*	.27**	-.06	.32**	1.00					
10	.15	-.02	.19	.07	.00	-.12	.11	.05	.12	1.00				
11	.01	.12	.40**	.10	.32**	.05	.22*	.11	.26*	.28**	1.00			
12	.38**	-.11	.26*	-.11	.04	.18	-.09	.16	.50**	.27**	.01	1.00		
13	-.10	.16	.62**	-.19	.36**	.16	.11	.23*	.48**	-.07	.49**	-.10	1.00	
14	.15	-.02	-.09	-.10	.09	.16	-.01	.23*	.24*	.11	.28**	.15	-.07	1.00

Notes. $^{**}p< .01$; $^{*}p< .05$.

Numbers 1 up to and including 14 represent the learning strategies. Table 2 shows the numbers belonging to the strategies.

6.2. Average effect of strategy instruction on student performance

Using meta-analysis, we computed the summary effect of all 95 interventions, resulting in an average (weighted) effect size estimate of Hedgesö *g* = 0.66 (*SE* =0 .05; confidence interval of Hedgesö *g* = 0.56 to 0.76): a significant effect. Following Cohen (1988), this is a medium to high effect size. The *Q*-statistic indicates that there was a significant heterogeneity among the effect sizes (*Q* = 439.3; *df* = 94; *p* = 0.000), which means that it is unlikely that all interventions shared the same true effect size. Considering the differences among the interventions, this result is not surprising. The interventions included in the meta-analysis differed from one another in many respects; just consider the differences in learning strategies taught. Given these differences, it is very unlikely that each intervention had exactly the same effect on student performance. The I^2 = 78.6, which suggests that 78.6% of the dispersion of the effect sizes of the interventions reflects real differences in true effect size, only 11.4% was due to random error.

We also tested if there was any publication bias. In a meta-analysis it is plausible to assume that studies reporting on non-significant or negative effects are underrepresented, because they are less likely to be published. To reveal to what degree publication bias might have occurred in the current meta-analysis, we applied Duval and Tweedieǿs *Trim and Fill* method (Borenstein, et al., 2009; Peters, Sutton, Jones, Abrams & Rushton, 2007). We used a random effects model to estimate if there were any interventions missing in the meta-analysis. With the trim and fill method, the extreme effect sizes of interventions on the right hand of a funnel are trimmed to obtain a symmetric funnel plot. In this way a new unbiased estimate of the summary effect size is calculated. Next, the funnel plot is filled again with the trimmed effect sizes of the interventions and their counterparts on the left hand of the funnel plot (the missing interventions), after which a pooled estimate of the summary effect size is calculated. Figure 1 shows the funnel plot of the relationship between standard error and effect size in the current meta-analysis. The interventions with a small sample size have in general a larger standard error and appear at the bottom of the figure. Larger interventions appear higher up. As can be seen in the figure, the interventions are quite neatly spread. According to the trim and fill method, there were no missing studies, suggesting that there was no publication bias. This result was supported by Rosenthalǿs classic Fail-safe *N*, which was 5196, and Orwinǿs Fail-safe *N*, which was 777, indicating that 5196 and 777 interventions, respectively, had to have been added to the meta-analysis with an effect size of Hedgesǿs $g = 0$, before the effect found would have become non-significant (at p <0.05).

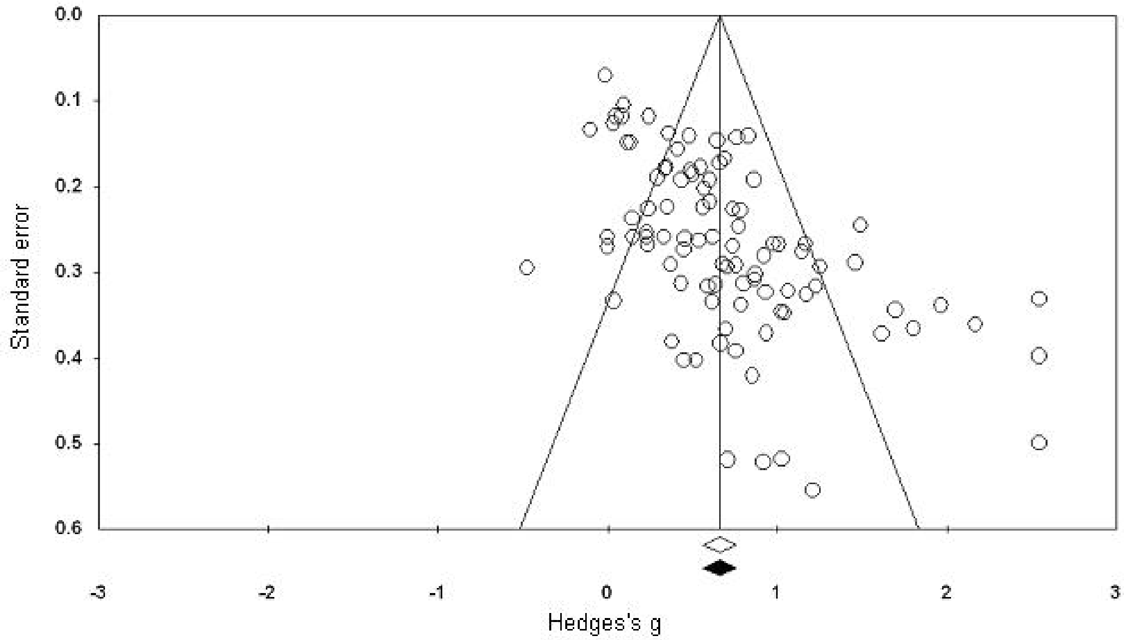

Figure 1. *Funnel plot of standard error by effect size for all interventions. The observed interventions are represented by an open circle; imputed interventions would have been represented by a filled circle.*

6.3. Effects of intervention characteristics (other than strategies) on student performance

6.3.1. Subject domain. In our meta-analysis most interventions were directed at one of the four subject domains reading comprehension, writing a text, mathematics and science. Table 4 depicts the average strategy instruction effects estimated for each of the subject domains (see column with Hedgesǵ*g*). Table 4 shows that strategy instruction has the largest effect on student performance for the subject writing a text. With a Hedgesǵ*g* of 1.25, the average effect is very high. For the other subjects the effect sizes are much lower, although they are still considerable for science and math. For reading comprehension the effect of strategy instruction on student performance is on average small to moderate. The three interventions applying to other subjects have on average a small effect, as Table 4 indicates. The between subject differences proved to be significant. The meta-regression analysis with the measurement instrument as covariate revealed that the average effect of strategy instruction in writing was significantly higher than in all other subjects. The average effect of strategy instruction in reading comprehension was significantly lower than in writing, math and science, but not compared to the other-subject interventions. The effects of strategy instruction in math and science did not differ significantly from each other. The last column of Table 4 shows the meta-regression results with as reference category the subject domain reading comprehension.

Table 4

Mean effect size per subject domain and meta-regression

	Mean Hedgesô *g* (*SE*)	Regression *B* (*SE*)
Intercept		.34 (.07)**
Meas. instr. self-developed		.07 (.10)
Reading	.36 (.08)**	
Writing	1.25 (.12)**	.80 (.14)**
Math	.66 (.06)**	.28 (.11)*
Science	.73 (.13)**	.33 (.14)*
Other	.23 (.23)	-.20 (.18)

Notes. $^{**}p< 0.01$; $^{*}p< 0.05$.

With as reference category for the measurement instrument óintervention independent testô and for the subject óreadingô.

6.3.2. Measurement instrument. The effects of the 95 interventions in the meta-analysis were measured via both self-developed tests and tests not specifically designed for the intervention, the so-called intervention independent tests. A meta-regression with the measurement instrument as the predictor showed that self-developed tests obtained an average effect size of Hedgesô *g* = 0.78 and intervention independent tests an effect size of Hedgesô *g* = 0.45 (unstandardized regression coefficient (and standard error) of the intercept: 0.45 (0.07) and of the measurement instrument 0.33 (0.09)). The difference in effect size was significant.

It appeared that in particular reading comprehension interventions and other-subject interventions were measured using intervention independent tests. Of the 43 measures for reading comprehension, 30 were measured with an intervention independent test (70%). For the other-subject interventions, 67% of the six measures were intervention independent. Writing, math and science interventions were far less often measured with an intervention independent test. For science, 29% of the 17 measurements were independent of the intervention, for writing 11% of the 45 and for math 10% of the 61. As Table 4 shows, the strategy instructions for reading comprehension and other-subjects were also the interventions with the lowest average effect size. However, this remained to be the case after taking the measurement instrument into account, as indicated in the last column of Table 4. When analyzing the effects of the predictors ómeasurement instrumentô and ósubject domainô simultaneously, the effect of the measurement instrument turned out to be not significant. The average effect sizes per subject domain only differed slightly compared to the effect sizes reported in the first column of Table 4. For example, for the reference category ‘reading comprehension’ the estimated effect size equaled the intercept, which was 0.34. For writing, the average estimated effect size was the intercept plus the coefficient for writing, so 0.34 +0.80 = 1.24.

Because of the relationship between the measurement instrument and the subject domain, we also analyzed the effect of the measurement instrument separately for each subject domain. It appeared that only for reading comprehension, intervention independent tests result in significantly lower effects than self-developed tests (the difference in effect size was 0.58; *SE* = 0.15; $p = 0.001$). For writing, math and science, the effect sizes of intervention independent tests did not differ significantly compared to those of self-developed tests (difference in effect size was 0.24 (*SE* = 0.41), 0.23 (*SE* = 0.14) and 0.25 (*SE* = 0.18) respectively, whereby for writing self-developed tests yielded larger effects and for math and science intervention independent tests produced higher impact scores).

6.3.3. Student characteristics. Table 5 shows the average strategy instruction effect sizes for the different categories of the predictor ‘student characteristics’. As there was only one intervention participated by high SES students, we decided to merge this category with the gifted students.

Table 5

Mean effect size for student characteristics and meta-regression

	Mean Hedges' *g* (*SE*)	Regression *B* (*SE*)
Intercept		.40 (.07)**
Meas. instr. self-developed		.33 (.09)**
Regular	.61 (.06)**	
Low SES	.72 (.18)**	.06 (.15)
Special needs	.89 (.14)**	.23 (.12)
Gifted/ high SES	.72 (.18)**	.16 (.17)

Notes. $^{**}p< 0.01$; $^{*}p< 0.05$.

