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Self-regulated strategy development's effectiveness: underlying cognitive and metacognitive mechanisms

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Abstract

Self-Regulated Strategy Development (SRSD) is a method designed to explicitly teach students self-regulation skills and help them implement them. While SRSD's beneficial effect on writing quality has been confirmed in a large body of literature, the questions of why, how, and for whom SRSD works remain unclear. To investigate the underlying cognitive and metacognitive mechanisms, and identify the factors that potentially moderate SRSD's effectiveness, we compared fourth- and fifth-graders who either received regular writing instruction or underwent an SRSD intervention in a quasi-experimental setting. Students' abilities to plan, write quality texts, and self-evaluate were measured. Factors that have been demonstrated to be related to writing abilities were assessed to study whether they might facilitate or hinder acquisition of strategies taught in the SRSD intervention. The results indicated that compared with students who received regular writing instruction, students who underwent the SRSD intervention produced higher-quality texts and evaluated their texts' quality more accurately, despite persistent overestimation. Mediation analyses indicated that progress in producing high-quality texts was explained by improvements in students' planning skills, enabling them to write stories that were better-structured and contained more ideas. However, the results also indicated that some students under the SRSD condition struggled to implement the planning strategies they were taught, particularly students with poor working memory. Recommendations for optimizing the SRSD intervention's effectiveness in developing all students' writing skills are discussed.

Keywords Writing · Self-regulated strategy development · Metacognition · Monitoring · Strategy instruction

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Introduction

France's Ministry of National Education and Youth (2022) recently identified writing as one of the three national educational priorities, along with reading and numeracy, as writing skills exert a major influence on learning and professional success (Barnier, 2021; Graham et al., 2020). At the end of primary school, French students are required to be able to write texts in different genres, such as writing stories or playlets (Ministry of National Education and Youth, 2024). However, French students have difficulty drafting coherent texts that respect writing genre characteristics (Direction de l'Évaluation de la Prospective et de la Performance [DEPP], 2015). Also, 40% of fifth-grade teachers reported that they have received no training related to the French language, its teaching, or students' learning processes in this area (Centre national d'étude des systèmes scolaires [Cnesco], 2018). To overcome writing difficulties, the international research has demonstrated that explicitly teaching writing skills to students by following the intervention principles of Self-Regulated Strategy Development (SRSD) enables them to improve the quality of the texts they produce (e.g., Graham et al., 2012). However, to date, no studies have examined whether a French version of this intervention would achieve such results with French elementary school students. Furthermore, although many extant studies have indicated a positive effect from the SRSD intervention (e.g., Graham et al., 2012), very few extant studies actually have examined its effect on students' self-regulation skills. Furthermore, few studies have investigated whether or not students' preexisting cognitive skills and motivation to write might facilitate or hinder acquisition of the strategies taught in the SRSD intervention. Gaining knowledge of all these points would enable us to identify more precisely why and under what condition SRSD works, which could open up promising avenues to optimize its efficacy. Consequently, the present study has two main objectives: (1) to test whether receiving SRSD-type instruction would enable French students to produce better texts than if they had received conventional French writing instruction, and (2) to better understand the cognitive and metacognitive mechanisms that underlie the SRSD intervention's effectiveness and identify factors that could moderate it.

French students' writing skills

Standardized national surveys conducted in various countries or states consistently have found poor writing performance among students (e.g., DEPP, 2015; National Center for Education Statistics, 2012; Persky et al., 2003; Salahu-Din et al., 2008; State of Texas Assessments of Academic Readiness [STAAR], 2017; UK Department for Education, 2012). A recent Australian survey found that students' writing performance significantly declined between 2011 and 2018, with 30–40% of seventh- and ninth-graders scoring below the national minimum benchmark (*Australian Curriculum, Assessment and Reporting Authority* [ACARA], 2019; for a discussion of this survey, see McLean, 2022; Thomas, 2020). French students are no exception and also show difficulties in writing quality texts. For instance, the French Education Ministry examined 2,500 fifth-grade French students' ability to create a story from an image (see Andreu, 2018). Students were assessed on their ability to retrieve and integrate information present in the image into their stories, and to write a coherent text containing a beginning, plot development, and end. The results revealed that

only 54% succeeded in writing narrative texts that met these criteria. In another survey, the French Education Ministry examined the writing skills of 8,051 ninth-graders from a wide range of socioeconomic backgrounds enrolled in both public and private secondary schools (DEPP, 2015). The students were asked to create a narrative text. In this case, nearly half were unable to produce a structured narrative, and 40% wrote little or nothing at all.

Most surveys on writing skills are dated, and standardized and systematized international surveys—as with reading, mathematics and sciences—are needed to give us a better picture of the evolution of students' writing skills. Existing national writing surveys have found that, like students in many other countries, a substantial proportion of French students do not have writing skills that correspond to their education levels, affecting their ability to write well-structured and high-quality texts and, thus, their ability to succeed in different academic disciplines. Students' difficulties in producing high-quality texts arise from the writing task's complex nature, requiring both implementation and autonomous regulation of numerous demanding cognitive processes (Beauvais et al., 2011).

Writing: a demanding self-regulated task to master

Effectively self-regulating one's writing involves the ability to (i) set goals and requirements that are appropriate to the writing task and take the recipient's characteristics into account, (ii) deploy effective planning, formulation, and revision strategies to achieve these goals, and (iii) regularly and accurately monitor whether the previously set goals have been achieved and whether the strategies that are implemented allow these goals to be achieved (Beauvais et al., 2011; Escorcía et al., 2017; Raković et al., 2022, 2023). In some cases, students also are required to write texts using one or more sources (e.g., Collins et al., 2021; FitzPatrick & McKeown, 2021; Harris et al., 2019; Raković et al., 2021, 2023). In such a case, in addition to self-regulating their writing, students first need to process the various documents and extract information deemed relevant to the task at hand, making their texts' quality dependent on mastery of text comprehension strategies as well (Raković et al., 2021, 2023). During the writing phase, students must, in addition, ensure that graphomotor and orthographic operations take place properly, constituting an additional load on working memory. However, limited working memory capacity can constrain the use and regulation of strategies (e.g., Roussey & Piolat, 1991). Furthermore, students are not always familiar with the most appropriate strategies for writing texts and do not know when, why, and how to use them (Englert et al., 1988; Saddler & Graham, 2007), meaning that they use planning and revision processes less frequently than expert writers do (Bai, 2018; Hayes et al., 1987; Lim et al., 2021). Therefore, novice writers tend to transpose their thoughts and ideas into writing as a stream of consciousness, make few modifications, and do not take the writing objectives and readers into account (Bereiter & Scardamalia, 1987; Raković et al., 2021). This results in the writing of texts that are unstructured, contain few ideas, and do not have the information needed for readers to understand (see, Beauvais et al., 2011; Bereiter & Scardamalia, 1987; Kellogg, 2008; McCutchen, 1996). For instance, a French Education Ministry survey (DEPP, 2015) showed that ninth graders hardly ever use an extra sheet to generate and structure their ideas before writing a story, indicating that planning skills are probably not fully mastered. According to Flower et al. (1992), to be viewed as an expert writer, students must be able to use and switch between three kinds of planning strategies

depending on the writing situation encountered: (1) schema-driven planning strategies, in which writers adopt a conventional frame adapted to the discourse type (e.g., story, argumentative text) to orient information selection and organization process; (2) knowledge-driven planning strategies, in which the writer constructs associative chains on the bases of rich and well-structured pre-existing knowledge stored in memory; and (3) constructive planning strategies, in which writers develop their own criteria and procedures for meeting their own goals for the task. Given the importance of writing skills at school and more widely in society, it is essential for teachers to identify and implement best practices, in order to strengthen these fundamental skills in their students.

Explicit writing strategy instruction: benefits and unresolved questions

In the French curriculum, the section devoted to written production is quite meager, compared with others (DEPP, 2015). Even though students are expected to master planning, formulation and revision skills (Ministry of National Education and Youth, 2024), little guidance is given to teachers as to how to achieve this. According to previous research, the most effective writing interventions are those that (a) explicitly teach students writing knowledge and effective writing strategies to help them develop planning, formulation and revision skills (b) show them how to implement these strategies using a modeling technique, and (c) accompany students until they acquire the metacognitive knowledge needed to regulate these strategies (Graham et al., 2012). Several interventions have been developed in line with these principles (for intervention examples, see cognitive self-regulation instruction [CSRI]; Rodríguez-Málaga et al., 2021; Torrance et al., 2007; self-regulated strategy development [SRSD]; Harris et al., 2008; Tekster; Bouwer et al., 2018). Currently, the most popular intervention, which has been the subject of the greatest number of classroom implementations and empirical research, is the SRSD intervention. SRSD interventions' long-term goal is to train students so that they can independently implement writing strategies in a new context without any explicit prompting from the teacher, and to help them develop greater self-efficacy in writing tasks and a better motivation to write. For example, as part of the SRSD lesson dedicated to teaching students how to write stories, an important part of the intervention is devoted to developing their planning skills. To do so, they are first trained to identify the important parts of a story in multiple texts (presentation of characters, time, place, trigger, events, denouement, and resolution) so that they then can use this knowledge to build a schema-driven strategy that will guide their planning phases when writing their own stories. Indeed, including each important part of a story on a planning sheet offers students a series of subgoals to meet, which also can help them retrieve information from long-term memory to write their texts. To facilitate this process, students are taught to structure their planning sheets with a graphic organizer, which is expected to help them generate and organize their ideas during a planning phase to help them write higher-quality stories. Students also are taught a self-evaluation strategy that comprises indicating on a sheet whether the important parts of a narrative text were included in the text. These writing strategies are taught to students through a series of steps during which the teacher first presents the strategies to students, then models their use, proposes exercises to consolidate these strategies in memory, and supports students in their first implementation until they can perform these tasks autonomously.

Graham et al. (2012)'s meta-analysis showed that an SRSD intervention that explicitly teaches students from grade 2 to 6 self-regulated strategies has a mean effect size of 1.17 versus 0.59 for other types of intervention. More generally, explicit self-regulated strategy teaching methods (i.e., CSRI, SRSD, or Tekster) have been found to promote the development of the knowledge and skills needed for writing descriptive, narrative, argumentative and informative texts (e.g., Graham et al., 2005) in students from first and second grade (e.g., Finlayson & McCrudden, 2021; Harris et al., 2006; Harris et al., 2012; Harris et al., 2015; Klein et al., 2022; McKeown et al., 2019) to university (e.g., Chen et al., 2022). Similarly, beneficial effects have been observed in students with writing difficulties (e.g., Graham et al., 2005; Harris et al., 2006; Harris et al., 2019), with special needs (e.g., Asaro-Saddler et al., 2021; FitzPatrick & McKeown, 2020), or from disadvantaged socio-economic backgrounds (e.g., Salas et al., 2021). These different studies have shown that students who receive these types of strategy instruction produce texts of higher quality and contain more ideas or arguments than students who are given either repeated writing opportunities or usual writing instruction (e.g., Graham et al., 2012).

Explicit self-regulated strategy teaching's beneficial effects on students' writing skills have led to the development of practice-based professional development (PBDP) to help teachers apply explicit teaching in their classrooms (Harris et al., 2023; McKeown et al., 2016, 2023; McKeown, FitzPatrick McKeown et al., 2019a, b). Teachers found PBDPs to be useful (Finlayson & McCrudden, 2021; FitzPatrick & McKeown, 2020, 2021; McKeown et al., 2016, 2019a, b; McKeown, FitzPatrick McKeown et al., 2019a, b), and several studies have indicated that training teachers to apply the SRSD approach in real-life class situations also significantly affected the quality of pupils' texts (FitzPatrick & McKeown, 2020; McKeown, FitzPatrick McKeown et al., 2019a, b, 2023), provided that teachers faithfully applied each step of the various sessions (McKeown, FitzPatrick McKeown et al., 2019a, b). Altogether, these beneficial effects are tied to SRSD interventions helping students develop important self-regulation abilities, including the use of effective writing strategies in planning their texts, accurately monitoring the progress of the writing process, and efficiently adapting their writing based on their monitoring output. However, to date, little is known about the underlying cognitive and metacognitive mechanisms that explain SRSD efficiency, nor about factors that could moderate it.

Do SRSD interventions impact monitoring accuracy?

Beyond the scientific literature on writing, research on self-regulated learning has regularly shown that when students perform educational tasks on their own, they often implement unsuitable strategies, partly because they tend to be overconfident (Bjork et al., 2013; Dunlosky & Rawson, 2012; Fernandez & Jamet, 2017; Greene & Azevedo, 2009; Panadero et al., 2017). Overconfidence arising from inaccurate monitoring prevents students from using effective strategies and from spending sufficient time on the task. Concerning the actual writing activity, achieving the right level of confidence, based on the monitoring process, requires students to accurately estimate the discrepancy between the current status of their production and the goals they have set themselves (Graham, 2018). In other words, students who do not (1) clearly understand what is expected of them, or (2) possess a suitable strategy for efficiently self-estimating the quality of their written production, will have difficulty

producing accurate monitoring, thereby decreasing their likelihood of engaging appropriately in writing tasks.