With as reference category for the measurement instrument ‘intervention independent test’ and for the characteristics ‘regular students’.

A meta-analysis of variance revealed no significant between groups differences for the predictor student characteristics. Using meta-regression, we examined the between groups differences more thoroughly. In this way, we could compare the two groups with each other rather than analyzing the between groups differences as a total. A meta-regression analysis with the measurement instrument as the covariate and student characteristics as the predictor also indicated that there were no significant differences between the groups. However, there was a weak signal of a trend showing that special needs students benefited slightly more from strategy instruction than regular students (estimated difference in effect size 0.23 (SE = 0.12; p = 0.058). The last column of Table 5 presents the meta-regression results.

6.3.4. Grade. There was no relationship between the effect of strategy instruction on student performance and the grade the students were in. A meta-regression with grade as predictor and measurement instrument as covariate revealed a coefficient of only B = -0.01 (SE = 0.02; p = 0.548) for grade.

6.3.5. Implementer of the intervention. Table 6 provides the results of the analysis of the influence of the implementer on the intervention’s effectiveness.

Table 6

Mean effect size per implementer and meta-regression

	Mean Hedges' *g* (*SE*)	Regression *B* (*SE*)
Intercept		.68 (.13)**
Meas. instr. self-developed		.38 (.09)**
Researcher	.81 (.17)**	
Teacher	.60 (.06)**	-.32 (.14)*
Pc	.59 (.13)**	-.43 (.18)*
Other person	.95 (.16)**	.09 (.18)

Notes. $^{**}p< 0.01$; $^{*}p< 0.05$.

With as reference category for the measurement instrument ‘intervention independent test’ and for the implementer ‘researcher’.

It appeared that interventions implemented by a person other than the researcher or teacher (mostly a research assistant) had the largest effects, followed by interventions implemented by the researcher him/herself. The effects of strategy instruction were the lowest when the teacher or a computer delivered the intervention. A meta-analysis of variance however, indicated that there were no significant between groups differences. Using meta-regression, the group differences were examined more thoroughly. In this analysis the measurement instrument served as the covariate. The analysis revealed that there was no significant difference in effect between interventions implemented by the researcher and those implemented by another person. Interventions implemented by the researcher or by another person did, however, produce larger effects than those implemented by the teacher or the computer. There were no differences in effect between interventions implemented by the teacher and those implemented by the computer.

6.3.6. Duration and intensity of the intervention. We found a small effect of the duration of the intervention on the effectiveness. Longer interventions had slightly smaller effects on student performance than shorter interventions. Meta-regression analysis with the measurement instrument as the covariate and duration and intensity as predictors reported an unstandardized regression coefficient of B = -0.01 for the number of weeks that the intervention took, as can be seen in Table 7. This finding implies that an intervention with a duration of 10 weeks had on average a 0.1 higher effect size than an intervention of 20 weeks. The intensity of the intervention, measured in number of sessions per week, had no influence on its effectiveness.

Table 7

Meta-regression of the duration and intensity of the intervention

	B (*SE*)
Intercept	.68 (.09)**
Meas. instr. self-developed	.18 (.09)
Duration in weeks	-.01 (.00)*
Intensity in times per week	-.00 (.00)

Notes. $^{**}p< 0.01$; $^{*}p< 0.05$.

Whereby the reference category for the measurement instrument is ‗intervention independent test'.

6.3.7. Cooperation during the intervention. A meta-regression analysis with the measurement instrument as the covariate showed no significant differences between interventions in which students could cooperate and those in which cooperation were not allowed (unstandardized coefficient for cooperation: B = 0.13; SE = 0.09; p = 0.142).

6.3.8. Computer use during the intervention. A meta-regression analysis with the measurement instrument as the covariate also showed no significant differences between interventions in which students used a computer and those in which students did not (unstandardized coefficient for computer use: B = -0.08; SE = 0.09; p = 0.420).

6.4. Effects of learning strategies on student performance

We first separately tested the effects of each learning strategy on student performance in a meta-regression model with the measurement instrument as the covariate. Table 8 shows the resulting regression coefficients for the learning strategies. The analyses showed significant positive effects of four of the fourteen learning strategies. Strategy instruction containing the strategies general metacognitive knowledge, planning and prediction, rehearsal or task value produced significantly higher effects than strategy instruction that did not include these strategies. For example, the effect size of strategy instruction aimed at general metacognitive knowledge was on average 0.3 higher than that of strategy instruction that did not include this approach. Table 8 shows that the inclusion of the motivational strategy ótask valueô had by far the largest positive impact on the instructionøs effectiveness. Furthermore, the coefficients in the table reveal that inclusion of the learning strategy ógoal orientationô had a negative influence on the interventionøs effectiveness.

Table 8

Effects of the individual learning strategies on student performance: meta-regression results

	B (*SE*)
Metacognitive knowledge personal	.04 (.12)
Metacognitive knowledge general	.31 (.08)**
Cognitive strategy rehearsal	.42 (.15)**
Cognitive strategy elaboration	.14 (.09)
Cognitive strategy organization	.09 (.09)
Metacognitive strategy planning and prediction	.20 (.09)*
Metacognitive strategy monitoring and control	.07 (.12)
Metacognitive strategy evaluation and reflection	.06 (.08)
Management strategy effort	.02 (.13)
Management strategy environment	-.03 (.15)
Management strategy peers/others	.03 (.10)
Motivation strategy self-efficacy	-.10 (.13)
Motivation strategy task value	.94 (.21)**
Motivation strategy goal orientation	-.35 (.16)*

Notes. $^{**}p < 0.01$; $^{*}p < 0.05$.

For all learning strategies the reference category is óstrategy not in interventionô.

Next, we analyzed the effects of the significant learning strategies on student performance simultaneously. Again, the measurement instrument served as the covariate in the meta-regression. Table 9 lists the results of this analysis. The effects of all learning strategies on student performance remained to be significant, except for those of the cognitive strategy ‘rehearsal’. The effect of including ‘goal orientation’ in the strategy instruction remained negative. This analysis indicates that strategy instruction based on the combination of general metacognitive knowledge, planning and prediction, and task value enhances student performance the most effectively. According to the tested model, the added value of instructing these three strategies was expected to be Hedges’ *g* = 1.23 (calculated as the sum of the coefficients of the three strategies).

Table 9

Meta-regression of multiple learning strategies on student performance

	B (*SE*)
Intercept	.29 (.08)**
Measurement instrument self-developed	.20 (.08)*
Metacognitive knowledge general	.25 (.08)**
Cognitive strategy rehearsal	.01 (.16)
Metacognitive strategy planning and prediction	.17 (.08)*
Motivation strategy task value	.81 (.23)**
Motivation strategy goal orientation	-.33 (.14)*

Notes. $^{**}p < 0.01$; $^{*}p < 0.05$.

With as reference category for the measurement instrument ‘intervention independent test’ and for the the learning strategies ‘strategy not in intervention’.

6.5. Effects of the learning strategies on reading comprehension

Before presenting the results of the analysis of the effects of learning strategies on reading comprehension, we will provide some descriptives of the 23 reading comprehension interventions. First of all, there appeared to be no publication bias for the reading comprehension interventions. The funnel plot in Figure 2 depicts this finding. According to the trim and fill method, there were no missing studies and therefore no publication bias. This result was supported by Rosenthal’s classic Fail-safe *N*, which was 438, and Orwin’s Fail-safe *N*, which was 80, indicating that the number of interventions added to the meta-analysis had to have been 438 and 80 respectively, with an effect size of Hedges’ s *g* = 0, before the effect found would become non-significant (at $p < 0.05$).

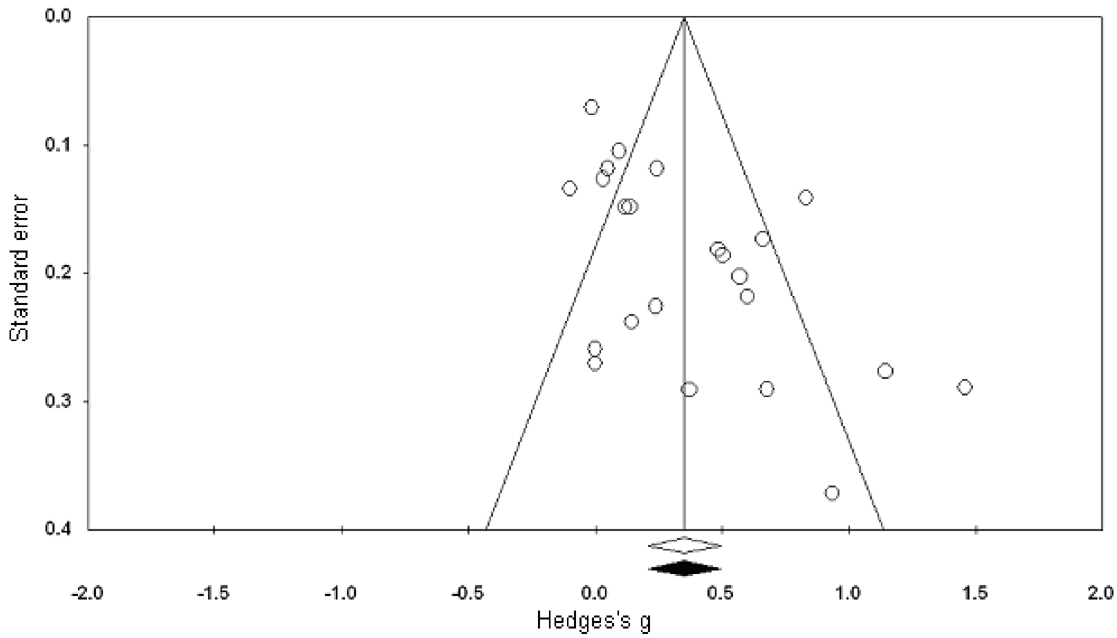

Figure 2. *Funnel plot of standard error by effect size for reading comprehension interventions. The observed interventions are represented by an open circle; imputed interventions would have been represented by a filled circle.*

Table 10 shows the frequency of the learning strategies in the reading comprehension interventions. The large majority of the interventions included the metacognitive strategy ómonitoring and controlô and the cognitive method óelaborationô. Less frequently, but still often, the metacognitive approaches óplanning and predictionô and óevaluation and reflectionô and the cognitive strategy óorganizationô were taught. In none of the reading comprehension interventions the motivational strategies ótask valueô and ógoal orientationô were offered.

To examine which learning strategies often co-occurred in the reading comprehension interventions, the correlations among the approaches were calculated. Table 11 gives an overview. óPlanning and predictionô and óevaluation and reflectionô were often taught simultaneously, which also applied to óelaborationô and óorganizationô, as well as to óeffortô and óself-efficacyô. Some strategy combinations did not co-occur. Interventions aimed at general metacognitive knowledge often did not include óorganizationô, and vice versa. Other combinations which did not occur were óplanning and predictionô and the management strategy óenvironmentô, and óplanning and predictionô and the management strategy ópeers/othersô.

Table 10

Frequency of the learning strategies in reading comprehension interventions

Learning strategies	N	%
1. Metacognitive knowledge personal	2	8.7
2. Metacognitive knowledge general	8	34.8
3. Cognitive strategy rehearsal	2	8.7
4. Cognitive strategy elaboration	19	82.6
5. Cognitive strategy organization	11	47.8
6. Metacognitive strategy planning and prediction	14	60.9
7. Metacognitive strategy monitoring and control	22	95.7
8. Metacognitive strategy evaluation and reflection	12	52.2
9. Management strategy effort	3	13.0
10. Management strategy environment	3	13.0
11. Management strategy peers/others	6	26.1
12. Motivation strategy self-efficacy	3	13.0
13. Motivation strategy task value	0	0.0
14. Motivation strategy goal orientation	0	0.0

Table 11

Correlations between the learning strategies of reading comprehension interventions

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.00													
2	-.23	1.00												
3	-.10	.10	1.00											
4	-.27	-.39	.14	1.00										
5	-.30	-.52*	-.30	.44*	1.00									
6	.25	.02	.25	-.37	-.12	1.00								
7	.07	.16	.07	-.10	-.22	-.17	1.00							
8	-.01	.15	-.01	.25	.05	.48*	-.20	1.00						
9	-.12	-.28	-.12	.18	.15	.31	.08	.37	1.00					
10	-.12	-.01	-.12	.18	.15	-.48*	.08	-.15	-.15	1.00				
11	.17	-.23	-.18	.27	.22	-.54**	.13	-.22	-.23	.36	1.00			
12	-.12	-.28	.34	.18	.15	.31	.08	.11	.62**	-.15	-.23	1.00		
13														
14														

Notes. $^{**}p < .01$; $^{*}p < .05$.

Numbers 1 to 14 represent the learning strategies. Table 10 shows which number belongs to which strategy.

Next, we examined the effect of the separate learning strategies on reading comprehension. For each strategy, we ran a meta-regression model with ólearning strategyô as the predictor, ómeasurement instrumentô as the covariate and the effect sizes of the reading comprehension interventions as the criterion. Table 12 displays the regression coefficients of the learning strategies. The teaching of general metacognitive knowledge had a significant positive effect on reading comprehension. Strategy instruction that included this strategy had on average a 0.27 higher effect size than interventions without this method. Furthermore, the table reveals some interesting results with respect to the learning strategy ëelaborationí and the management strategy ëpeers/othersí. Strategy instructions that included one of these approaches had on average lower effects on reading comprehension than those that did not include (one of) these methods. With respect to ëelaborationí we should keep in mind that there were only four reading comprehension interventions that did not include this strategy. Thus, the effects were computed on the basis of a small amount of interventions. Nonetheless, the effect found was highly significant.

Table 12

Effects of the individual learning strategies on reading comprehension: meta-regression results

	B (*SE*)
Metacognitive knowledge personal	-.17 (.13)
Metacognitive knowledge general	.27 (.12)*
Cognitive strategy rehearsal	.08 (.21)
Cognitive strategy elaboration	-.48 (.15)**
Cognitive strategy organization	-.07 (.11)
Metacognitive strategy planning and prediction	.15 (.11)
Metacognitive strategy monitoring and control	-.29 (.23)
Metacognitive strategy evaluation and reflection	-.05 (.11)
Management strategy effort	.07 (.16)
Management strategy environment	.04 (.13)
Management strategy peers/others	-.27 (.09)**
Motivation strategy self-efficacy	.10 (.17)
Motivation strategy task value	
Motivation strategy goal orientation	

Notes. $^{**}p < 0.01$; $^{*}p < 0.05$.

For all learning strategies the reference category is ëstrategy not in interventioní. The cells are grey when there are less than five interventions which include or which do not include the strategy under study. The cells are empty when there are no interventions which include the strategy, or when there are no interventions without the strategy.

After analyzing the significant learning strategies simultaneously, we saw that only the negative effect of the management strategy ëpeers/othersí had remained significant. The positive effect of general metacognitive knowledge decreased after taking the other strategies into account, as a result of which it became non-significant. Table 13 lists the results of the meta-regression.

Table 13

Meta-regression of multiple learning strategies on reading comprehension

	B (*SE*)
Intercept	.59 (.17)**
Measurement instrument self-developed	.48 (.14)**
Metacognitive knowledge general	.09 (.12)
Cognitive strategy elaboration	-.34 (.17)
Management strategy peers/others	-.19 (.09)*

Notes. $^{**}p< 0.01$; $^{*}p< 0.05$.

With as reference category for the measurement instrument ‘intervention independent test’ and for the learning strategies ‘strategy not in intervention’.

6.6. Effects of learning strategies on writing

We started by analyzing if there was any publication bias for the 16 writing interventions in our meta-analysis. The Duval and Tweedie's *Trim and Fill* method applied to a random effects model indicated that there were no interventions missing. This finding was supported by Rosenthal's classic Fail-safe *N*, which was 836, and Orwin's Fail-safe *N*, which was 338. Firgure 3 shows the funnel plot of the interventions.

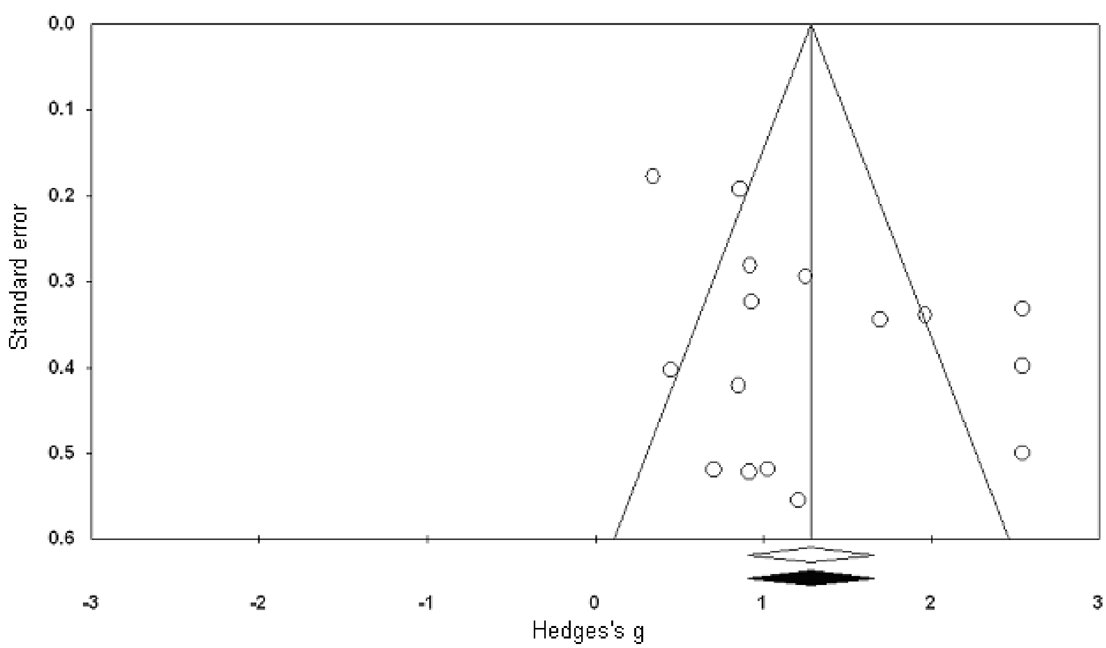

Figure 3. *Funnel plot of standard error by effect size for writing interventions. The observed interventions are represented by an open circle; imputed interventions would have been represented by a filled circle.*

The most frequently taught learning strategies in the writing interventions were the cognitive strategy óorganizationô and the metacognitive strategies óplanning and predictionô, ómonitoring and controlô and óevaluation and reflectionô. General metacognitive knowledge, the management strategy ópeers/othersô and the cognitive strategy óelaborationô were also quite common: see Table 14. The relatively high percentages demonstrate that the writing interventions included on average quite a large number of learning strategies.

Table 14

Frequency of the learning strategies in writing interventions

Learning strategies	N	%
1. Metacognitive knowledge personal	2	12.5
2. Metacognitive knowledge general	9	56.3
3. Cognitive strategy rehearsal	7	43.8
4. Cognitive strategy elaboration	8	50.0
5. Cognitive strategy organization	14	87.5
6. Metacognitive strategy planning and prediction	13	81.3
7. Metacognitive strategy monitoring and control	12	75.0
8. Metacognitive strategy evaluation and reflection	11	68.8
9. Management strategy effort	7	43.8
10. Management strategy environment	1	6.3
11. Management strategy peers/others	9	56.3
12. Motivation strategy self-efficacy	3	18.8
13. Motivation strategy task value	6	37.5
14. Motivation strategy goal orientation	2	12.5

Table 15

Correlations between the learning strategies of writing interventions

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.00													
2	-.05	1.00												
3	.05	.27	1.00											
4	.00	-.13	-.13	1.00										
5	.14	-.33	-.05	.00	1.00									
6	.18	-.10	.42	-.16	.30	1.00								
7	.22	-.22	.51*	.00	.22	.83**	1.00							
8	-.56*	-.05	.32	.13	.15	.37	.55*	1.00						
9	.05	.02	.75**	-.38	-.05	.42	.51*	.32	1.00					
10	-.10	.23	.29	.26	-.68**	.12	.15	.17	.29	1.00				
11	-.43	-.02	.52*	-.13	.05	.55*	.66**	.76**	.52*	.23	1.00			
12	.79**	.10	.22	.16	-.30	.23	.28	-.37	.22	.54*	-.22	1.00		
13	-.29	.16	.62*	-.52*	.29	.37	.45	.52*	.62*	-.20	.68**	-.37	1.00	
14	-.14	-.43	-.33	.38	.14	.18	.22	.25	-.33	-.10	.33	-.18	-.29	1.00

Notes. $^{**}p < .01$; $^{*}p < .05$.