Many studies have tested the efficacy of different tools for recalibrating students' monitoring process, generally by offering students feedback on their learning, or by encouraging them to use metacognitive strategies to help them self-generate feedback (e.g., Fernandez & Jamet, 2017; Schleinschok et al., 2017). These investigations have shown that recalibrating monitoring accuracy by giving students feedback on the quality of their learning has a beneficial effect on students' task engagement, resulting in substantial improvements in their memory and their comprehension of the concepts to be learned. In the writing field, feedback is also necessary, as students may produce texts that are incorrect or incoherent (Graham, 2018). Formative feedback provides an accurate assessment of students' written production and helps them adjust their use of writing strategies, thereby enhancing the quality of their production (FitzPatrick & McKeown, 2020; Graham, 2018; Graham et al., 2012, 2015; McKeown et al., 2015, 2020; Skar et al., 2022). Research has shown that adult feedback, peer feedback, self-feedback, or computer feedback on students' writing often improves the quality of their texts (FitzPatrick & McKeown, 2020; McKeown et al., 2015, 2020; for a special issue on this topic, see Skar et al., 2022). However, in the long run, one of the objectives of the teaching of writing is to develop students' ability to autonomously and accurately estimate the quality of their production, to allow them to effectively self-regulate their production. The SRSD intervention aims precisely to help students better define their writing goals and use strategies to effectively self-estimate the quality of their texts. However, no studies have so far measured the effect of SRSD on monitoring accuracy, meaning that we do not know whether this type of intervention can enhance students' ability to accurately and autonomously gauge the quality of their texts. This is an important skill for students to develop, as overconfidence may lead students to misuse or underuse strategies newly acquired through SRSD interventions.

Do SRSD interventions really develop students' planning strategies?

SRSD interventions intend to promote the use of effective writing strategies, but the literature often has focused on the intervention's effect on the quality of the texts produced, and few researchers actually have investigated SRSD interventions' effects on development of students' planning strategy skills (e.g., generating and organizing story ideas on an extra planning sheet). FitzPatrick and McKeown (2021) examined an SRSD intervention's effectiveness in developing a planning strategy to write text using information extracted from multiple sources. In this study, eight fifth-graders were taught to memorize and use a five-step strategy to plan their essays before writing them. The results revealed that the quality of the students texts' increased from pre- to posttest. Moreover, although the students did not use planning strategies before the intervention, after the intervention, they all organized their planning sheets and noted information using the five planning steps taught to them. In another SRSD study, Glaser and Brunstein (2007) also tested SRSD intervention's effects on the development of planning and revising abilities, as well as writing quality, among 113 fourth-graders. The results revealed that compared with students in the control condition, students in the SRSD condition wrote higher-quality texts that contained more story components at both posttests and maintenance tests. Also in this study, an analysis found that students in the SRSD condition added more story parts on their planning sheets and made

more revisions to their stories (for similar results in planning strategy development, see FitzPatrick & McKeown, 2021; Harris et al., 2019; Limpo & Alves, 2018; Salas et al., 2021). However, no correlation or mediation analyses were conducted, making it impossible to reach any conclusion about the extent to which writing strategy development accounted for students' writing progress. Furthermore, and surprisingly, in the maintenance test, the strategy plus the self-regulation group differed from the other two groups only on the number of revisions and no longer differed on their planning activities. It is unclear why writing quality was maintained over time, but not the planning strategy, given that the latter is supposed to be pivotal to students' progress. Thus, even though several studies have demonstrated that the SRSD intervention enabled students to develop planning strategies (FitzPatrick & McKeown, 2020, 2021; Glaser & Brunstein, 2007; Harris et al., 2019; Limpo & Alves, 2018; Salas et al., 2021), it remains to be demonstrated that development of this planning strategy is, indeed, at the root of the improvement in students' writing production.

Is the use of planning strategies really behind the SRSD intervention's positive effects?

Few studies have investigated whether the newly acquired planning strategy taught as part of an SRSD intervention (i.e., generating and organizing ideas on a planning sheet before writing a text) fully explains improvements in students' text quality reported in previous research. Torrance et al. (2007) found interesting results that potentially question whether the development of planning skills contributes to students' writing progress. The researchers ran a first study with a follow-up 28 months later (see Fidalgo et al., 2008) to explore the effect of a cognitive self-regulation instruction (CSRI) intervention (following the basic principles of the SRSD intervention) on students' strategic approaches to writing and the quality of their texts. Results showed that students in the CSRI versus ordinary curriculum group produced texts that were rated as more coherent, better structured, and of better quality. Also, in line with the objective of the intervention, students in the CSRI group spent more time making notes than the control group, attesting to greater effort spent in the planning process. However, and more surprisingly, time spent planning was not related to text quality, such that the cognitive mechanism behind the positive impact of training on text quality remains unclear. Fidalgo et al. (2008) attributed the absence of a causal link in their study between greater use of planning strategies and improved performance to the measure of writing strategy. Time spent planning may be a poor measure of students' knowledge-transforming process. As Torrance et al. (2007) put it, "Quantity does not necessarily equate with quality: Students could plan for long periods, but still fail to knowledge-transform" (p. 282).

Only one study has so far yielded direct evidence that the positive effect of SRSD on writing stems partly from the development of planning strategies. In Brunstein and Glaser (2011)'s study, 117 fourth graders were randomly assigned to either a strategy instruction only or strategy plus self-regulation instruction condition. Instruction took place in groups of four to six students over five sessions, each comprising two 45-minute lessons. A pre-test, post-test and follow-up test 6 weeks later were conducted to assess the impact of both conditions on writing abilities. During these test sessions, students had to write a story based on a set of four interconnected pictures. They were asked to plan the story for 10 min, after which they had 20 min to write their story, before revising it for 10 min. Rather than measur-

ing planning and revising times, the authors tallied the number of ideas children generated during the planning phase and the number of corrections made during the revision phase. Mediation analysis indicated that the writing gains after the intervention were partially due to students producing more ideas in the planning phase and more corrections in the revising phase. It also revealed the persistence of a direct effect of the intervention on text quality, suggesting that while planning and revising explained part of the SRSD effect on writing, other unknown variables also contributed to the effectiveness of the intervention. Although Brunstein and Glaser measured the number and structure of ideas in the planning sheet, they did not look at whether the final written story was well structured and included numerous ideas. This raises the question of whether the planning stage actually helped all the students to generate more ideas and to organize them better in their story. In other words, translating the generating and structuring work done at the planning stage into a coherent story that is pleasant to read may also be an important ability to take into account in the mediation model. In addition to this, an SRSD intervention may lead some students to plan their story better mentally without needing to structure their ideas on a planning sheet. If so, measuring the number and structure of ideas in the planning sheet may be a poor proxy of the planning process for these students. If the effect of SRSD on story quality is mediated not only by the number and structure of ideas in a planning sheet, but also by the number and structure of ideas in the story, it suggests that some students engage in more covert planning activity. However, to the best of our knowledge, no study has so far explored the extent to which the newly acquired planning skills (i.e., strategies to generate and organize ideas on a planning sheet before writing a text) explain the characteristics of the resulting story (i.e., text quality and numbers of story parts, words, and ideas).

Are there factors that moderate the SRSD intervention's effectiveness?

Beyond mastering writing strategies, other cognitive and motivational factors are related to writing quality and could affect the SRSD intervention's efficacy. First, extant studies have indicated that working memory capacity was related significantly to students' writing skills (Ruffini et al., 2024). Indeed, writing is a complex and demanding task that requires students to activate and shift between several writing processes that place heavy demands on working memory (see Olive, 2014). Ruffini et al.'s (2024) recent systematic review revealed that of the 21 studies that examined working memory's role in text composition, 19 found a significant relationship between working memory and writing skills in children. Specifically, working memory was found to be related to written expression, structural complexity, number of produced words, narrative quality, translating, handwriting, spelling, and writing fluency. According to Ruffini et al. (2024), working memory plays an important role in retrieving and organizing ideas and knowledge to write a text that meets pre-established goals. Consequently, students who have low working memory capacity may have more difficulty acquiring the planning strategies taught by the SRSD intervention.

Second, a large body of research has found a positive relationship between handwriting fluency and writing quality in primary and middle grades (e.g., Graham et al., 2017; Limpo & Alves, 2018; Skar et al., 2022; Rocha et al., 2022; Rocha et al., 2023). For instance, Limpo and Alves (2018) found indirect effects from handwriting fluency on writing performance via planning in seventh and eighth grades. More recently, Rocha et al. (2022) found that handwriting speed was a significant predictor of text quality among fifth-grade stu-

dents. Also, and interestingly, studies have indicated that the addition of transcription training to SRSD interventions leads to better improvement of text quality than an SRSD-only intervention or an SRSD program combined with attention training in elementary school children (Limpó & Alves, 2018; Rocha et al., 2023). According to Skar et al., handwriting fluency can tax young writers' processing capacity, which will impact writing performance negatively. Automatic and fluent handwriting requires fewer attentional resources, which, in turn, may be allocated to the higher-level processes involved in text composition. Conversely, producing non-automated handwriting movement is such a demanding activity that it may interfere with other writing processes, such as planning, given the limited working memory capacity. Altogether, these findings suggest that automatic and fluent handwriting could facilitate acquisition of writing strategies taught by the SRSD intervention.

Finally, beyond cognitive factors, motivation and self-efficacy also were found to be related to writing quality (e.g., De Smedt et al., 2018). In a recent systematic review, Camacho et al. (2021) noted that of the 32 studies examined, 29 indicated that motivation was associated positively with writing performance. Unfortunately, Boscolo and Gelati's (2019) study found that motivation decreased in higher grades. Writing is a complex and demanding cognitive task, thereby creating a motivational challenge for students (for a discussion, see Camacho et al., 2021). These perceived difficulties and students' perceptions of their ability to write quality texts may decrease their willingness to engage in the use of costly writing strategies that may undermine their writing performance (Zimmerman & Risemberg, 1997). These results align with Brunstein and Glaser (2011), whose SRSD intervention increased student self-efficacy for writing, subsequently exerting a positive effect on planning and writing quality. Interestingly, Limpó and Alves (2014) also found that students with an incremental belief about writing benefited more from SRSD intervention than those who did not, indicating that students' beliefs impacted the quality of their engagement in the learning tasks presented to them. Therefore, students' motivation and self-efficacy to write may impact SRSD interventions' effectiveness in developing their writing skills.

Extant studies have demonstrated that many factors influence the quality of texts that students produce (e.g., working memory, handwriting, motivation, self-efficacy). Therefore, it is relevant to posit that these factors also may influence the ease of acquisition of writing strategies taught through SRSD lessons. However, few studies have been conducted on whether students' initial predispositions and abilities can moderate SRSD's effect on the acquisition of writing skills. This knowledge could prove important in fine-tuning the SRSD intervention and proposing adaptations based on each student's specific needs.

The present study

The SRSD training program was designed to teach writing self-regulation abilities gradually and explicitly (e.g., Harris et al., 2008; McKeown et al., 2021), and has been demonstrated to be a more effective way of teaching writing skills than other teaching methods in many countries. However, a French version of the intervention never has been tested experimentally in a real-life classroom setting. This is an important issue, as French students have been found to have great difficulty using scratch paper for planning and writing high-quality texts (see Andreu, 2018; DEPP, 2015). Therefore, the SRSD intervention may prove to be a promising tool for French students to overcome writing difficulties, as the intervention is

designed to teach students how to generate and organize ideas before writing their texts. Thus, this study's first aim was to test whether French students who received the SRSD intervention for teaching writing strategies would then be able to write higher-quality stories than those written by students who received regular writing instruction.

More importantly, as Harris and McKeown (2022) pointed out, more research is needed to help us understand why, how, and for whom SRSD works; whether it truly develops the entire set of self-regulatory skills needed for all students to write high-quality texts and whether certain aspects of the intervention could be reinforced. For instance, it remains unclear: (1) whether SRSD impacts monitoring accuracy; (2) whether schema-driven planning strategies that encourage students to generate and organize ideas around the important parts of a story really help them expand and better structure their texts; (3) whether the text's structure and the number of ideas it contains explain improvements in text quality; and (4) whether certain factors moderate the SRSD intervention's effectiveness. Also, while some studies have yielded some initial clues as to the nature of the psychological mechanism that could underpin SRSD's effectiveness (Brunstein & Glaser, 2011; Fidalgo et al., 2008; Fitz-Patrick & McKeown, 2020, 2021; Glaser & Brunstein, 2007; Harris et al., 2019; Torrance et al., 2007), the literature on this subject remains limited, with contradictory results concerning the real benefit of the newly acquired planning strategies in explaining the SRSD intervention's positive effects. Furthermore, not all of these studies were conducted in real-life classroom settings (i.e., Brunstein & Glaser, 2011; Glaser & Brunstein, 2007), and in some cases, students were required to plan their texts within a mandatory time frame, so we cannot know whether the students who underwent the SRSD training would have spontaneously (i.e., without prompting) used planning strategies (e.g., Brunstein & Glaser, 2011; Glaser & Brunstein, 2007). Having better insights into the cognitive and metacognitive mechanism behind the SRSD intervention's effectiveness and the factors that might hinder it could help enhance teachers' use of SRSD by providing clear recommendations on (1) the aspect of the intervention they should emphasize to their students, (2) which skills to monitor to identify students' difficulties and adjust their teaching if needed, and (3) how to design effective adaptive scaffolding that will offer process-oriented support to help students better internalize self-regulation writing skills taught to them. Thus, the present study's second aim was to better understand the cognitive and metacognitive mechanisms that underlie the SRSD intervention's effectiveness and identify factors that potentially could hinder it.