Numbers 1 to 14 represent the learning strategies. Table 14 shows which number belongs to which strategy.

Because of the relatively high number of learning strategies included in the writing interventions, there were a lot of combinations of methods often taught together. This is shown by the high correlations among the learning strategies, as reported in Table 15.

Table 16 indicates the effect of the learning strategies on studentsô writing performance (with measurement instrument as the covariate). There were only two significant strategies found: general metacognitive knowledge and the metacognitive approach óevaluation and reflectionö. Both had a large positive effect on studentsô writing performance. Strategy instruction in writing which included general metacognitive knowledge had on average a 0.78 higher effect size than instructions without this strategy. The effect of óevaluation and reflectionö was 0.60. Looking at the other coefficients in Table 16, we see that some are quite high, but not significant. Most of the learning methods were represented in less than five interventions in one of the categories óstrategy includedö and óstrategy not includedö. This number might be too low to provide a sufficiently powerful statistical significance base.

Table 16

Effects of the individual learning strategies on writing: meta-regression results

	B (*SE*)
Metacognitive knowledge personal	-.43 (.47)
Metacognitive knowledge general	.78 (.26)**
Cognitive strategy rehearsal	.37 (.30)
Cognitive strategy elaboration	.47 (.29)
Cognitive strategy organization	-.42 (.45)
Metacognitive strategy planning and prediction	.38 (.38)
Metacognitive strategy monitoring and control	.46 (.32)
Metacognitive strategy evaluation and reflection	.60 (.30)*
Management strategy effort	-.17 (.31)
Management strategy environment	.72 (.54)
Management strategy peers/others	.45 (.30)
Motivation strategy self-efficacy	.08 (.39)
Motivation strategy task value	.43 (.30)
Motivation strategy goal orientation	-.72 (.58)

Notes. $^{**}p < 0.01$; $^{*}p < 0.05$.

For all learning strategies the reference category is óstrategy not in interventionö. The cells are grey when there are less than five interventions with or without the strategy under study.

Next, we analyzed the effects of the two significant learning strategies simultaneously. Table 17 reports the results of this analysis. Now both the learning strategies ógeneral metacognitive knowledgeö and óevaluation and reflectionö had a significant positive effect. This finding indicates that strategy instruction in writing which includes these two learning strategies, is the most effective approach to promoting studentsô writing skills. The expected added value of these strategies to writing performance was Hedgesô *g* = 1.32.

Table 17

Meta-regression of multiple learning strategies on writing

	B (*SE*)
Intercept	.60 (.32)
Measurement instrument self-developed	-.16 (.35)
Metacognitive knowledge general	.75 (.24)**
Metacognitive strategy evaluation and reflection	.57 (.26)*

Notes. $^{**}p< 0.01$; $^{*}p< 0.05$.

With as reference category for the measurement instrument óintervention independent testô and for the learning strategies óstrategy not in interventionö.

6.7. Effects of learning strategies on mathematics

Similarly to the reading comprehension and writing interventions, the analysis revealed no publication bias for the 44 mathematics instructions included in the meta-analysis. Duval and Tweedieös trim and fill method for random models found no missing interventions, as is shown in the funnel plot in Figure 4, while Rosenthalös classic Fail-safe *N* (3105) and Orwinös Fail-safe *N* (491) were fairly high.

Table 18 reports the frequency with which the learning strategies were used in the mathematics interventions. It shows that most interventions included the metacognitive strategies ómonitoring and controlô and óplanning and predictionö. The next mostly used strategies were the metacognitive method óevaluation and reflectionô and the cognitive strategy óelaborationö. None of the interventions included the motivational strategy ótask valueö. Compared to the reading comprehension and writing interventions, the average number of strategies taught in the mathematics instructions was somewhat lower. The average relative frequency of the learning strategies (calculated as the mean percentage of frequency) was 32.6% for reading comprehension, 46.5% for writing and 25.0% for math.

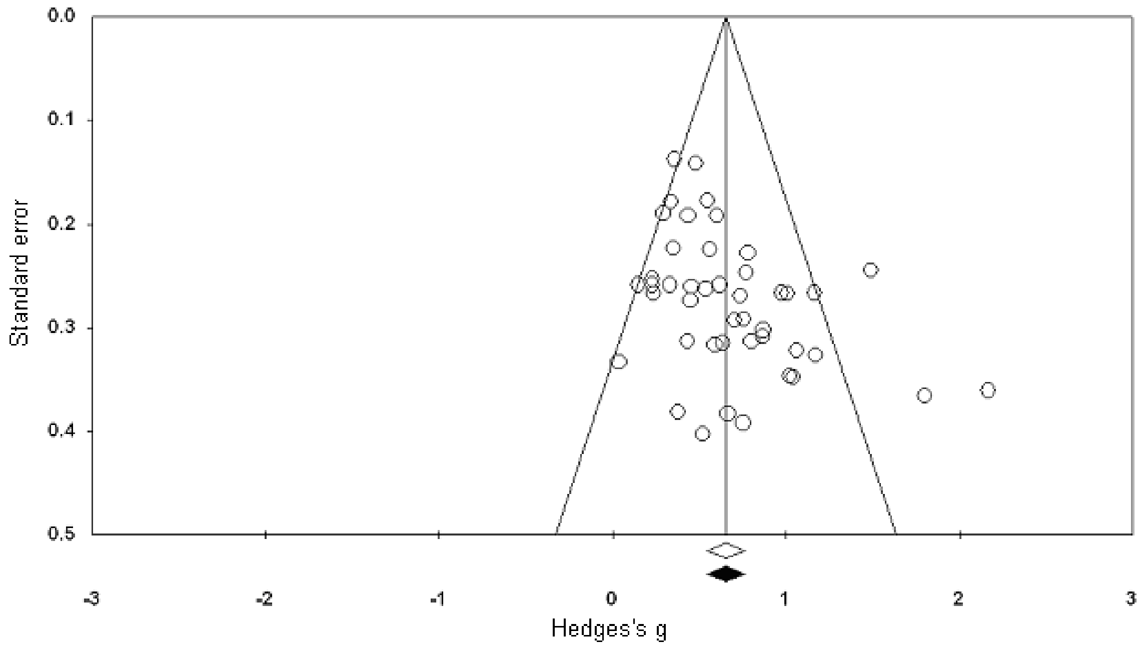

Figure 4. *Funnel plot of standard error by effect size for math interventions. The observed interventions are represented by an open circle; imputed interventions would have been represented by a filled circle.*

Table 18

Frequency of the learning strategies in math interventions

Learning strategies	N	%
1. Metacognitive knowledge personal	6	13.6
2. Metacognitive knowledge general	14	31.8
3. Cognitive strategy rehearsal	1	2.3
4. Cognitive strategy elaboration	18	40.9
5. Cognitive strategy organization	4	9.1
6. Metacognitive strategy planning and prediction	32	72.7
7. Metacognitive strategy monitoring and control	36	81.8
8. Metacognitive strategy evaluation and reflection	21	47.7
9. Management strategy effort	5	11.4
10. Management strategy environment	2	4.5
11. Management strategy peers/others	5	11.4
12. Motivation strategy self-efficacy	7	15.9
13. Motivation strategy task value	0	0.0
14. Motivation strategy goal orientation	3	6.8

Table 19 shows that the math interventions frequently included various combinations of learning strategies. We will only describe the strong combinations (*r*Ó0.5). Personal metacognitive knowledge was often taught simultaneously with ómanaging the environmentô or the motivational strategy óself-efficacyô. When evaluation and reflection were taught, the use of the strategy óelaborationô was not common (and vice versa). óRehearsalô and ómanaging the environmentô often co-occurred, just as the combinations óeffortô and óself-efficacyô and óeffortô and ógoal orientationô. Finally, ómanaging the environmentô and óself-efficacyô also often co-occurred.

Table 19

Correlations between learning strategies of math interventions

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.00													
2	-.13	1.00												
3	.38*	-.10	1.00											
4	-.20	.33*	-.13	1.00										
5	.10	-.22	-.05	-.10	1.00									
6	.09	.09	.09	.41**	-.16	1.00								
7	.19	.20	.07	.27	-.26	.37*	1.00							
8	.42**	-.26	.16	-.52**	.17	-.03	-.26	1.00						
9	.28	.06	-.05	-.30*	.14	.22	-.39**	.38*	1.00					
10	.55**	-.15	.70**	-.18	-.07	.13	.10	.23	.27	1.00				
11	.28	.37*	.43**	.14	-.11	.22	.17	-.06	.10	.27	1.00			
12	.55**	-.16	.35*	-.36*	.08	.13	-.28	.46**	.63**	.50**	.24	1.00		
13														
14	.42**	.20	-.04	-.23	-.09	.17	-.11	.28	.76**	.37*	.19	.38*		1.00

Notes. $^{**}p< .01$; $^{*}p< .05$.

Numbers 1 to 14 represent the learning strategies. Table 18 shows which number belongs to which strategy.

Table 20

Effects of the individual learning strategies on math: meta-regression results

	B (*SE*)
Metacognitive knowledge personal	.16 (.15)
Metacognitive knowledge general	.03 (.11)
Cognitive strategy rehearsal	-.22 (.33)
Cognitive strategy elaboration	.21 (.10)*
Cognitive strategy organization	.11 (.20)
Metacognitive strategy planning and prediction	.08 (.12)
Metacognitive strategy monitoring and control	.20 (.14)
Metacognitive strategy evaluation and reflection	-.03 (.11)
Management strategy effort	-.28 (.15)
Management strategy environment	-.25 (.22)
Management strategy peers/others	.16 (.17)
Motivation strategy self-efficacy	-.27 (.14)
Motivation strategy task value	
Motivation strategy goal orientation	-.21 (.19)

Notes. $^{**}p< 0.01$; $^{*}p< 0.05$.

For all learning strategies the reference category is óstrategy not in interventionô. The cells are grey when there are less than five interventions with or without the strategy under study. The cells are empty when there are no interventions which include the strategy, or when there are no interventions which do not include the strategy.

Meta-regression analyses with the effect sizes of mathematics performance as the criterion, ómeasurement instrumentô as the covariate and each separate learning strategy as the individual predictors, indicated that only the cognitive learning strategy óelaborationô significantly contributed to studentsô mathematics performance. Instruction which included elaboration had on average a 0.2 higher effect size than interventions without this strategy. Table 20 lists the results of the meta-regression analyses. Because we only found one significant learning strategy, we could not simultaneously analyze the effects of multiple learning strategies here.

6.8. Effects of learning strategies on science

Our meta-analysis included nine interventions in science. Unfortunately, in this domain there was some publication bias. Duval and Tweedieôs trim and fill method for random models located three missing interventions. This result is shown in the funnel plot in Figure 5, in which the missing interventions are displayed as a filled circle. These missing interventions had on average a lower effect size than the interventions included in the study. According to Duval and Tweedieôs method, the average weighted effect size of the interventions was now Hedgesô g = 0.69 (due to differences in method of analysis, this rate was slightly higher than the estimate of 0.66 reported earlier for the science interventions), whereas the unbiased estimate would be 0.61; a small difference. Rosenthalôs classic Fail-safe N, which was 228, and Orwinôs Fail-safe N, which was 114, however, indicated that we would have needed a considerable number of interventions with a zero effect size for the average impact of the science interventions to become non-significant.

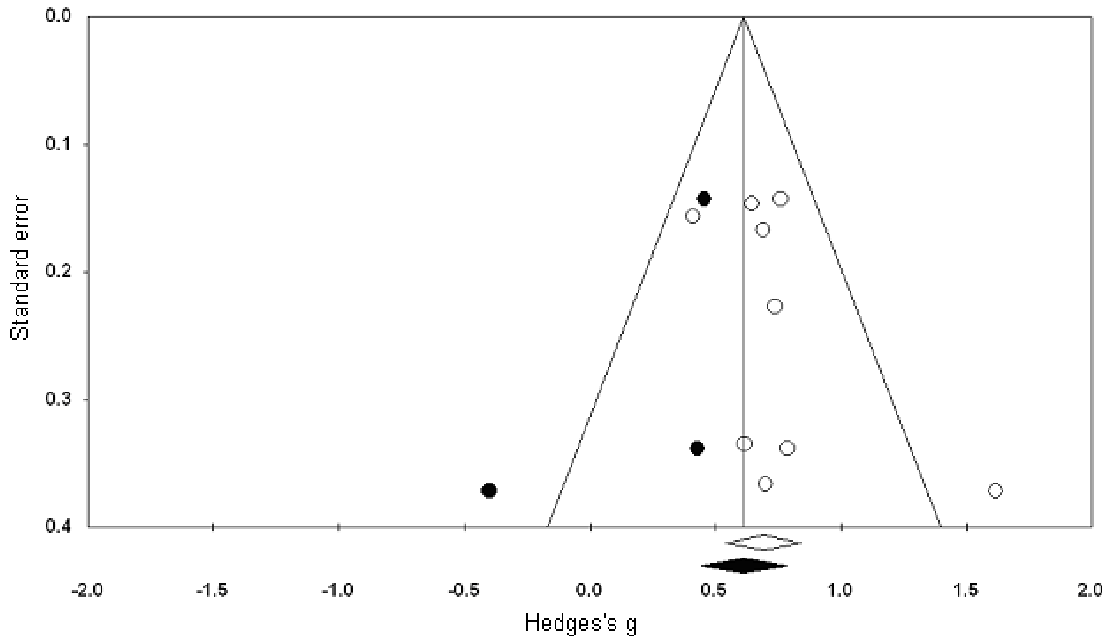

Figure 5. *Funnel plot of standard error by effect size for science interventions. The observed interventions are represented by an open circle and the imputed interventions by a filled circle.*

Table 21 shows that the science interventions often included the three metacognitive strategies ómonitoring and controlö, óevaluation and reflectionö and óplanning and predictionö. The cognitive strategy óelaborationö was also taught quite often. Strikingly, none of the science interventions included any of the management or motivation strategies. Compared to the interventions in other subjects, the science instructions included a relatively small number of different learning strategies. The average relative frequency of the learning strategies was 27%, slightly higher than for math, but lower than for reading comprehension and writing.

The correlations between the learning strategies indicate that the science interventions often included a combination of personal metacognitive knowledge and the cognitive strategy óelaborationö. We found no significant relationships between the other learning strategies. Table 22 presents the correlations. As can be seen, some correlations are quite high, but likely due to the small number of interventions, they are not significant.

Table 21

Frequency of the learning strategies in science interventions

Learning strategies	N	%
1. Metacognitive knowledge personal	3	33.3
2. Metacognitive knowledge general	3	33.3
3. Cognitive strategy rehearsal	0	0.0
4. Cognitive strategy elaboration	4	44.4
5. Cognitive strategy organization	1	11.1
6. Metacognitive strategy planning and prediction	7	77.8
7. Metacognitive strategy monitoring and control	8	88.9
8. Metacognitive strategy evaluation and reflection	8	88.9
9. Management strategy effort	0	0.0
10. Management strategy environment	0	0.0
11. Management strategy peers/others	0	0.0
12. Motivation strategy self-efficacy	0	0.0
13. Motivation strategy task value	0	0.0
14. Motivation strategy goal orientation	0	0.0

Table 22

Correlations between the learning strategies of science interventions

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.00													
2	-.50	1.00												
3														
4	.79*	-.63		1.00										
5	-.25	-.25		.40	1.00									
6	.38	.38		-.06	-.66	1.00								
7	.25	-.50		.32	.13	-.19	1.00							
8	.25	.25		-.40	-1.00**	.66	-.13	1.00						
9														
10														
11														
12														
13														
14														

Notes. ** $p < .01$; * $p < .05$.

Numbers 1 to 14 represent the learning strategies. Table 21 shows which number belongs to which strategy.

The meta-regression analyses of the effects of the individual learning strategies on studentsô science performance (with the measurement instrument as the covariate) revealed no significant effects. Table 23 presents the learning strategiesô regression coefficients. Of nine interventions the statistical power was too low to detect significant effects. Especially smaller effects are harder to detect in the case of low statistical power. We can see in Table 23 that for all of the learning strategies the regression coefficients are not very high.

Table 23

Effects of the individual learning strategies on science: meta-regression results

	B (*SE*)
Metacognitive knowledge personal	.25 (.22)
Metacognitive knowledge general	.15 (.15)
Cognitive strategy rehearsal	
Cognitive strategy elaboration	.16 (.19)
Cognitive strategy organization	-.02 (.25)
Metacognitive strategy planning and prediction	.08 (.18)
Metacognitive strategy monitoring and control	-.07 (.38)
Metacognitive strategy evaluation and reflection	.02 (.25)
Management strategy effort	
Management strategy environment	
Management strategy peers/others	
Motivation strategy self-efficacy	
Motivation strategy task value	
Motivation strategy goal orientation	

Notes. $^{**}p< 0.01$; $^{*}p< 0.05$.

With as reference category for the individual learning strategies ‘strategy not in intervention’. The cells are grey when there are less than five interventions with or without the strategy under study. The cells are empty when there are no interventions which include the strategy, or when there are no interventions which do not include the strategy.

6.9. Maintenance effects of strategy instruction interventions on student performance

For 18 of the 95 interventions, the maintenance effects on the students’ performance were measured using a follow-up test. For one of the interventions (that of Reynolds & Perin, 2009) the maintenance effects were measured not later than one week after the end of the intervention. We excluded this intervention from the meta-analysis because we considered the period between the end of the strategy instruction and the follow-up test to be too short. For the other interventions the follow-up test was administered about the same amount of weeks after the end of the strategy instruction as the duration of the intervention. So, if an intervention took five weeks, the follow-up test was conducted about five weeks after the end of the strategy instruction. On average, the follow-up test took place after 12.5 weeks (*SD* = 8.3), the shortest period being three weeks and the longest period 25 weeks. In Table 24, the maintenance effects of the 17 interventions are compared with the effects on student performance straight after the termination of the strategy instructions. The results show that the maintenance effects are even slightly higher than the effects straight after the end of the strategy interventions, although the differences were not significant. We can therefore conclude that the effects of the interventions did not decline after the programs ended.

We also tested if the duration of the intervention and the time between the end of the strategy instruction and the follow-up test influenced the maintenance effects. There appeared to be a small negative effect produced by the duration of the intervention as well as by the number of weeks between the end of the strategy instruction and the administration of the follow-up test (B = -0.03; SE = 0.01; p= 0.01, respectively, B = -0.02; SE = 0.01; p= 0.03 (tested separately in models with the measurement instrument as the covariate)). When analyzing the effects simultaneously, however, both effects became non-significant.

Table 24

Maintenance effects of 17 interventions on student performance

Measurement instrument	Post effect Hedges' *g* (*SE*)	Maintenance effect Hedges' *g* (*SE*)
Total	.53 (.14)**	.60 (.11)**
Self-developed test	.75 (.19)**	.77 (.16)**
Independent test	.47 (.22)*	.60 (.19)**

Notes. $^{**}p< 0.01$; $^{*}p< 0.05$.

7. Discussion

Until now a large amount of studies has been published to describe the effects of a self-regulated learning intervention on student performance. Although all these interventions deal with self-regulated learning, almost none of them are exactly alike. In the current meta-analysis we examined which self-regulated learning interventions were the most effective in enhancing student performance. Our meta-analysis included 95 self-regulated learning instructions. When coding these interventions we identified fourteen specific learning strategies, the subject domains, the measurement instruments used, the participantsô characteristics and grade level, the implementers of the interventions, whether computers were used, whether there was cooperation among the students during the interventions, and the duration and intensity of the interventions.