To meet our goals, the present study compared, in a naturalistic context, French fourth- and fifth-graders from disadvantaged social backgrounds who received either the SRSD intervention or regular French writing instruction to learn how to write stories. Writing stories is a task regularly taught in French primary school, and one that students are expected to master by the end of fifth grade (Ministry of National Education and Youth, 2024). The task observed in this study did not involve the use of multiple external sources and, therefore, did not require mastery of comprehension strategies, unlike certain other writing tasks that students sometimes encounter in school situations (e.g., Raković et al., 2021, 2023). We adopted a quasi-experimental approach that allowed for whole-class teaching. Over a three-month period, the students received either the SRSD intervention or regular French curriculum-based story writing instruction in their usual classrooms during normal teaching hours.

Several measurements were taken prior to the writing lessons to create two equivalent groups using the propensity score matching (PSM) method after the writing lessons to study

the SRSD intervention's effects and to understand the roots of its effectiveness. At these two measurement time points (before and after the writing lessons), students were asked to imagine and write a story based on a picture that the experimenter provided. Their texts were assessed on four criteria: number of words produced; number of idea units; number of story parts; and overall quality (estimated by two hypothesis-blind teachers). They also were asked to self-rate their stories' quality to determine whether those who received the SRSD intervention would produce more accurate monitoring judgments than those who received regular writing instruction. Furthermore, students' planning skills were measured (number of words, number of idea units, and number of story parts included on an extra planning sheet). We ran mediation analyses with the planning measures as mediators to study whether the difference observed between the two groups on the quality of text produced could be attributed to better planning activity. Finally, students' working memory capacity, graphomotor skills, self-efficacy, and writing motivation were assessed to determine whether these factors moderated the SRSD intervention's effectiveness.

Research questions and hypotheses

Research question 1 Can the SRSD intervention enable French students to write higher-quality stories than those written by students who receive regular writing instruction?

Extant studies consistently have demonstrated in various countries that SRSD-type interventions enabled students to write higher-quality texts than those written by students who received regular writing instruction. For example, a positive effect from the SRSD intervention on text quality was found in China (e.g., Chen et al., 2022), Canada (e.g., Klein et al., 2022), Germany (e.g., Brunstein & Glaser, 2011), the Netherlands (e.g., Bouwer et al., 2018), New Zealand (Finlayson & McCrudden, 2021), Portugal (e.g., Festas et al., 2015), Spain (e.g., Fidalgo et al., 2007), and the United States (e.g., McKeown et al., 2023). Based on these myriad successful translations of the SRSD intervention to different countries with various spoken languages, we expected that a French version of the SRSD intervention also would lead students to produce higher-quality texts than those written by students who received regular writing instruction (Hypothesis 1).

Research question 2 does the SRSD intervention impact monitoring accuracy?

To produce accurate monitoring judgment, students need a good representation of the task's expectations, as well as suitable strategies for efficiently self-estimating their texts' quality (Graham, 2018). The SRSD intervention explicitly teaches these two aspects. Also, other studies have demonstrated that SRSD could help students better self-regulate their revision process to adjust their text to the task's expectations effectively (McKeown & FitzPatrick, 2015, 2020), suggesting that students probably were able to make more accurate judgments about their written production during the task. Therefore, by explicitly teaching students writing goals, as well as developing a strategy to estimate whether these goals had been achieved, we expected that the SRSD intervention would lead to students making more accurate monitoring judgments than their peers in the regular writing instruction group (Hypothesis 2).

Research question 3 Does the SRSD intervention enable students to use more developed writing strategies and write texts that are longer and better-structured than students who receive regular writing instruction?

The SRSD intervention aims to teach students to use a planning sheet to generate and organize their ideas before writing their texts. A few extant studies have provided evidence that SRSD-type interventions enable students to spend more time planning (Torrance et al., 2007), then using their planning sheets to develop ideas structured around the text's key elements (Brunstein & Glaser, 2011; FitzPatrick & McKeown, 2020, 2021; Glaser & Brunstein, 2007; Harris et al., 2019; Limpo & Alves, 2018; Salas et al., 2021). Thus, like our predecessors, we expected students in the SRSD group to score better on planning measures (time spent planning, number of words, number of ideas, and number of story parts included in the extra planning sheet; Hypothesis 3a) than the regular writing instruction group. Also, students' extra efforts to plan should lead them to engage more time in the writing of longer stories that include more ideas and essential story parts. Thus, we also expected students in the SRSD group to score better on story measures (time spent writing the story, number of words, number of ideas, and number of story parts included in the story; Hypothesis 3b) than the regular writing instruction group.

Research question 4 Is the use of planning strategies behind the SRSD intervention's positive effects?

Other extant studies have elicited contradictory results as to the explanatory power of the development of planning strategies on student stories' quality (Brunstein & Glaser, 2011; Fidalgo et al., 2007; Glaser & Brunstein, 2007). We believe that these results can be attributed to the choice of measurement methods used by previous studies and that considering the number of ideas and their organization on the planning sheet is a better proxy for planning skills than measuring the time spent planning. Also, no extant study so far has examined the extent to which newly acquired planning skills explain resulting student stories' characteristics. We expected the generation and organization of ideas on the extra planning sheet enabled by the SRSD intervention to help students expand and better structure their stories (Hypothesis 4a), which would explain improvements in holistic quality judgments regularly observed following the SRSD intervention (Hypothesis 4b).

Research question 5 Are there cognitive or motivational factors that moderate the SRSD intervention's effectiveness?

Working memory plays an important role in retrieving and organizing ideas and knowledge to write a text that meets preestablished goals (e.g., Olive, 2014; Ruffini et al., 2024). Students' limited working memory resources can be taxed by non-automated handwriting (Graham et al., 2017; Limpo & Alves, 2018; Rocha et al., 2022, 2023; Skar et al., 2022). Finally, students' perceptions of their ability to write quality texts may decrease their willingness to engage in the use of costly writing strategies taught as part of the SRSD intervention. Therefore, we expected the SRSD intervention's effectiveness to be moderated by factors that have been demonstrated to be related to writing abilities, namely graphomotor

skills (Hypothesis 5a), self-efficacy (Hypothesis 5b), writing motivation (Hypothesis 5c), and working memory (Hypothesis 5d).

Methods

Participants

To test our hypotheses, we adopted a between subject design with a quasi-experimental approach that enables us to compare two matched groups (SRSD and “business-as-usual” [BAU]) in a real-life classroom setting. We considered several criteria to determine sample size. First, we ran a power analysis with G*Power 3.1 (Faul et al., 2007), using the 1.17 mean SRSD effect size highlighted in Graham et al. (2012)’s meta-analysis as the effect size input. Results showed that a minimum of 20 participants would be needed ($d=1.17$, $\alpha=0.05$, $1 - \beta=0.80$) for a one tailed t-test testing the difference between two independent means. The quasi-experimental nature of our study required us to consider additional factors. According to the U.S. Institute of Education Sciences, to design a strong quasi-experimental study, a minimum of two classes must be assigned to each experimental and control condition (see Scher et al., 2015; What Works Clearinghouse, [WWC], 2022). We chose to assign a minimum of three classes to each group, in case any classes dropped out. To meet WWC standards for quasi-experimental studies, data must be pretested, in order to construct two equivalent groups at baseline using a matching method. This required a sufficiently large BAU group, to ensure that we would find enough comparable students from the control group to match with students in the SRSD group.

We put out a call for participants in the research project. The French Ministry of Education relayed this call to districts that had schools in areas with a high proportion of children from socially disadvantaged backgrounds. The recruitment period took place over five months. At the end of this period, the French Ministry of Education informed us that three schools from the same district in the eastern suburbs of Paris responded positively to this call. According to the criteria of the French Ministry of National Education and Youth, all three schools could be described as having a high proportion of children from socially disadvantaged backgrounds (based on rate of disadvantaged socio-professional groups, rate of grant-holders, rate of pupils living in sensitive urban areas, and rate of pupils late in entering sixth grade). Within these schools, nine teachers of 199 fourth- and fifth-graders volunteered to participate in this research. All students and teachers who were invited to participate in the study received a consent pack. All teachers consented to participate in the study. Teachers, parents, and students were informed of the study’s overall goal, as well as that no foreseeable risk or disadvantages were associated with participation in this study and that the data collected from students would be anonymized. Overall, 195 parents and their children provided consent to participate in the study. They were informed that students remained free to withdraw from the study at any time and without prejudice. No exclusion criteria were applied at this stage, so all 195 students were invited to participate in the study. Each of the nine classes was allocated to one of the two experimental conditions: SRSD or BAU. The three classes in the SRSD condition underwent the SRSD intervention, whereas the six classes in the BAU condition underwent the usual French curriculum-based writing instruction. In November, prior to the first session, to form two equivalent groups using the pro-

pensity score matching method, several tests were administered to students in both groups to obtain baseline measures of their writing skills, motivation to write, self-efficacy, and working memory ability. Students' writing skills in each group were measured once again in March, after each intervention's final session, to compare intervention effects. Two students refused to perform the experimental task, and one produced an illegible text. The data of these three students were not included in the analyses. School closures owing to the COVID pandemic prevented 88 children in four classes from performing the post-test. Thus, a total of 104 students (54 boys, 50 girls) from five classes completed the entire experiment: two classes in the SRSD condition ($n=39$), and three classes in the BAU condition ($n=65$).

Most attrition was due to the COVID pandemic and, therefore, was not related to the constructs being measured. Contrary to randomized controlled trials, attrition in quasi-experimental studies is not an issue and does not impact WWC study quality ratings as long as the treatment and comparison groups are carefully matched at baseline, using the analytic sample after any attrition since the beginning of the study (see Scher et al., 2015). Thus, to ensure a valid comparison between the experimental and BAU groups, we followed the WWC recommendation and applied a propensity score matching (PSM) procedure to construct two equivalent groups at baseline. The PSM procedure ensured balance on the covariates between groups, by matching participants in the experimental group with similar participants in the BAU group according to their demographic characteristics and other data relevant to the study aim (see Thoemmes, 2012). PSM was chosen rather than Mahalanobis metric matching, as this approach is better suited when there are more than seven covariates and they are not normally distributed (Stuart, 2010), which was the case for all the writing measures used in our study. All the pretest measures collected in the present study were used to estimate the students' propensity score: age, writing motivation, self-efficacy, graphomotor and working memory skills, planning sheet data (time spent planning and numbers of words, ideas, and story parts), and writing production data (time spent writing and numbers of words, ideas, and story parts). Details of all measures are set out in the following "Measures" subsection. PSM procedure was run using the PSMATCHING3 R extension command on SPSS version 28. We used the nearest neighbor matching algorithm with a caliper width equal to 0.2 of the standard deviation of the logit of the propensity score, as recommended by Austin (2011).

On the basis of their propensity scores, 52 (30 boys, 22 girls) of the 104 students were matched to fill the SRSD (14 boys, 12 girls) and regular instruction (i.e., BAU; 16 boys, 10 girls) groups (26 per group), excluding the 52 nonmatched participants. The overall balance test showed that there was no significant difference ($\chi^2=3.824$, $df=14$, $p=.99$), and no covariate exhibited a large imbalance ($|d| > 0.25$). According to the WWC recommendation, Hedges' g effect size differences between two groups must be no greater than 0.25 standard deviation for any of the measures, in order to satisfy the baseline equivalence standard. Balance checks indicated that the PSM procedure gave rise to SRSD and BAU groups with equivalent characteristics and equivalent writing, working memory and graphomotor abilities prior to the writing intervention. Power analysis indicated that the study had a 99.4% chance of finding a true effect ($d=1.14$, $\alpha=0.05$, $n=52$), meaning that with 52 matched participants, the study was appropriately powered. Means, standard deviations, and ranges for the SRSD and BAU groups are set out in Table 1, together with Hedges' g effect sizes between the two groups on all pretest measures.