In each subject domain, strategy instruction had, on average, substantial positive effects on student performance. In reading comprehension it had an average effect size of Hedgesô g = 0.36 (*SE* = 0.08), which is a small to moderate effect. With respect to writing, strategy instruction produced a very high average effect size of 1.25 (*SE* = 0.12), and in the case of mathematics and science, its average effect size was medium to high, namely 0.66 (*SE* = 0.06) and 0.73 (*SE* = 0.13), respectively. This finding indicates that for most subjects, it is worthwhile to instruct students in learning strategies in order to improve their performance. This approach is always better than no strategy instruction at all. The answer to the question which method is the best is more complicated, however, because we did not find one particular learning strategy or a combination of methods which is clearly the most effective, although we did obtain some clues about the most preferable approach.

Our first research question was as follows:

1. Which (combination of) learning strategies (particular strategies, or substrategies, within the broad spectrum of cognitive, metacognitive, management and motivational strategies) should be instructed to enhance student performance the most effectively?

To answer this question, we first analyzed the effect of each individual learning strategy on student performance. The learning strategies that appeared to have a significant effect on student performance were then analyzed together. In all the models tested, the measurement instrument was used as the covariate. The analyses showed that strategy instructions that include the combination of ógeneral metacognitive knowledgeö, the metacognitive strategy óplanning and predictionô and the motivational strategy ótask valueô enhance student performance the most effectively. Therefore, teaching students skills such as determining when, why and how to use learning strategies, how to plan a learning task, and explaining the relevance and importance of a task (so that they see the importance of what they are doing) are therefore important aspects of self-regulated learning interventions. Especially the inclusion of task value in the strategy instruction had a large effect on student performance. We calculated an expected added value of instructing these strategies of Hedgesô *g* = 1.23. In prior meta-analyses the added value has mostly been in line with the findings of Hattie et al. (1996). Hattie et al. established that interventions in which strategy learning was taught in combination with self-regulated learning (metacognition and motivation) produced larger effects on the enhancement of student performance than interventions focused on teaching only one or a small number of strategies.

We hypothesized that the most effective (combination of) learning strategies varies along with the subject domain. Therefore, we also analyzed each subject domain separately. In this way, we hoped to answer the following four research questions:

2a. Which (combination of) learning strategies should be instructed to enhance student performance the most effectively in reading comprehension?

2b. Which (combination of) learning strategies should be instructed to enhance student performance the most effectively in writing a text?

2c. Which (combination of) learning strategies should be instructed to enhance student performance the most effectively in mathematics?

2d. Which (combination of) learning strategies should be instructed to enhance student performance the most effectively in science?

With respect to strategy instruction in reading comprehension, we found that the only strategy with a significant positive effect on studentsô reading performance was general metacognitive knowledge. Furthermore, we observed significant negative effects of the inclusion of the cognitive strategy óelaborationô and the management strategy ópeers/othersô. These negative effects indicate that including these approaches decreases the effect sizes, which means that without them the positive impact on student performance is higher. This finding is an unexpected one. When analyzing the three significant learning strategies simultaneously, we found that only the negative effect of the management strategy ópeers/othersô remained significant. The positive effect of general metacognitive knowledge decreased after taking the other strategies into account and became non-significant. We thus found no combination of learning strategies that enhances studentsô reading comprehension performance clearly more effectively than other combinations. A possible explanation for the negative effect of ómanaging peers/othersô could be that teaching students to apply this

method effectively is particularly difficult in the subject domain reading comprehension. Perhaps, this learning strategy was, on average, not properly taught in the interventions. The extra time required for teaching this element may have reduced the focus on other strategies, causing a negative effect on the interventionøs overall effectiveness.
With respect to strategy instruction in writing, metacognitive knowledge also appeared to be an effective component, as well as the metacognitive strategy óevaluation and reflectionô. Strategy instruction focused on teaching students how, when and why to use learning strategies combined with evaluation of and reflection on their writing assignments, enhanced the studentsô writing performance the most effectively. The expected added value of these two strategies together was Hedgesô g = 1.32.

With regard to mathematics, we found only one learning strategy that was significantly more effective than the other ones. The inclusion of the cognitive strategy óelaborationô had positive effects on the studentsô mathematics performance. The average Hedgesô g of the interventions in which this strategy was taught was 0.21 higher than that of the instructions without this strategy. Using prior knowledge, actively making connections between new material and existing knowledge and elaborating the material in order to facilitate the storage of knowledge in the long term memory are all examples of effective ways to tackle mathematical problems.

The meta-analysis of the effect of learning strategies on science performance revealed no approaches that were significantly more effective than other ones.

These results imply that for each subject domain there are only a very few (if any) learning strategies clearly more effective than other methods. However, difficulties in comparing the interventions might have confused our findings. We will go into this issue more thoroughly in the limitations section.

As prior meta-analyses indicated that the effects of self-regulated learning interventions are often moderated by aspects other than the learning strategies instructed, we also addressed these. The prior research has generally provided mixed results for the same moderator variables. In the current meta-analysis, we examined if the effectiveness of strategy instruction differed per group of students. Furthermore, we investigated if the intervention characteristics (subject domain, implementer of the intervention, measurement instrument, duration and intensity of the intervention, computer use and cooperative learning) moderated the effectiveness. The research questions concerning the moderator variables were as follows:

3a. Do the effects of strategy instruction on student performance differ per student group?

3b. Do the effects of strategy instruction on student performance depend on characteristics other than the learning strategies instructed?

Addressing question 3a, we found no differences in the effectiveness of strategy instruction with respect to studentsô ability, socioeconomic status or grade (and thus age). However, as regards studentsô ability, there was a trend noticeable that special needs students benefited slightly more from strategy instruction than the regular students (the estimated difference in effect size was Hedgesô $g = 0.23$; $p = 0.058$). The prior meta-analysis of Chiu (1998) also established that low ability students benefited slightly more from strategy instruction. On the other hand, the results of the study of Hattie, et al. (1996) pointed in the reverse direction. We also wanted to examine if studentsô socioeconomic status moderated the effectiveness of strategy instruction. But although there were a considerable number of interventions directed at low SES students, unfortunately only one focused on high SES students. Therefore, we were not able to properly analyze the influence of high socioeconomic status on the effectiveness of strategy instruction.

The examination of the influence of intervention characteristics other than the instructed strategies (question 3b) yielded the following results.

As depicted above, there were large differences in effectiveness as regards the subject domain. In the subject domain of writing, strategy instruction had the highest effects, followed by math and science. In reading comprehension it had the lowest impact. An explanation for these differences might be that students need the most guidance in text writing. Therefore, each instruction is welcome and enhances their performance. In addition, in text writing the evaluation of student performance is the least objective. For math, science and reading comprehension, an answer is either correct or wrong, but evaluating a written text is more personal. It is often the evaluator who individually determines the criteria for the evaluation of a text.

The type of measurement instrument used to estimate the interventionsô effectiveness also mattered. Self-developed tests on average resulted in higher effect size estimates than tests designed independent of the intervention. However, when analyzing the differences in measurement instrument for each subject domain separately, we found that this finding only applied to reading comprehension measures. Chiu (1998), who only examined reading comprehension interventions, also found that non-standardized tests yielded larger effects than with standardized ones. As non-standardized tests are often self-developed, the results of the current meta-analysis are in agreement with the findings of Chiu. The self-developed tests for reading comprehension might have been closer related to the training situation than those not specially developed for the interventions in which they were used. So, self-developed tests might have measured the near transfer of the training situation, whereas intervention independent tests assessed the far transfer. As Hattie, et al. (1996) reported, when the training task and the performance goal are more closely related, the effect sizes are higher. That we found no relationship between the measurement instrument and the effect size for the other subject domains, might be explained by a lack of statistical power. For the other subject domains, only a small number of effect sizes were estimated on the basis of intervention independent tests.

Furthermore, the results revealed that interventions implemented by the researcher or another person produced higher effects than those introduced by the teacher or the computer. Prior research has also indicated that researcher-implemented interventions have larger effects than instructions provided by the teacher. Chiu (1998) suggested that researcher-implemented interventions might produce higher results because researchers are more inclined to óteach to the testô than teachers are. Another explanation might be that tuition by someone else than the regular teacher creates a novelty effect, which influences the studentsô performance. Students may find it interesting when a researcher or a research-assistant comes to teach them, as a result of which they put more effort in their work. This phenomenon is called the Hawthorne effect.

With respect to the duration of the intervention, we found a very small relationship between the timespan of the intervention and its effectiveness. Longer interventions had slightly lower effects than shorter ones. The intensity of the interventions, the number of sessions per week, did not affect the interventionsô effectiveness. Prior meta-analyses have also shown small effects produced by the duration of the interventions, but in a contradictory direction compared to our results.

Finally, we analyzed if the effects of strategy instruction were moderated by whether or not students were allowed to cooperate during the intervention and whether or not they used a computer. For both aspects we found no significant differences.

Our last research question concerned the maintenance effects of strategy instruction interventions. We formulated the final research question as follows:

4. *Do the effects of the strategy instruction on student performance sustain once the instruction has ended?*

For 17 of the 95 interventions included in the meta-analysis, the maintenance effects were measured. The analysis indicated that strategy instruction interventions have a sustaining effect on student performance. So their effects do not decline after the termination of the program. This is a promising result.

7.1. Limitations

As we suggested, difficulties in comparability of the interventions might have obscured our findings. We compared the strategy instruction interventions as a whole, whereas we were actually interested in particular aspects of their content, namely the substrategies taught. The interventions differed from one another in many aspects. In the meta-analysis, however, we were not able to take each different aspect into account. To give an example, in a meta-analysis one variable can be added per approximately ten interventions (Borenstein, et al., 2009). With 95 interventions in total (and many less per subject domain), we could not include all fourteen learning strategies in the meta-regression equation at once. Let alone that we could also take the other moderators into account. Therefore, we do not know if a variable that was omitted in the analysis might have influenced the results.