Table 1 Means and standard deviations for students' characteristics and pretest writing measures according to group

Variable	Condition				g
	SRSD group		BAU group		
	Mean (SD)	Range	Mean (SD)	Range	
Students' characteristics					
Age	10.01 (0.58)	[9.00, 10.83]	10.11 (0.49)	[8.83, 10.83]	0.18
Digit span <i>z</i> score	0.32 (1.65)	[-2.34, 4.05]	0.44 (1.37)	[-1.71, 3.27]	0.06
Graphomotor <i>z</i> score	0.00 (1.49)	[-3.18, 4.04]	-0.08 (1.38)	[-2.96, 2.24]	0.08
Motivation to write	6.23 (1.88)	[2, 8]	6.15 (2.31)	[1, 8]	0.04
Self-efficacy	6.00 (2.12)	[1, 8]	5.81 (2.25)	[1, 8]	0.09
Planning sheet					
Number of story parts	0.96 (1.18)	[0, 4]	1.08 (1.35)	[0, 4]	0.09
Number of ideas	3.54 (5.43)	[0, 20]	3.77 (5.41)	[0, 20]	0.04
Number of words	5.04 (7.28)	[0, 24]	6.88 (12.43)	[0, 52]	0.17
Time spent on task	56.96 (95.40)	[0, 343]	68.42 (103.27)	[0, 390]	0.11
Story					
Number of story parts	2.58 (1.39)	[1, 5]	2.85 (1.43)	[1, 6]	0.18
Number of ideas	22.69 (16.41)	[4, 61]	24.65 (12.35)	[8, 58]	0.13
Number of words	68.00 (49.14)	[10, 183]	72.31 (41.51)	[22, 207]	0.09
Time spent on task	522.85 (304.37)	[90, 1040]	585.19 (315.87)	[104, 1360]	0.19
Text quality	3.83 (2.14)	[1, 8]	4.02 (1.39)	[1.5, 6]	0.11
Text quality estimation	6.12 (1.73)	[2, 8]	6.23 (1.66)	[1, 8]	0.07

Note SRSD=Self-Regulated Strategy Development

The study followed the principles expressed in the Declaration of Helsinki and was reviewed and approved by a consortium of academics and members of the National Education Ministry. All data, analysis code, research materials and all the material for the writing intervention are available on the Open Science Framework: https://osf.io/gncm8/?view_only=f2731ecc6f8047079fb4b860830ed76a.

Measures

A research assistant team was trained to lead the test sessions. The team was given a script detailing the steps to follow to apply the test procedure. The first author supervised the tests' experimental runs. The test sessions were administered to groups of five to seven students in quiet classrooms at their schools, with pencils and paper provided. The research assistants were available to answer students' questions about the task instructions, but could not help students complete the task. School administrators and teachers were unaware of the tasks conducted during the tests in the experimental runs.

Writing Task

Students were asked to write a story from a picture. A set of six pictures were selected for this purpose by the nine teachers involved in the research project from a pool of 28 pictures. They were asked whether they thought these pictures would encourage their students to imagine and write a story (picture order was counterbalanced across the teachers). For each picture, they indicated their answer on a Likert scale ranging from 1 (*Strongly disagree*) to

7 (*Strongly agree*). The six pictures used for the task were those that received the highest ratings ($M=5.88$, $SD=0.20$; see Fig. 1). As in Graham et al. (2005)'s study, students were given a choice between two pictures to help them perform the writing task. The six pictures were divided into three different sets of two pictures that were counterbalanced across students. Each student received a different set of pictures at each test (i.e., before and after interventions). Statistical analysis on all the stories produced by students in the two groups indicated that pictures did not have a significant effect on either time spent writing, numbers of story parts, words and ideas, or text quality. Students were instructed to use their chosen picture to imagine and write a story. Participants had one minute to choose a picture, after which they were offered a sheet of scratch paper. Students were told that this scratch paper was a planning sheet and was to be used only for planning. It was not to be used to write sentences or a first draft of their story, but instead to identify, write down and organize their ideas before writing their story. As the goal of the research was to study the spontaneous use of planning strategies, students were free either to take the scratch paper or to give it back to the experimenter if they felt they did not need it. Students who did not want to plan could start writing their story straight away, the others had as much time as they wanted

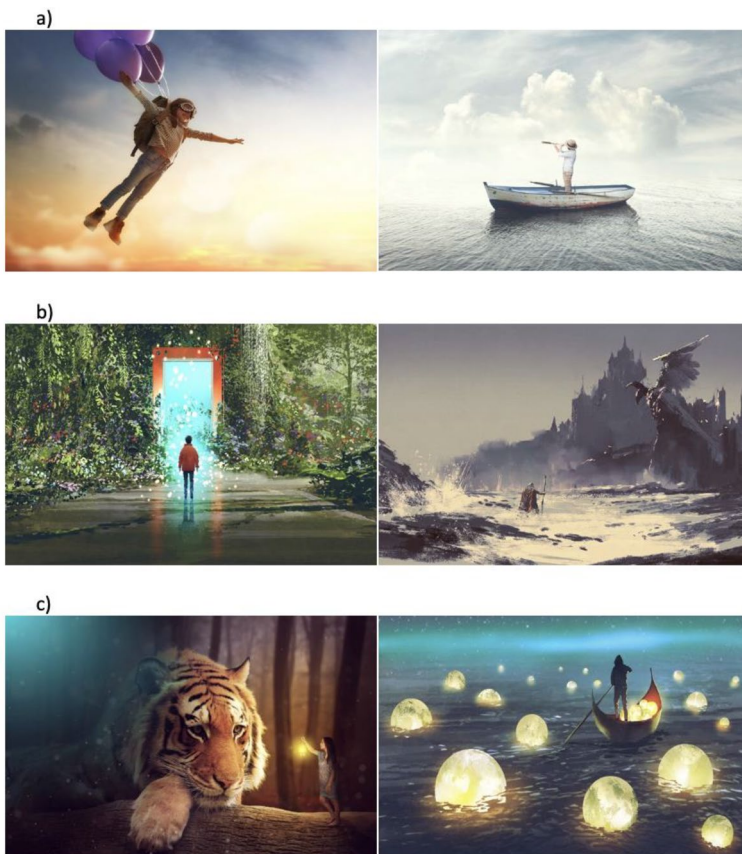


Fig. 1 Six pictures selected for the pre- and post-test writing assignments, divided into three sets: (a), (b), and (c)

to plan their story. When students were ready to start writing their story, they were given a blank sheet of paper. Students who had used a planning sheet could keep it with them to write their story, but were not allowed to add any new content to it. They had as much time as they wanted to write their story. Once they had finished, they handed their story to the experimenter.

Text quality: teachers' assessment

Each story's quality was double-scored by two former elementary school teachers blind to the hypotheses following Graham et al.'s (2005) procedure (in their study, interrater reliability correlation for story quality assessment was 0.87). Stories were typed up and their spelling mistakes were corrected before scoring, to avoid bias due to handwriting or spelling. Teachers were instructed to independently rate the overall quality of each story on an 8-point Likert scale ranging from 1 (*Low quality*) to 8 (*High quality*). They were asked to take into account the number and quality of ideas, the organization of the words, the structure of the sentences, and the richness of the vocabulary (interrater reliability correlation: 0.73). The ratings of both teachers for each story were averaged to obtain text quality scores.

Text quality: students' self-assessment

After completing the written assignment, to ascertain whether SRSD intervention influenced monitoring accuracy, students were asked to assess the overall quality of each story on an 8-point Likert scale ranging from 1 (*Low quality*) to 8 (*High quality*). They were asked to take into account the number and quality of ideas, the organization of the words, the structure of the sentences, and the richness of the vocabulary.

Planning measures: time on task, number of words, ideas, and story parts

First, we recorded the amount of time spent by students on an extra planning sheet and the number of words included in this sheet. No time limit was imposed to participants to write their story. Consequently, no word limit was imposed on participants. Furthermore, the number of ideas included on the planning sheet also was recorded. To do so, the first author extracted each idea unit (i.e., the smallest meaningful unit) included on each planning sheet and coded it based on the characteristics set out in Table 2. For example, if a student wrote "The broomstick was magic", it was coded as an object characteristic. A total of 1107 ideas were coded for the planning sheets collected at pretest and post-test. An undergraduate blind to the hypotheses independently double coded all the ideas. The two raters agreed on the coding of 90.24% of the ideas (Cohen's kappa=0.89). The 9.76% of conflict emerged when the coders had a divergent interpretation of the ideas' classification (e.g., "Is 'to be an adventurer' a social or mental characteristic?"), when two categories could fit for one idea unit (e.g., "Is 'Ninja' a character or social characteristic of the character?"), or in rarer cases, due to coders' inattention errors. Conflicts were resolved through discussions. We summed up the ideas contained in each planning sheet. Students could obtain a score on this variable ranging from 0 to positive infinity.

Finally, we scored the planning sheet on the presence of story parts, using Graham et al. (2005)'s coding scheme: main characters, location, information on time, what characters

Table 2 Coding Scheme for Students' ideas

Ideas coded	Student example
Characters	"Ines (...)"
Physical characteristics	"She was so small we could not see her"
Social characteristics	"She was an animal trainer at the circus"
Mental characteristics	"He was very happy"
Object	"A broomstick"
Object characteristics	"It was magic"
Location	"The world of wonders"
Location characteristics	"This place was secret"
Time	"It was a long long time ago"
Action	"She jumped away"
Action characteristics	"These jumps were like those of a kangaroo"

want to do, actions to achieve a goal, story resolution, and character reaction. Each story parts included in the planning sheets was scored 1 point. Points were summed for each planning sheet. Students could obtain a score on this variable, which could range from 0 to 7. An experimenter and a trained graduate blind to the hypotheses double-coded all the planning sheets (interrater reliability: 0.96). Limpo and Alves (2018) used a similar approach to code planning sheets and obtained a similar average interrater reliability of 0.97. If a student did not produce text on the planning sheet, time on planning sheets and numbers of words, ideas and story parts were scored zero.

Story measures: time on task, number of words, ideas, and story parts

As with the planning sheet, we recorded the amount of time students spent writing their story on the new sheet of paper, and the numbers of words (as provided by the word processor), ideas and story parts. We used the same idea and story parts coding schemes as for the planning sheets. A total of 7846 ideas were double coded by the first author and a graduate student blind to the hypotheses. The two raters agreed on the coding of 7090 (90.24%) ideas (Cohen's kappa=0.89). Conflicts were resolved through discussion. We then summed the ideas contained in each story. The first author and the graduate student also coded the parts of each story, using the same scoring principle as for the planning sheets (interrater reliability=0.85). Graham et al. (2005) used the same coding scheme, with interrater reliability for the coding of stories at 0.86.

Handwriting

Following Limpo and Alves (2018)'s procedure, we used two tasks to measure handwriting fluency. In the first task, students were asked to write down the letters of the alphabet as quickly and accurately as possible. After 15 s, the experimenter stopped the task and asked students to immediately raise both hands. The score for this first task was the number of letters correctly written in the time allowed. As this measure has no upper limit, students could obtain a score that could range from 0 to positive infinity. The first and second author double-coded one-third of the production. We obtained an interrater reliability of 0.99, which was identical to the one that Limpo and Alves (2018) obtained. In the second task, students had to write a pangram several times in a row until they were told to stop. After 90 s, the

experimenter stopped the task and asked students to immediately raise both hands. The score for this second task was the number of words correctly written in the time allowed. As this measure has no upper bound, students could obtain a score that could range from 0 to positive infinity. We obtained an interrater reliability of 0.99, similar to that of Limpo and Alves (2018), at 0.98. A handwriting skill score was obtained by summing the standardized scores on the two tasks.

Writing motivation and self-efficacy for writing

Writing motivation and self-efficacy for writing have been shown to be enhanced by SRSD (e.g., Brunstein & Glaser, 2011; De Smedt et al., 2018), we assessed these two constructs in order to check that the two groups were initially equivalent and to see whether the constructs moderated the efficacy of the SRSD intervention. To limit the duration of tests, we used single-item measures. Single items have been shown to be a suitable alternative to multiple-item measures assessing these constructs, notably when the goal is simply to understand the relations between measures or to control for variables (see Gogol et al., 2015). To design our two items, we based our approach on the autonomous items on the Self-Regulation Questionnaire-Writing Motivation (SRQ-WM) and the ideation items on the Self-Efficacy for Writing Scale (SEWS), designed by De Smedt et al. (2018). Both questionnaires were tested on 799 fifth- and sixth-graders using CFA and have demonstrated good validity. Acceptable fit was found for the SRQ-WM questionnaire (Satorra-Bentler; $\chi^2 [116] = 653.45, p < .001$, CFI=0.94, RMSEA=0.06, SRMR=0.05), and good fit was found for the SEWS questionnaire (Satorra-Bentler; $\chi^2 [51] = 204.88, p < .001$, CFI=0.95, RMSEA=0.04, SRMR=0.04). Both questionnaires demonstrated good reliability (autonomous motivation: Bentler's $\rho = 0.90$; self-efficacy ideation Bentler's $\rho = 0.82$). For our study, the writing motivation item that we used (i.e., "I enjoy imagining and writing stories") was based on the SRQ-WM (e.g., De Smedt et al., 2018). The writing self-efficacy item that we used (i.e., "I find it easy to imagine and write stories") was designed from the ideation items used in the SEWS (De Smedt et al., 2018). Students were asked to indicate their agreement with each of the two items on a Likert scale ranging from 1 (*Strongly disagree*) to 7 (*Strongly agree*). They had previously been trained to use a Likert scale by having to indicate their level of agreement with several statements about liking different types of food. They were told that there was no right or wrong answer and they just had to indicate the most appropriate degree of agreement.