Another aspect that most likely confused our findings is that the effect sizes of the interventions were measured by means of a large spectrum of different tests. These tests were of course not calibrated, so the studentsô performance was measured in many different ways. In addition, when taking a closer look at the effect sizes estimated, we noticed that also within the individual interventions there were large differences in the effect sizes determined. This large differentiation among the effect sizes within the interventions made it even more difficult to compare the effects among the interventions and analyze the moderator impact.

Furthermore, as the interventions were implemented by a large variety of people, there might have been fluctuations in the level of teaching quality. Moreover, some interventions might have paid more attention to the mastery of the learning strategies than other ones. Therefore, differences in instruction quality and focus among the interventions may also have been factors which influenced the results.

7.2. Scientific contribution

Meta-analysis is a valuable method to summarize the findings from primary studies. As such, the current study has contributed to the body of knowledge about effective strategies for self-regulated learning. Despite the limitations of meta-analytical research, an analysis of several primary publications yields more reliable conclusions than that of a single primary study. In meta-analysis, measurement and implementation errors of the primary studies are averaged out, which leads to more balanced results. A generally heard critique on meta-analysis is that one compares apples with oranges. However, if one is interested in fruit, it is the appropriate method of analysis. To extend the metaphor to the current meta-analysis, we were interested in the effects of the vitamins in fruit on health.

The scientific contribution of this meta-analysis is that it has provided a fairly clear picture of the effective characteristics of self-regulated learning interventions. Our main focus was on the self-regulated learning strategies taught. Prior meta-analyses of self-regulated learning training interventions have concentrated on the broader categories of learning approaches (for example, metacognitive strategies). However, we were interested in a more finely grained analysis of the particular learning strategies taught. The current study demonstrated which learning strategies enhance student performance the most effectively. We examined this issue in four subject domains. Furthermore, we analyzed the significant learning strategies simultaneously to find out if there are certain combinations which are the most effective in enhancing student performance.

7.3. Practical implications

Based on our results we recommend that strategy instruction should at least teach students how, when and why to use self-regulated learning methods (general metacognitive knowledge). In addition, it has to contain the metacognitive strategy óplanning and predictionô and the motivational strategy ótask valueô.

As regards the specific subject domains, we argue that for reading comprehension it is important to teach students self-regulated learning approaches, as the effect size of these interventions is on average small to moderate. Which strategies exactly should be taught, however, is not yet clear, but they will have to be preceded by an introduction to students about how, when and why to use these methods. Methods not preferred are the cognitive strategy óelaborationô and the management strategy ópeers/othersô.

With respect to writing, we again recommend to provide students with general metacognitive knowledge about their strategy use. Furthermore, it is advisable to teach students how to evaluate and reflect on their writing products.

Strategy instruction in mathematics should at least involve the cognitive strategy óelaborationô.

Finally, there is no specific recommendation for strategy instruction in science, other than that it is desirable to teach students to self-regulate their learning. The effect sizes of the self-regulated learning interventions for science were on average quite high, but we were not able to detect learning strategies which particularly stood out in terms of effectiveness.

In addition to our advice with respect to the specific content of self-regulated learning interventions, we have some general recommendations for future studies focused on testing the effectiveness of strategy instruction. First, we suggest using a standardized test as the measurement instrument, so that the effects of multiple interventions can be better compared with each other. Second, in our meta-analysis we had to leave several studies out because the interventions were not tested against a control group. A control group is essential to correct for effects caused by natural developments. We therefore strongly recommend future studies to include a control group. Finally, we advocate the use of a pretest-posttest approach to be able to foster the preciseness of the effect size calculations to a maximum.

Literature

Alexander, P. A., Graham, S., & Harris, K. R. (1998). A perspective on strategy research: Progress and prospects. *Educational Psychology Review, 10*, 129-154.

Azevedo, R., & Cromley, J. G. (2004). Does training on self-regulated learning facilitate studentsô learning with hypermedia? *Journal of Educational Psychology, 96,* 523-535.

Boekaerts, M. (1996). Self-regulated learning at the junction of cognition and motivation. *European Psychologist, 1,* 100-112.

Boekaerts, M. (1997). Self-regulated learning: A new concept embraced by researchers, policy makers, educators, teachers, and students, *Learning and Instruction, 7,* 161-186.

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). *Introduction to meta-analysis*. Chichester, UK: Wiley.

Brown, A. L. & Palincsar, A. S. (1989). Guided, cooperative learning and individual knowledge acquisition. In L. B. Resnick (Ed.), *Knowing, learning and instruction: Essays in honor of Robert Glaser (pp. 393-451)*. Hillsdale, NJ: Lawrence Erlbaum.

Chiu, C. W. T. (1998). Synthesizing metacognitive interventions: What training characteristics can improve reading performance? *Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.*

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences.* New York: Taylor & Francis.

Cromley, J. G., Snyder-Hogan, L. E. & Luciw-Dubas, U. A. (2010). Reading comprehension of scientific text: A domain-specific test of the direct and inferential mediation model of reading comprehension. *Journal of Educational Psychology, 102,* 687-700.

Dekkers, H. P. J. M., Bosker, R. J., & Driessen, G. W. J. M. (2000). Complex inequalities of educational opportunities. A large-scale longitudinal study on the relation between gender, social class, ethnicity and school success. *Educational Research and Evaluation, 6,* 59-82.

Denson, N., & Seltzer, M. H. (2011). Meta-analysis in higher education: An illustrative example using hierarchical linear modeling. *Research in Higher Education, 52,* 215-244.

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 Learning, 3,* 231-264.

Dignath, C., Büttner, G., & Langfeldt, H. (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*, 101-129.

Dinsmore, D. L., Alexander, P. A., & Loughlin, S. M. (2008). Focusing the conceptual lens on metacognition, self-regulation, and self-regulated learning. *Educational Psychology Review, 20,* 391ï 409.

Flavell, J. H. (1979). Metacognition and cognitive monitoring. A new area of cognitive-development inquiry. *American Psychologist, 34,* 906-911.

Haller, E., Child, D. A., & Walberg, H. J. (1988). Can comprehension be taught? A quantitative synthesis of ñmetacognitiveò studies. *Educational Researcher, 17,* 5-8.

Harackiewicz, J. M., Barron, K. E., Pintrich, P. P., Elliot, A. J., & Thrash, T. M. (2002). Revision of achievement goal theory: necessary and illuminating. *Journal of Educational Psychology,* 94, 638-645.

Hattie, J., Biggs, J., & Purdie, N. (1996). Effects of learning skills interventions on student learning: A meta-analysis. *Review of Educational Research, 66,* 99-136.

Hedges, L. V., & Olkin, I. (1985). *Statistical methods for meta-analysis.* San Diego, CA: Academic Press.

Kostons, D., Van Gog, T., & Paas, F. (2010). Self-assessment and task selection in learner-controlled instruction: Differences between effective and ineffective learners. *Computers & Education, 54,* 932-940.

Lipsey, M. W., & Wilson, D. B. (2001). *Practical meta-analysis.* Thousand Oaks, CA: Sage Publications.

Mayer, R. E. (2008). *Learning and Instruction* (2nd ed). Upper Saddle River, NJ: Pearson Merrill Prentice Hall.

Peters, J. L., Sutton, A. J., Jones, D. R., Abrams, K. R., & Rushton, L. (2007). Performance of the trim and fill method in the presence of publication bias and between-study heterogeneity. *Statistics in Medicine, 26,* 4544-4562.

Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. In M. Boekaerts, P.R. Pintrich & M. Zeidner (eds.) *Handbook of Self-Regulation* (pp. 451-502). San Diego: Academic Press.

Pintrich, P. P. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology,* 95, 667-686.

Pintrich P. R. (2004). A conceptual framework for assessing motivation and self-regulated learning in college students. *Educational Psychology Review, 16,* 385-407.

Pressley, M. (2002). Comprehension strategies instruction: A turn-of-the-century status report. In C. C. Block & M. Pressley (Eds.), *Comprehension instruction: Research-based best practices* (pp. 11ï 27). New York: Guilford.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical Linear Models. Applications and data analysis methods. Second edition.* Thousand Oaks, CA: Sage Publications.

Sammons, P. (1995). Gender, ethnic and socio-economic differences in attainment and progress: A longitudinal analysis of student achievement over 9 years. *British Educational Research Journal, 21,* 465-485.

Werf, M. P. C. van der, Lubbers, M. J., & Kuyper, H. (2002). *Het interne rendement van het voortgezet onderwijs [The internal rates of return of secondary education].* Groningen, the Netherlands: GION.

Weinstein, C. E., & Mayer, R. E. (1986). The teaching of learning strategies. In M. Wittrock (Ed.), *Handbook of research on teaching* (pp. 3 15-327). New York, NY: Macmillan.

Weinstein, C. E. (1994). Strategic learning/strategic teaching: flip sides of a coin. In: Pintrich, P. R., Brown, D.R., & Weinstein C. E. (Eds.). Student motivation, cognition, and learning: essays in honor of Wilbert J. McKeachie (pp. 257-273). Hillsdale, NJ: Lawrence Erlbaum.

Wigfield, A., & Eccles, J. S. (2002). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology*, 25, 68-81.

Zimmerman, B. J. (1990). Self-regulated learning and academic achievement: An overview. *Educational Psychologist*, *25,* 3-17.

Zimmerman, B. J. (2002). Becoming a self-regulated learner: an overview. *Theory into Practice, 41,* 64-70.

Studies included in the meta-analysis

Aleven, V. A. W. M. M., & Koerdinger, K. R. (2002). An effective metacognitive strategy: learning by doing and explaining with a computer-based cognitive tutor. *Cognitive Science: a Multidisciplinary Journal, 26,* 147-179.

Allen, K. D., & Hancock, T. E. (2008). Reading comprehension improvement with individualized cognitive profiles and metacognition. *Literacy Research and Instruction, 47,*124-139.

Blank, L. M. (2000). A metacognitive learning cycle: a better warranty for student understanding? *Science Education, 84,* 486-506.