Working memory

We used the Digit Span subtest of the Wechsler Intelligence Scale for Children Fourth Edition (2003) to measure working memory, testing each student individually (retest reliability of 0.83, internal consistency reliability of 0.93; Wechsler, 2008). Students had to recall items composed of a series of numbers, first two numbers, then three numbers, and so on up to eight numbers. There were two trials for each item. The numbers were presented at the rate of one number per second. No number series was presented twice. Participants had to recall the numbers either in the same order (Digit Span Forward) or in the reverse order (Digit Span Backward). If there was a missing number or the series was recalled in the wrong order, the trial was deemed to be incorrect. The experimenter stopped the test if both

trials of an item were incorrect. An example including a correction was given to students to familiarize them with the test beforehand. Each successful trial was scored 1 point, and each unsuccessful trial was scored 0 points. Students could obtain a score ranging from 0 to 16 for both digit span tasks (8 items including each 2 trials). We summed each student's scores on the Forward and Backward trials. We then calculated a working memory score for each one by summing the standardized Forward and Backward scores.

SRSD intervention

The SRSD intervention designed to teach students how to write narrative texts was used in a real-life classroom setting (for detail of the intervention, see Harris et al., 2008). The intervention was applied by three experimenters in eight 50-minute sessions. Each experimenter led at least two of these sessions. Session 1 was used to define writing goals (i.e., essential parts of a narrative text and their organization, number of ideas include in the text) as well as to explain the notions of *writing strategy* and *self-regulation*. To this end, French versions of the two SRSD mnemonics were introduced. *POW* was used to help students remember the three important steps to follow when writing a story (P=Pick my ideas; O=Organize my notes; W=Write and say more). *WWW*, *What=2*, *How=2* was used to help students memorize the seven important story parts (W=Who is the main character?; W=When does the story take place?; W=Where does the story take place?; What=What does the main character do or want to do, and what do the other characters do?; What=What happens then and what happens to the other characters?; How=How does the story end?; How=How does the main character feel and how do the other characters feel?). Students were told that these mnemonics would help them achieve the writing goals that are to find and organize the ideas needed to write well-structured stories that would be fun to write and fun for others to read. They then had to write the two mnemonics and their meanings down on a sheet of scratch paper, to anchor them in memory. Students were given a graphic organizer featuring the seven story parts, as well as two short texts. The experimenter worked with them to find the story parts of each text and to note them in the graphic organizer. As the SRSD intervention could not exceed eight 50-minute sessions, we chose to remove the work on vocabulary improvement that is classically included in the SRSD intervention for writing narrative texts. The first session ended with a transfer lesson encouraging students to use the newly learned strategies in other contexts (e.g., summarizing a story, describing a holiday). Each of the seven subsequent sessions started with a reminder of the two SRSD mnemonics and an examination of how students had transferred the strategies at home or in school.

Session 2 was dedicated to teaching students how to monitor the quality of their stories. To this end, they were asked to identify the story parts and count the number of ideas they had included in one of their previous stories written prior to the intervention. For each story part, students colored one of seven stages of a rocket. They were then asked to indicate the number of ideas included in their story at the top of the rocket. This allowed them to monitor their progress across the writing practice sessions in terms of the structure and number of ideas included in their stories, as well as to self-generate feedback on the quality of their productions.

In Session 3, the experimenter modeled writing a story. To write her story, she used the two mnemonics, the graphic organizer, and the rocket to generate and organize her ideas in an extra planning sheet, write her story, and assess the quality of the text she had produced.

Throughout this process, the experimenter verbalized her thoughts to help students understand the covert cognitive and metacognitive activity that took place during the writing process (e.g., mental self-instruction, setting of objectives, writing strategies, monitoring, and self-reinforcement). Students were asked on the basis of their observation of the modeling session to elaborate their own self-instruction and self-reinforcement.

Sessions 4–6 were dedicated to guided practice writing, during which all the students in the class, with the help of the experimenter, actively cooperated to find and organize ideas with the help of the graphic organizer to write a new story. The experimenter provided the participants with regular incentives and feedback, then gradually decreased support based on the students' progress in mastering the strategies they had been taught and the regulation of the writing process. During this phase, for each story, once the graphic organizer was completed collectively, the students were asked to write their own stories using their own self-instruction or self-reinforcement strategies, and to monitor their stories' quality.

Sessions 7 and 8 corresponded to an autonomous phase where students worked on their own planning, writing and monitoring. They could use the graphic organizer to help them in the planning phase. However, for their last story (Session 8), no graphic organizer was provided to students. Instead, they were given a sheet of scratch paper, on which they were asked to draw their own graphic organizer. During these last two sessions, the experimenter continued to answer students' questions and provided them with feedback when necessary.

SRSD implementation fidelity

To ensure that SRSD was implemented, several precautions were taken. First, the first author trained the instructors on how to apply each of the SRSD sessions. Second, the instructors received a folder containing the documents to be provided to the students (e.g., strategy sheets, transfer sheets, texts, self-assessment sheets), as well as a checklist of the points to be addressed and instructions on how to distribute the various documents. Third, for the modeling session, the instructor was given a pre-drafted planning sheet that included the strategy on the front and a pre-written graphic organizer and story on the back. The elements to be addressed orally during the application of these strategies in front of the students were written on the planning sheet. Fourth, for each SRSD session, experimenters were supplied with a PowerPoint presentation to project in class. This allowed us to dictate to the instructor the content and structure of each lesson (see Material section on the Open Science Framework website), minimizing the risk of overlooking any element of the intervention. Fifth and finally, the first author attended all SRSD lessons and used Harris et al. (2008)'s checklist to ensure that the intervention was accurately presented (see Chap. 6, POW+WWW lesson checklists). If at any point, a component of the intervention was forgotten, the operator would intervene in real time discreetly to remind the instructor to apply it. Nevertheless, the arrangements outlined above limited the risk of this happening, and the first author did not need to intervene more than twice per session. Consequently, all the steps of the SRSD intervention were correctly implemented.

Writing instruction in the business-as-usual condition

The teachers of the three BAU conditions all had considerable experience, having taught between 9 and 21 years. Between the pre- and post-tests, all three teachers were asked to

implement the writing instruction they usually provided, in line with the French curriculum: (1) writing a variety of texts; (2) mobilizing previous language learning (spelling, syntax, lexicon, conjugation); and (3) organizing a text in a planning phase and following the first draft, rereading, and revision steps (see Ministry of National Education, 2024). To identify their teaching practices more precisely, we followed the procedure used by Festas et al. (2015) and administered a questionnaire focused on the teacher's writing-based classroom practices. The questionnaire items were taken from Brindle et al. (2016)'s surveys, and covered French curriculum expectations, as well as components addressed by SRSD. As in Festas et al. (2015)'s study, teachers had to indicate how often each item occurred in their classroom on a 5-point scale: 0 (*Never*), 1 (*Up to 30 min a week*), 2 (*31–60 min a week*), 3 (*61–90 min a week*), or 4 (*More than 90 min a week*). For results by teacher, see Table 3.

Procedure

The tests conducted prior to the interventions comprised five tasks, starting with the two handwriting tasks (an alphabet task followed by a pangram task). Students then had to rate their writing motivation and self-efficacy for writing on a Likert scale. The fourth task was to write their stories from a picture. They then were asked to rate their stories' quality. The final task was the working memory test. Once the prior intervention tests had been completed, the students received writing instructions over a three-month period in either the SRSD condition (two classes) or BAU condition (three classes). With the post-intervention

Table 3 Teachers' characteristics and teaching practices in the BAU group

	Teacher 1	Teacher 2	Teacher 3
Teachers' characteristics			
Gender	Female	Female	Female
Age	32	44	43
Years of teaching	9	21	20
Preservice or in-service instruction in the teaching of writing	Yes	No	Yes
Teaching practices in class			
Graphomotor skills	Up to 30 min	Never	Up to 30 min
Grammar, spelling, and conjugation	More than 90 min	More than 90 min	More than 90 min
Punctuation	Up to 30 min	Never	Up to 30 min
Sentence construction	Never	Never	61–90 min
Narrative text writing assignments	More than 90 min	31–60 min	More than 90 min
Explicitly setting writing goals	Up to 30 min	Never	Up to 30 min
Planning	Up to 30 min	Up to 30 min	Up to 30 min
Planning strategies	31–60 min	Up to 30 min	Never
Use of graphic organizer	Up to 30 min	Up to 30 min	Up to 30 min
Reviewing	61–90 min	Up to 30 min	Up to 30 min
Reviewing strategies	Up to 30 min	Never	Up to 30 min
Modeling technique	Never	Never	Never
Reading one's own written work	Up to 30 min	Never	Never
Self-assessment strategies	Up to 30 min	Never	Up to 30 min
Self-instruction strategies	Never	Never	Never
Self-reinforcement strategies	Never	Never	Never

tests, participants performed the same tasks as in the prior-intervention tests, except for the two handwriting tasks and the working memory task. Studying the SRSD intervention's effects on motivation was not this study's aim, but as the two questions measuring these effects were quick and easy to administer, we included them to check whether the intervention exerted any effect on these aspects. As the results indicated no significant effect on these two variables, and as these analyses were not the study's main objective, they are not discussed further in this manuscript. Readers who nevertheless would like to access these data can do so freely on the data file made available on OSF. A summary of the procedure is presented in Fig. 2.

Data analysis

Analysis of SRSD's impact on planning and writing data

To examine whether the SRSD intervention impacts development of students' writing strategies and improves text length, structure, and quality (Research Questions 1 and 3), we calculated generalized linear mixed models (GLMMs) to estimate differences between groups (SRSD vs. BAU) on the post-intervention measures taken on the planning sheets (time spent planning, number of words, ideas, and story parts) and stories (text quality, time spent writing, number of words, ideas, and story parts). These models included fixed effects for the predictor factor group, and a random effect was added to the model, allowing for random intercept with classes to account for the data's nested nature. The data obtained for each of the writing measures examined by groups did not distribute normally (skewness, kurtosis, and Shapiro-Wilk test results on each variable's data distribution by groups are available on OSF). Thus, we looked for the best error distribution type by using the maximum likelihood estimation method. The Akaike information criterion (AIC) and Bayesian information criterion (BIC) fit indices indicated that the conditional distribution of the numbers of words and ideas included in the planning sheets and in the stories were best modeled by negative binomial distribution. Time spent planning and time spent on the story was best modeled by

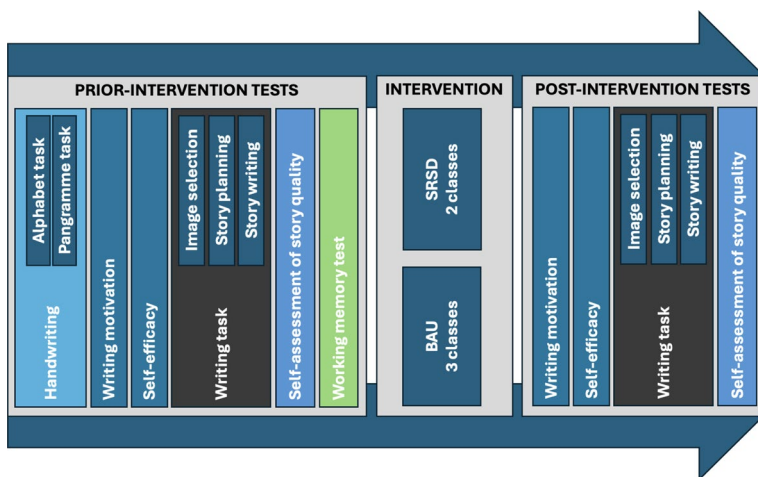


Fig. 2 Summary of the study procedure

a gamma distribution. We added 1 s to each observation for the time spent planning variable, in order to avoid nonpositive values, which are not allowed in the gamma distribution family. The number of story parts was best modeled by a Poisson distribution. Finally, we used a cumulative link mixed model to deal with the ordinal nature of the text quality measure. To measure effect size, we did not use Cohen's d , as this measure is inappropriate for data that do not distribute normally. Instead, we calculated Wilcoxon test effect size ($r \geq .10$, $r \geq .30$, and $r \geq .50$ represent small, medium, and large effect sizes, respectively). All GLMM analyses were run in RStudio 1.4.1717 using the glmmTMB package (Brook et al., 2017), except for those on text quality, which were run using the ordinal package (Christensen, 2019). Effect sizes were calculated using the rstatix package (Kassambara, 2020). Figures were produced using ggplot2 (Wickham, 2016).

Analysis of SRSD's impact on monitoring accuracy

To examine whether the SRSD intervention impacted monitoring accuracy (Research Question 2), we conducted a hierarchical multiple regression analysis to assess whether text quality produced after the writing lessons was predicted by students' ratings of text quality and whether this prediction was impacted by intervention (SRSD vs. BAU). We used Akaike Information Criterion (AIC) values to select the best model. Figures were produced using ggplot2 (Wickham, 2016).

Analysis to identify factors that mediate and moderate the SRSD intervention's effects

To examine whether the use of planning strategies is behind the SRSD intervention's positive effects (Research Question 4) and whether cognitive or motivational factors moderate the SRSD intervention's effectiveness (Research Question 5), we ran mediation and moderation analyses based on bootstrapping procedure (Hayes, 2017, 2022; Preacher & Hayes, 2004). This analysis allowed us to estimate the indirect effects of the SRSD intervention on text quality through planning and story measures and whether handwriting, motivation, self-efficacy or working memory moderate its effectiveness. Bootstrapping is a nonparametric test that is not based on any distribution shape assumption. It is well suited to small samples, as it produces a test that is not based on large sample theory. The estimated indirect effect had a 95% confidence interval, allowing us to rule out the null hypothesis. If 0 is not included in the confidence interval, the estimated indirect effect differs significantly from 0 at $p < .05$ (Preacher & Hayes, 2004). Before proceeding with the mediation and moderation analyses, we checked whether some of the planning and writing measures were collinear. Using Dormann et al.'s (2013) recommended procedure to detect and deal with collinearity, we proceeded in two steps. First, we regressed planning and writing measures on text quality, as well as computed variance inflation factors to detect whether some variables were collinear. We then conducted principal component (PC) analysis to build principal components on collinear variables. Principal component analysis is the most common way to deal with collinearity issues, allowing for construction of PCs based on variables that share substantial amounts of information to perform subsequent unbiased analyses. The PCs variables built then were used to conduct the mediation analysis. Mediation analysis

was computed using SPSS28 and Model 6 of the SPSS PROCESS macro (see Hayes, 2017). Moderation analysis was run using Model 92 of the SPSS PROCESS macro (see Hayes, 2022).

Results

Can the SRSD intervention enable French students to write higher-quality stories than those written by students who receive regular writing instruction?

We predicted that the SRSD intervention would allow students to produce higher-quality texts than those written by students who receive regular writing/BAU instruction (Hypothesis 1). While the students in these two groups did not differ in any of these variables prior to intervention (see Table 1), the statistical analysis revealed that at post-intervention, students in the SRSD group wrote higher-quality texts than those written by students in the BAU group (Estimate=1.67, 95% CI [0.46, 2.89], $\chi^2=4.52$, $p=.033$; see Fig. 3). The size effect's magnitude is moderate ($r=.44$).

Does the SRSD intervention impact monitoring accuracy?

We predicted that at post-test, compared with students in the BAU group, students in the SRSD group would more accurately judge the quality of their texts (Hypothesis 2). We

Fig. 3 Text quality according to groups (BAU vs. SRSD)

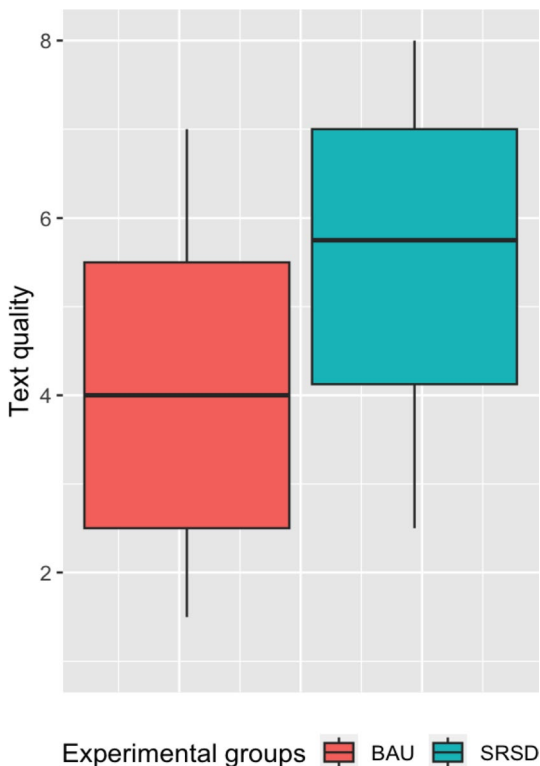
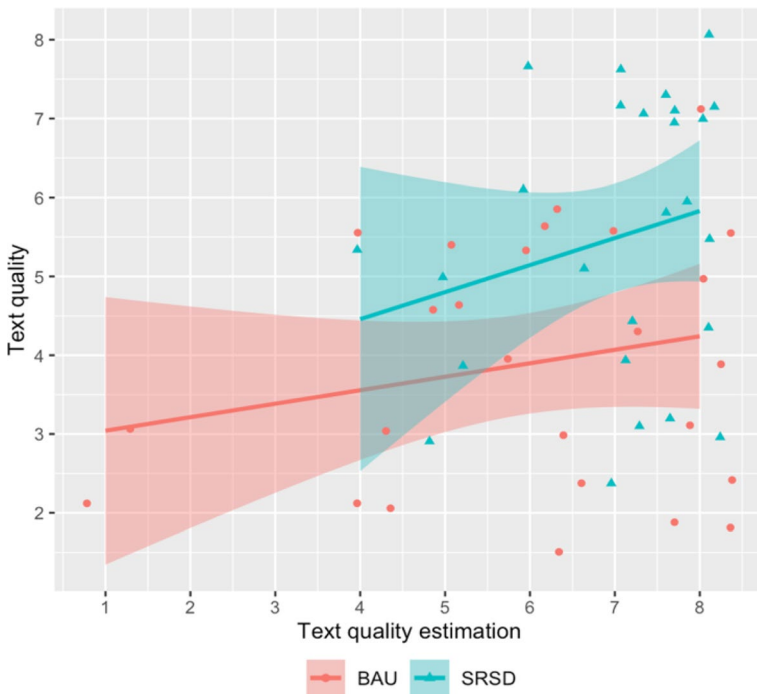


Table 4 Akaike information criterion values for model selection to test whether the students' estimation of text quality and the intervention (SRSD vs. BAU) predict quality of texts produced by students

Model name	Model	AIC
Model 1	$\text{TextQ} \sim 1 + (1 \text{Class})$	260.39
Model 2	$\text{TextQ} \sim \text{TQE} + (1 \text{Class})$	255.38
Model 3	$\text{TextQ} \sim (\text{TQE} + \text{Group}) + (1 \text{Class})$	255.21
Model 4	$\text{TextQ} \sim (\text{TQE} * \text{Group}) + (1 \text{Class})$	256.74

Note TQE=text quality estimation; TextQ=text quality ; A random effect of class is added for all models to account for the nested nature of the data

**Fig. 4** Accuracy of text quality estimation for the SRSD and BAU groups. A small amount of random variation was added to each point's location to deal with the overlapping points due to the two variables' discrete nature

expected that students who benefited from the SRSD intervention would have a better representation of the writing task's expectations, enabling them to produce an estimation of the quality of their text that would better correspond to its actual quality. The best model identified by AIC (see Table 4) indicated that the text quality was predicted by students' text quality estimation and that students in the SRSD group produced better assessments of text quality than students in the BAU group (see Fig. 4). Thus, the present results supported our hypothesis 2 that posited SRSD intervention makes a positive impact on monitoring accuracy. However, despite this improvement in monitoring accuracy, students in the SRSD group still overestimate by an average of 1.53 points the quality of their written production.

Does the SRSD intervention enable students to use more developed writing strategies to write texts that are longer and better-structured than those written by students who receive regular writing instruction?

We predicted that students in the SRSD group would spend more time planning and include more words and ideas on their planning sheets than students in the BAU group (Hypothesis 3a). We also predicted that students in the SRSD group would spend more time writing their stories and include more words and ideas on their story sheets than students in the BAU group (Hypothesis 3b). While the students in these two groups did not differ in any of these variables prior to the intervention (see Table 1), a statistical analysis revealed that at post-intervention, students in the SRSD group spent more time on their drafts and stories, and included more words, ideas, and story parts in their drafts and stories than students in the BAU group (see Fig. 5; for statistical data, see Table 5). All effect sizes demonstrated high magnitude.

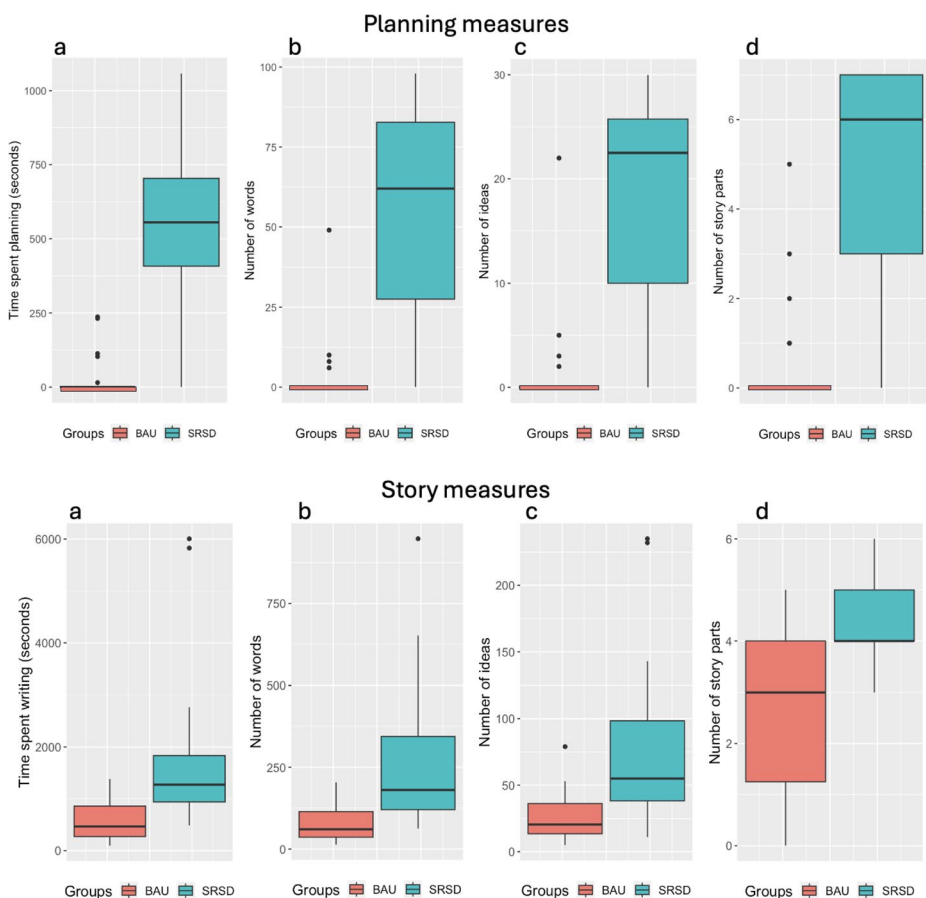


Fig. 5 Time spent writing (a), numbers of words (b), ideas (c), and story parts (d) included in the planning sheet (top) and in the story (bottom) according to each group (BAU vs. SRSD)

Table 5 Intervention effect for each planning and story measures

Variables	Estimate	95% CI	χ^2	<i>p</i>	<i>r</i> size effect
Planning measures					
Time spent writing	2.91	[2.02, 3.80]	41.45	<.001	.70
Number of words	2.96	[1.83, 4.10]	26.06	<.001	.71
Number of ideas	2.87	[1.42, 4.32]	15.06	<.001	.70
Number of story parts	2.30	[1.71, 2.90]	57.84	<.001	.68
Story measures					
Time spent writing	1.12	[0.77, 1.47]	39.46	<.001	.68
Number of words	1.18	[0.82, 1.54]	40.33	<.001	.64
Number of ideas	1.05	[0.63, 1.47]	24.25	<.001	.59
Number of story parts	0.45	[0.16, 0.75]	9.22	.002	.50

Table 6 Correlation matrix of planning sheet and story variables

Variable	1	2	3	4	5	6	7	8	9
1. Planning sheet – Number of story parts	1.00								
2. Planning sheet– Number of ideas	.94***	1.00							
3. Planning sheet– Number of words	.94***	.96***	1.00						
4. Planning sheet – Time spent planning	.90***	.92***	.89***	1.00					
5. Story – Number of story parts	.53***	.54***	.49***	.44**	1.00				
6. Story – Number of ideas	.34*	.37**	.35*	.26	.55***	1.00			
7. Story – Number of words	.37**	.40**	.39**	.31*	.55***	.97***	1.00		
8. Story – Time spent writing	.26	.30*	.27*	.27	.46***	.94***	.94***	1.00	
9. Story – Text quality	.38**	.43***	.42**	.25	.69***	.73***	.70***	.60***	1.00

Note * $p < .05$. ** $p < .01$. *** $p < .001$

Is the use of planning strategies behind the positive effects of the SRSD intervention?

We predicted that the planning strategies taught in the SRSD intervention would help students to expand and better structure their stories (Hypothesis 4a), which in turn would explain the improvement in text quality (Hypothesis 4b). To test these hypotheses, we ran mediation analyses to find out whether the relationship between SRSD intervention and text quality at post-test was explained by planning and story measures (numbers of story parts, ideas and words, and time spent on task).

Building of principal components for the mediation analysis

Very high correlations between both planning measures and story measures (see Table 6) made it highly likely that these variables had collinearity issues (for a discussion of how to detect and deal with collinearity, see Dormann et al., 2013). Therefore, all planning measures and story measures were regressed on text quality, and variance inflation factors were computed to detect whether some variables were collinear. Using a threshold of 10, as recommended by Dormann et al., these factors indicated that for the planning measures, numbers of story parts, ideas and words were collinear, while for the story, numbers of ideas and

words, and time spent writing were collinear (see Table 7), meaning that substantial amounts of information were shared within each set of variables. Thus, to avoid inaccurate tests of significance caused by collinearity, we followed Dormann et al.'s (2013) recommendations and conducted two principal component analyses on these two sets of variables using varimax rotation to form two PCs. The first PC constructed from the three planning measures (numbers of story parts, ideas and words) was named *generating and organizing ideas on a planning sheet*. The second PC constructed from the three story measures (numbers of ideas and words, and time spent writing) was named *text generation and transcription*.