Boulware-Gooden, R., Carreker, S., Thornhill, A., & Malatesha J. R. (2007). Instruction of metacognitive strategies enhances reading comprehension and vocabulary achievement of third-grade students. *The Reading Teacher, 61*, 70-77.

Bruce, M. E., & Robinson, G. L. (2001). The clever kid's reading program: metacognition and reciprocal teaching. Paper presented at the *Annual European Conference on Reading*, Dublin.

Brunstein, J. C., & Glaser, C. (2011). Testing a path-analytic mediation model of how self-regulated writing strategies improve fourth graders' composition skills: A randomized controlled trial. *Journal of Educational Psychology, 103,* 922-938.

Camahalan, F. M. G. (2006). Effects of self-regulated learning on mathematics achievement of selected Southeast Asian children. *Journal of Instructional Psychology, 33*, 194-205.

Cantrell, S. A., Almasi, J. F., & Carter, J. C. (2010). The impact of a strategy-based intervention on the comprehension and strategy use of struggling adolescent readers. *Journal of Educational Psychology, 102,* 257-280.

Dejonckheere, P., Van de Keere, K., & Tallir, I. (2011). Are fourth and fifth grade children better scientists through metacognitive learning? *Electronic Journal of Research in Educational Psychology, 9*, 133-156.

Dresel, M., & Haugwitz, M. (2008). A computer-based approach to fostering motivation and self-regulated learning. *The Journal of Experimental Education, 77,* 3-18.

Erktin, E. (2004). Teaching thinking for mathematics through the enhancement of metacognitive skills. *Research in the Schools, 11*, 3-13.

García-Sánchez, J. N. & Fidalgo-Redondo, R. (2006). Effects of two types of self-regulatory instruction programs on students learning disabilities in writing products, processes, and self-efficacy. *Learning Disability Quarterly, 29*, 181-211.

Glaser, C., & Burnstein, J. C. (2007). Improving fourth-grade students' composition skills: effects of strategy instruction and self-regulation procedures. *Journal of Educational Psychology, 99*, 297-310.

Graham, S., Harris, K. R., & Mason, L. (2005). Improving the writing performance, knowledge, and self-efficacy of struggling young writers: The effects of self-regulated strategy development. *Contemporary Educational Psychology, 30,* 207-241.

Guterman, E. (2003). Integrating written metacognitive awareness guidance as a 'psychological tool' to improve student performance. *Learning and Instruction,13*, 633-651.

Harris, K. R., Graham, S., & Mason, L. H. (2006). Improving the writing, knowledge, and motivation of struggling young writers: effects of self-regulated strategy development with and without peer support. *American Educational Research Journal, 43,* 295-340.

Hauptman, H., & Cohen, A. (2011). The synergetic effect of learning styles on the interaction between virtual environments and the enhancement of spatial thinking. *Computers & Education*, *57,* 2106-2117.

Huff, J. D., & Nietfeld, J. L. (2009). Using strategy instruction and confidence judgments to improve metacognitive monitoring. *Metacognition and Learning, 4*, 161-176.

Jacobse, A., & Harskamp, E. (2009). Student-controlled metacognitive training for solving word problems in primary school mathematics. *Educational Research and Evaluation, 15,* 447-463.

Kapa, E. (2007). Transfer from structured to open-ended problem solving in a computerized metacognitive environment. *Learning and Instruction, 17,* 688-707.

Kim, H. J., & Pedersen, S. (2011). Advancing young adolescents' hypothesis-development performance in a computer-supported and problem-based learning environment. *Computers & Education, 57*, 1780-1789.

Kramarski, B., & Dudai, V. (2009). Group-Metacognitve support for online inquiry in mathematics with differential self-questioning. *Journal of Educational Computer Research, 40,* 377-404.

Kramarski, B., & Gutman, M. (2006). How can self-regulated learning be supported in mathematical e-learning environments? *Journal of Computer Assisted Learning, 22,* 24-33.

Kramarski, B., & Hirsch, C. (2003). Effects of computer algebra system (CAS) with metacognitive training on mathematical reasoning. *Educational Media International, 40,* 249-257.

Kramarski, B., & Mevarech, Z. R. (2003). Enhancing mathematical reasoning in classroom: the effects of cooperative learning and the metacognitve training. *American Educational Research Journal, 40,* 281-310.

Kramarski, B., Mevarech, Z. R., & Arami, M. (2002). The effects of metacognitve instruction on solving mathematical authentic tasks. *Educational Studies in Mathematics, 49*, 225-250.

Kramarski, B., Mevarech, Z. R., & Lieberman, A. (2001). Effects of multilevel versus unilevel metacognitve training on mathematical reasoning. *Journal of Educational Research, 94*, 292-300.

Kramarski, B., & Mizrachi, N. (2006). Online discussion and self-regulated learning: effects of instructional methods on mathematical literacy. *Journal of Educational Research, 99,* 218-230.

Kramarski, B., & Ritkof, R. (2002). The effects of metacognition and email interactions on learning graphing. *Journal of Computer Assisted Learning, 18,* 33-43.

Kramarski, B., & Zoldan, S. (2008). Using errors as springboards for enhancing mathematical reasoning with three metacognitive approaches. *Journal of Educational Research, 102,* 137-151.

Lubliner, S., & Smetana, L. (2005). The effects of comprehensive vocabulary instruction on title I students' metacognitive word-learning skills and reading comprehension. *Journal of Literacy Research, 37*, 163-200.

Mason, L. H. (2004). Explicit self-regulated strategy development versus reciprocal questioning: effects on expository reading comprehension among struggling readers. *Journal of Educational Psychology, 96*, 238-296.

Mevarech, Z. R., & Kramarski, B. (2004). The effects of metacognitve training versus worked-out examples on students' mathematical reasoning. *British Journal of Educational Psychology, 73,* 449-471.

Meyer, E., Abrami, P. C., & Wade, C. A. (2010). Improving literacy and metacognition with electronic portfolios: Teaching and learning with ePEARL. *Computers & Education, 55,* 84-91.

Michalsky, T., Mevarech, Z. R., & Haibi, L. (2009). Elementary school children reading scientific texts: effects of metacognitive instruction. *Journal of Educational Research, 102*, 363-376.

Molenaar, I., Chiu, M. M., & Sleegers, P. (2011). Scaffolding of small groups' metacognitive activities with an avatar. *International Journal of Computer-Supported Collaborative Learning, 6,* 601-624.

Mourad, A. E. (2009). The effectiveness of a program based on self-regulated strategy development on the writing skills of writing-disabled secondary school students. *Electronic Journal of Research in Educational Psychology, 7,* 5-24.

Pennequin, V., Sorel, O., Nanty, I., & Fontaine, R. (2010). Metacognition and low achievement in mathematics: The effect of training in the use of metacognitive skills to solve mathematical word problems. *Thinking and Reasoning, 16,* 198-220.

Perels, F., Dignath, C., & Schmitz, B. (2009). Is it possible to improve mathematical achievement by means of self-regulation strategies? Evaluation of an intervention in regular math classes. *European Journal of Psychology of Education, 24,* 17-31.

Perels, F., Gurtler, T., & Schmitz, B. (2005). Training of self-regulatory and problem-solving competence. *Learning and Instruction, 15,* 123-139.

Peters, E. E., & Kitsantas, A. (2010). Self-regulation of student epistemic thinking in science: The role of metacognitive prompts. *Educational Psychology, 30,* 27-52.

Peters, E. E., & Kitsantas, A. (2010). The effect of nature of science metacognitive prompts on science students' content and nature of science knowledge, metacognition, and self-regulatory efficacy. *School Science and Mathematics, 110,* 382-396.

Reynolds, G. A., & Perin, D. (2009). A comparison of text structure and self-regulated writing strategies for composing from sources by middle school students. *Reading Psychology, 30,* 265-300.

Sanz de Acedo Lizarraga, M. L., Sanz de Acedo Baquedano, M. T., & Oliver, M. S. (2010). Stimulation of thinking skills in high school students. *Educational Studies, 36,* 329-340.

Souvingnier, E., & Mokhlesgerami, J. (2006). Using self-regulation as a framework for implementing strategy instruction to foster reading comprehension. *Learning and Instruction, 16*, 57-71.

Stoeger, H., & Ziegler, A. (2010). Do pupils with differing cognitive abilities benefit similarly from a self-regulated learning training program? *Gifted Education International, 26,* 110-123.

Stoeger, H., & Ziegler, A. (2008). Evaluation of a classroom based training to improve self-regulation in time management tasks during homework activities with fourth graders. *Metacognition and Learning, 3,* 207-230.

Tajika, H., Nakatsu, N., Nozaki, H., Neumann, E., & Maruno, S. (2007). Effects of self-explanation as a metacognitive strategy for solving mathematical word problems. *Japanese Psychological Research*, *49*, 222-233.

Talebi, S.H. (2009). An attempt towards learner autonomy in L2 (English) and L3 (Arabic) reading through cognitive and metacognitive reading strategy instruction (CMRSI) in L2. *Indian Journal of Applied Linguistics, 35* (2), 101-112.

Torrance, M., Fidalgo, R., & García, J. N. (2007). The teachability and effectiveness of cognitive self-regulation in sixth-grade writers. *Learning and Instruction, 17* (3), 265-285.

Tracy, B., Reid, R., & Graham, S. (2009). Teaching young students strategies for planning and drafting stories: the impact of self-regulated strategy development. *Journal of Educational Research, 102* (2), 323-331.

Van Keer, H., & Vanderlinde, R. (2010). The impact of cross-age peer tutoring on third and sixth graders' reading strategy awareness, reading strategy use, and reading comprehension. *Middle Grades Research Journal, 5,* 33-45.

Vaughn, S., Klingner, J. K., & Swanson, E. A. (2011). Efficacy of collaborative strategic reading with middle school students. *American Educational Research Journal, 48,* 938-964.

Wright, J., & Jacobs, B. (2003). Teaching phonological awareness and metacognitive strategies to children with reading difficulties: a comparison of two instructional methods. *Educational Psychology, 23 (1), 17-47.*

Zion, M., Michalsky, T., & Mevarech, Z. R. (2005). The effects of metacognitive instruction embedded within an asynchronous learning network on scientific inquiry skills. *International Journal of Science Education, 27 (8),* 957-983.