Mediation analysis

Mediation analysis, based on 20,000 samples, showed that the relation between SRSD intervention and text quality was fully mediated by planning and story measures: $c = 1.54$, bias-corrected and accelerated (bca) CI [0.70, 3.00]. More specifically, serial analyses showed that the SRSD intervention led students to spend more time planning before writing and to develop their ability to generate and organize their ideas. Mediation analyses also showed that generating and organizing ideas on a planning sheet helped students in the SRSD group to include more story parts in their stories and to generate and transcribe more text in their stories, explaining why they managed to produce better quality stories than students in the BAU group. Importantly, a negative indirect effect was obtained ($a_1b_1 = -1.89$, bca CI [-3.27, -0.33]) when the relation between experimental group and text quality was mediated by time spent on the planning sheet, showing that increasing the amount of time spent on a planning sheet can be damaging if this extra effort does not translate into improving the organization of ideas (to visualize all mediation analyses, see Table 8; Fig. 6).

Are there cognitive or motivational factors that moderate the SRSD intervention's effectiveness?

We predicted that the effectiveness of the SRSD intervention would be moderated by factors that have been shown to be related to writing abilities, including graphomotor skills (Hypothesis 5a), self-efficacy (Hypothesis 5b), writing motivation (Hypothesis 5c), and working memory (Hypothesis 5d). To test this prediction, we ran a moderation analysis. Results revealed that graphomotor abilities, writing motivation, and self-efficacy did not moderate any of the mediation paths. However, working memory moderated the effect of the SRSD intervention on time spent planning ($b = 83.36$, bca CI [8.23, 158.48]). The con-

Table 7 Variance inflation factors for each predictor of Planning and Story measures

Predictors	VIF
Draft measures	
Number of story parts	12.12
Number of ideas	17.54
Number of words	15.00
Time spent planning	6.89
Story measures	
Number of story parts	1.52
Number of ideas	23.67
Number of words	20.93
Time spent writing	10.19

Table 8 Estimated indirect effects and bootstrapped confidence intervals for the indirect effects for the direct effect, total indirect effect and each mediation paths

Mediation paths	Estimated indirect effects	BCa CI
Direct effect	0.08	[-0.90, 1.06]
Total indirect effect	1.54	[0.70, 3.00]
ExpGr → TimePlan → TextQ	-1.89	[-3.27, -0.33]
ExpGr → GOPlan → TextQ	0.31	[-0.05, 0.88]
ExpGr → NbSP → TextQ	0.54	[0.08, 1.15]
ExpGr → TGT → TextQ	0.73	[0.03, 2.22]
ExpGr → TimePlan → GOPlan → TextQ	1.53	[0.35, 2.68]
ExpGr → TimePlan → NbSP → TextQ	-0.45	[-1.09, 0.04]
ExpGr → TimePlan → TGT → TextQ	-0.36	[-1.93, 0.28]
ExpGr → GOPlan → NbSP → TextQ	0.12	[-0.02, 0.34]
ExpGr → GOPlan → TGT → TextQ	0.02	[-0.10, 0.38]
ExpGr → NbSP → TGT → TextQ	0.20	[0.04, 0.53]
ExpGr → TimePlan → GOPlan → NbSP → TextQ	0.57	[0.09, 1.23]
ExpGr → TimePlan → GOPlan → TGT → TextQ	0.11	[-0.36, 1.31]
ExpGr → TimePlan → NbSP → TGT → TextQ	-0.16	[-0.49, 0.01]
ExpGr → GOPlan → NbSP → TGT → TextQ	0.04	[-0.01, 0.16]
ExpGr → TimePlan → GOPlan → NbSP → TGT → TextQ	0.21	[0.04, 0.51]

Note ExpGr=Experimental groups, GOPlan=Generating and organizing ideas, NbSP=Number of story parts, TGT=Text generation and transcription, TextQ=Text quality

ditional effect showed that although the SRSD intervention favored engagement in planning among all students, those with better working memory capacity spent more time on their planning sheet ($b=378.29$, bca CI [225.71, 530.87]) than those who had less capacity ($b=618.69$, bca CI [462.34, 775.10]). No other mediation path was moderated by working memory (for mediation and moderation model, see Fig. 6).

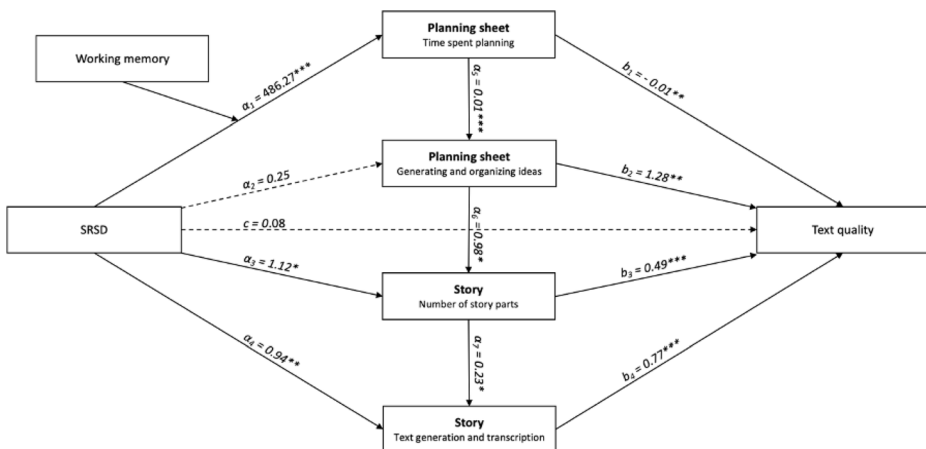


Fig. 6 SRSD effect on text quality mediated by writing processes. The confidence interval for the indirect effect was a bca bootstrapped CI based on 20,000 samples

Discussion

The present study had two main goals. The first was to assess the effectiveness of a French adaptation of the SRSD intervention implemented in a real-life educational setting to develop fourth- and fifth-graders' writing skills. The second was to improve understanding of the cognitive and metacognitive mechanisms behind SRSD effectiveness and to identify any factors that might moderate this effectiveness.

Effectiveness of a French version of the SRSD intervention

We predicted that students who underwent the SRSD intervention would produce higher-quality texts than those written by students who received regular writing instruction (Hypothesis 1). Our study's results supported this prediction. Students in the SRSD group produced higher-quality texts than those written by students who received regular writing instruction. The lower scores obtained by students who received regular writing instruction aligned with De Smedt and Van Keer (2018), who found that offering numerous opportunities to write is necessary, but not sufficient, to guarantee students' writing progress. Writing skills are difficult to master, and if writing strategies are not taught explicitly, with no attempt on the teachers' part to model their use and support their implementation, then students may have difficulty making progress. The SRSD intervention's positive effects observed in the present study aligned with results from many other studies conducted in other countries with different spoken languages (e.g., Bouwer et al., 2018; Brunstein & Glaser, 2011; Chen et al., 2022; Festas et al., 2015; Fidalgo et al., 2007; Finlayson & McCrudden, 2021; Klein et al., 2022; McKeown et al., 2023), enabling us to extend previous conclusions about SRSD's effectiveness to French students from disadvantaged backgrounds. Nevertheless, to ensure the SRSD intervention's effectiveness in the French education system, more research is needed. Indeed, McKeown, FitzPatrick McKeown et al. (2019a, b) demonstrated that the SRSD intervention's efficacy can be diminished if teachers implement it with low fidelity. Therefore, as has been done in other countries, we need to design professional training courses on implementation of the SRSD intervention for teachers, evaluate their adherence to the intervention, and test these training courses' impact on the development of their students' writing skills (for a recent example of effective practice-based professional development to support teachers' use of the SRSD intervention, see McKeown et al., 2023).

SRSD's effect on monitoring accuracy

As part of the SRSD intervention, students were taught explicitly about writing goals and strategies for assessing whether these goals have been achieved. Based on the metacognition literature (e.g., Fernandez & Jamet, 2017), we predicted that by clarifying expectations and providing feedback on written production, the SRSD intervention would help students produce more accurate monitoring judgments than students who received regular writing instruction (Hypothesis 2). The present study's results revealed that compared with students in the BAU group, students in the SRSD group estimated the quality of their text more precisely. Thus, clarifying writing expectations and teaching students how to self-estimate their production are effective at aligning students' perceptions of their writing skills with their actual writing skill levels more accurately. However, despite better monitoring accu-

racy, when results from the SRSD group were compared with those from the BAU group, the data indicated some lingering overconfidence among students in the SRSD group, suggesting that more could be done to optimize the SRSD intervention because overestimation has been demonstrated to be detrimental to effective self-regulated learning (Bjork et al., 2013; Dunlosky & Rawson, 2012; Fernandez & Jamet, 2017; Greene & Azevedo, 2009). In the writing context, miscalibrated monitoring may lead students to skip or prematurely deactivate fundamental writing processes that are cognitively demanding, thereby affecting the quality of the texts they produce.

Mechanisms behind SRSD effectiveness: successful development of writing skills

Planning is central to writing high-quality texts, and yet surveys by the French National Education Ministry have shown that ninth graders hardly ever use a planning sheet to generate and structure their ideas before writing a text (DEPP, 2015). Unsurprisingly, the present study showed that prior to interventions, fourth and fifth graders, like ninth graders, hardly ever used a planning sheet to plan their story. All three teachers in the BAU group spent time training their students how to plan and use graphic organizers, but the students did not demonstrate use of planning strategies after their writing lessons. These results underscore the difficulty of teaching writing strategy to young students in a real-life classroom setting. One possible explanation for this lack of effect is that none of the three teachers used a modeling technique to explicitly demonstrate the cognitive and metacognitive processes required to perform writing tasks and did not teach them any self-instruction or self-reinforcement strategies. However, although the teaching of planning strategies has been identified as an important prerequisite for writing skill development (Graham et al., 2012), research has shown that it is not sufficient to guarantee student progress. For instance, Hacker et al. (2015) showed that the beneficial effect of training students to use writing strategies fades over time unless teachers continue to coach students to implement and self-regulate these strategies. Furthermore, implementation of newly taught strategies requires significant conscious processing, which can compete with other components of written production such as graphomotor skills and spelling, and thus disrupt the usual writing process, notably for poorer writers (Limpo & Alves, 2018). To overcome these challenges, research indicates that the most effective interventions (e.g., SRSD) are those aimed not only at teaching writing strategies but also at training and guiding students so that they gradually anchor the strategies in memory and become able to regulate their writing processes autonomously in order to achieve writing task goals (Graham et al., 2012). We therefore predicted that students who were taught strategies for generating and structuring their ideas through an SRSD intervention would develop their planning skills better than students who received the usual writing instruction (Hypothesis 3a). Results of our study supported this prediction, as students who were taught a planning strategy with the SRSD approach spent substantially more time generating and structuring their ideas at the planning stage than those who have received the usual writing instruction. These results support Torrance et al. (2007)'s conclusion that planning activity does not emerge spontaneously in young students, but they do have the ability to master complex planning strategies if they are explicitly taught how to do so.

The results also supported Hypothesis 3b: Compared with the BAU group's students, the SRSD group's students spent more time writing their stories and included more words,

ideas, and story parts in them). Moreover, in line with Hypotheses 4a and 4b, a mediation analysis revealed that spending more time generating and structuring ideas around the important parts of a story on the planning sheet truly helped students in the SRSD group produce stories that contained more story parts and ideas, which explains why these students produced higher-quality texts than those written by students in the BAU group. These results indicate that SRSD group students' ability to use the taught planning strategy explains the SRSD intervention's positive effect on the texts they produce. However, the mediation analysis found that SRSD group students who spent more time planning, but who did not structure their ideas during the planning stage, ended up writing lower-quality stories than the other students. These results indicate that encouraging students to use a planning sheet can be counterproductive if they do not know how to use it properly. In other words, increasing the amount of time spent planning a story is a necessary but not sufficient condition for writing better quality texts. Therefore, it is important that teachers explicitly teach concrete planning strategies and scaffold their use until their students can implement them in complete autonomy. Finally, and importantly, these results explain why some previous studies failed to find a link between time spent planning and text quality (see for example Fidalgo et al., 2008). As Fan et al. (2022) found, the time that students spent on a task does not provide information on the mental operations they performed during that task, revealing the need to obtain more fine-grained information to infer nuanced self-regulated processes reliably. This aligned with the present study's data, which allowed us to conclude that time spent planning is a poor measure of students' knowledge-transforming process, and that data about the nature of the planning sheet provided a better account of it.

Factors moderating SRSD effectiveness

The present study gave us a better understanding of why some students do not respond to the SRSD intervention as well as others do. Results indicated that some students in the SRSD group did not fully benefit from the strategy instruction, as they spent more time planning without managing to generate more ideas and organize them. We predicted that factors that have been shown to be related to writing abilities would moderate the effectiveness of the SRSD intervention. However, data did not support all our hypotheses concerning moderators. For instance, students' graphomotor skill level did not moderate SRSD effectiveness (Hypothesis 5a), showing that even though these skills continue to develop across adolescence until Grade 9 (Graham et al., 1998), fourth and fifth graders had probably mastered sufficient graphomotor skills for them not to hinder the development of the writing skills taught in the SRSD intervention. It has been shown that children can use automatic movement control by about 10 years (Grade 4), when motor programs are memorized, allowing them to devote less attention to the handwriting task (Palmis et al., 2017). Results also showed that SRSD effectiveness was not moderated either by self-efficacy (Hypothesis 5b) or by writing motivation (Hypothesis 5c). In other words, students who exhibited a low level of self-efficacy or motivation, and who were thus at risk of engaging less effort in the development of writing skills, benefited just as much from the SRSD intervention as students who exhibited a high level of self-efficacy or motivation. However, our methodological controls could explain this lack of effect. Indeed, the propensity score matching (PSM) procedure used in the study tends to exclude outliers, as extreme values are rarer, and therefore, more difficult to match together. As a result, PSM procedures can slightly reduce

variance in graphomotor, motivation, and self-efficacy variables that we examined, which may reduce the chances of uncovering a true moderation effect. Nevertheless, a moderation analysis showed that working memory moderated SRSD effectiveness (Hypothesis 5d). Students with low working memory capacity were less likely to master the planning strategy they were taught than students with higher working memory capacity. This result supports previous research showing the importance of adjusting SRSD instruction to ensure that all students fully benefit from it (e.g., Harris et al., 2012; McKeown et al., 2016).

Optimizing SRSD efficacy: research and practice perspectives

Despite the SRSD intervention benefits, our analysis of underlying cognitive and metacognitive mechanisms suggests that more could be done to optimize its effectiveness. Indeed, students in the SRSD group demonstrated better improvement in their monitoring accuracy than students of the control (BAU) group, but they still remained overconfident. Furthermore, as observed in a previous teachers' survey (e.g., McKeown, Brindle McKeown et al., 2019a, b) some students struggled to create their own graphic organizers and used notes instead of full sentences on their planning sheets. Indeed, even though students in the SRSD group, on average, demonstrated better planning skills than students in the control (BAU) group, they produced a planning sheet of varying quality at post intervention (some students had part of the graphic organizer missing from their scratch paper and generated a small number of ideas), attesting to different levels of mastery in the planning strategy. Our results indicated that working memory skills partly explain this heterogeneity in mastery of the planning strategies, as students with low working memory skills have more difficulty applying the planning strategies taught than students with higher working memory skills. These results align with those of recent studies, revealing that some students need more support to help them internalize recently taught self-regulated activities to enable them to trigger newly acquired writing strategies spontaneously and effectively (Harris et al., 2012; Li et al., 2023; Lim et al., 2023; McKeown et al., 2016; McKeown, Brindle McKeown et al., 2019a, b; van der Graaf et al., 2023). Below, we propose several research perspectives that could help these students fully benefit from the SRSD intervention.

Implementing SRSD within the framework of the response to the intervention model

Some students have special needs that require more teaching time with more individualized support (Harris et al., 2012; McKeown et al., 2016). To meet these needs, future studies should focus on implementation of the SRSD intervention within the framework of the response to the intervention model. This proposes three tiers of teaching for preventing and remediating academic difficulties (e.g., Fletcher & Vaughn, 2009; Harris et al., 2012; McKeown et al., 2016): Tier 1 (whole-class teaching); Tier 2 (small-group teaching for at-risk students); and Tier 3 (intensive and individualized teaching). In the present study, students were taught as a whole class in real-life educational settings for eight 50-minute sessions, thereby corresponding to Tier 1. Our results suggest that the Tier 2 and Tier 3 instruction levels are probably needed to help all students benefit fully from the SRSD approach. We argue that the quality of the story structure at the planning stage should be used as a criterion for screening students, with those who have persistent planning difficulties benefiting

from Tier 2 instruction (e.g., part of the graphic organizer missing on their scratch paper, a small number of ideas generated for each part, taking notes). As McKeown, Brindle McKeown et al. (2019a, b) argued, small groups can allow teachers to remodel a set of subskills to students, maximizing interaction during the modeling session and, therefore, adapting modeling and support to students' needs. Tier 2 also can be used to train students who need it to move away gradually from using the formal graphic organizer and learn how to draw on their own autonomously. McKeown, Brindle McKeown et al. (2019a, b) also recommended grouping students based on their specific difficulties to offer them targeted mini-lessons (e.g., finding a trigger for the story). Future studies on development of students' writing skills through Tiers 1, 2, and 3 could yield useful information on the effectiveness of modulating the SRSD teaching approach's duration and intensity based on students' specific needs. Also, such data could help in designing adaptive scaffolds that recently have been demonstrated to support students' self-regulation activities effectively during writing tasks (Li et al., 2023; Lim et al., 2023; Skar et al., 2022; van der Graaf et al., 2023).

Adaptive scaffolds to support the guided and autonomous phase of the SRSD intervention

Adaptive scaffolds provided by adults, peers, or even a computer have been proven to be an effective tool for developing students' writing skills (e.g. Bannert, 2009; Li et al., 2023; Lim et al., 2023; Skar et al., 2022; van der Graaf et al., 2023). Adaptive scaffolds are designed to support students' self-regulated processes during various educational tasks, such as learning a chapter or writing an essay (Lim et al., 2023). They can take the form of feedback or a prompt from a teacher, or software that encourages students to activate or adapt writing strategies with regard to the task's goal. To be effective, those prompts need to be suited to students' needs and fade away as they internalize the regulatory skills needed to be autonomous. While these adaptive scaffolds can be difficult to implement during Tier 1 of the response to intervention model in class situations with a large number of students, teachers can use them more easily during Tiers 2 and 3. Also, recent studies have found that technology-enhanced learning environments that use trace data and artificial intelligence systems have the power to provide such adaptive scaffolds, which can help students better implement effective writing strategies (Li et al., 2023; Lim et al., 2023; van der Graaf et al., 2023). Thus, in the near future, new technology could prove to be an interesting tool to support students during the early stage of the SRSD intervention's autonomous phase. Thus, based on the difficulties of certain students, identified by our data, to plan and monitor their writing production properly, we argue that one of the most important research perspectives for optimizing SRSD efficiency concerns the development and efficacy assessment of formative feedback and adaptive prompts specifically designed for SRSD intervention.

Formative feedback

Although the SRSD intervention improved the accuracy of the students' self-assessments, our results indicate that students still tend to overestimate their work. This can be a problem, as research in fields other than writing has found that this overestimation can exert deleterious effects on self-regulation and learning outcomes (Bjork et al., 2013; Dunlosky & Rawson, 2012; Fernandez & Jamet, 2017; Greene & Azevedo, 2009; Panadero et al., 2017).

One way of developing students' self-assessment skills is to offer them substantial formative feedback during learning sessions (Panadero & Lipnevich, 2022). Formative feedback provided by adults, peers, or even a computer has been proven to be an effective tool for developing writing skills (e.g., McKeown et al., 2015, 2020; Skar et al., 2022). Implementing these feedback tools in the SRSD intervention could complement the self-assessment exercises already included in the intervention and boost the intervention's effect in terms of improving students' monitoring accuracy. However, to ensure the feedback's effectiveness, we need to study the nature of the feedback provided by teachers and their effects on self-regulation more precisely (see Panadero & Lipnevich, 2022). Indeed, students often receive feedback on the outcome of their text production, rather than on the writing process itself (for a similar discussion on the importance of offering process-focused feedback, see Raković et al., 2023). For instance, a survey by Stern and Solomon (2007) revealed that teachers tend to provide little to no feedback on the organization and quality of the ideas included in students' texts, preferring instead to provide feedback on surface aspects (i.e., spelling, grammar, word choice, and missing words) and on overall text quality. Therefore, feedback focusing on the written output could help students realize that their stories do not meet expectations, but they could still struggle to identify how to achieve these goals, particularly if too little attention is paid to the proper implementation of taught strategies. For example, in the present study, some students in the SRSD group produced a graphic organizer with missing parts and/or a lack of ideas. We postulated that some of these students probably overestimated the quality of their planning, leading them to end generation and idea organization processes prematurely, thereby undermining the quality of the texts they finally produced. Therefore, future studies investigating when and how to incorporate formative feedback into SRSD also should focus on what the feedback should be about (e.g., writing process, writing quality). McKeown et al. (2020) conducted very promising research on process-focused feedback's effect on revising behavior and writing quality (see also McKeown et al., 2015). During an SRSD intervention, a teacher provided her students with individualized, asynchronous audio feedback on whether they included important components of a persuasive text in their essays. Following the intervention, students were able to revise their texts independently, leading them to write higher-quality essays. Thus, this type of audio feedback, coupled with explicit teaching, has allowed students to better internalize written task expectations and make adapted decisions to adjust their written production based on these expectations. Also, the teacher who provided the audio feedback found this type of intervention useful and easy to implement. Thus, audio-process-focused feedback, combined with the self-assessment task, could correct the remaining monitoring accuracy problems observed in our study, which could help students better self-regulate their writing processes and overcome discrepancies between expectations and their written output.

Adaptive prompting

Beyond overestimation, another reason that may lead students who have received the SRSD intervention to engage in a poor planning process is that they could have a production deficiency, i.e., when they possess the necessary skills to engage effectively in a task, but fail to apply them independently (Bannert, 2009). In our context, even if the SRSD intervention could lead all students to develop the knowledge and skills needed to engage in the planning

process before writing their story, some may have difficulty triggering newly acquired writing strategies spontaneously and correctly. Thus, in addition to teaching explicit strategies and modeling techniques, some students could benefit from additional support during the first phases of independent writing to help them internalize recently taught self-regulated activities. One way of achieving this is to provide students, in addition to formative feedback, with a range of adapted prompts provided by a teacher or software that encourages the students to activate adapted knowledge and apply necessary skills to complete the task successfully (for recent research indicating a positive effect from such an intervention on self-regulation during writing tasks, see Li et al., 2023; Lim et al., 2023; McKeown et al., 2015, 2020; van der Graaf et al., 2023). For instance, to support the cognitive and metacognitive process, teachers or software could (1) regularly prompt students to monitor the quality of their production at different stages in the writing process (e.g., “Have you identified enough characters on your planning sheet?”), (2) provide formative feedback following each of their self-assessments to inform them about the true quality of the production (e.g., “You’ve only identified two main characters, so you’re missing one to achieve the session’s goal”), and (3) prompt students to use previously taught strategies to meet writing expectations (e.g., “Find and register on your planning sheet at least one more main character before starting to write your story”). Such intervention during the autonomous phase of writing could help students develop self-assessment routines, gradually correct the monitoring processes’ accuracy, and better internalize self-regulation strategies taught by the SRSD intervention.

Prerequisites for prompting efficiency on planning skills

Lim et al. (2023) found that adaptive scaffolding exerted a significant effect on fostering better self-regulated activities during writing tasks. However, this greater progress did not lead to these students writing better texts than students who have not benefited from adaptive scaffolding. Interestingly, despite personalized scaffolds’ generally positive effects on self-regulated activities, they did not lead students to engage in more planning activities specifically, which could explain the lack of effect on students’ text quality given the importance of planning strategies in producing high-quality texts. As Lim et al. (2023) argued, prompts are designed to encourage students to engage in skills they possess, but cannot trigger spontaneously. However, many students may not possess planning skills, even among adult students. In this case, a prompt may not be effective until students fully develop these skills. In some cases, these prompts may even prove to be counterproductive, as our study demonstrates that encouraging students to engage in planning when they have not mastered the appropriate skills can lead to students writing lower-quality texts. Therefore, we assumed that a learning environment that not only prompts students to plan, but also provides a video capsule that teaches and models how to use planning strategies effectively, could boost personalized scaffold effectiveness. Put another way, we argue that technology-enhanced learning environments designed to include a combination of the principles and recommendations of the SRSD literature and those of the adaptive scaffolding literature could hold great potential to enhance all students’ writing production quality.

Limitations

Numerous SRSD studies have focused on the effect of the writing intervention on text quality, rather than on the psychological mechanisms that underlie quality enhancement. The results of the present study help to highlight the cognitive and metacognitive roots of SRSD efficacy, but more needs to be done to improve our understanding of the effects of the writing intervention on students' self-regulation. As the COVID pandemic forced classes to close, meaning we were unable to conduct the maintenance test, research is needed to confirm that the development of self-regulated writing processes in the wake of the SRSD intervention continues over time. Also, the SRSD intervention that we implemented was dedicated to teaching students the use of schema-driven planning strategies to write good stories. Thus, it aimed to help them come to terms with the principle of identifying goals and subgoals that structure the planning phase and use a pre-established schema for generating and organizing ideas. However, although mastering these skills is an important step toward developing writing expertise, students also have more complex planning skills to develop to face a variety of writing tasks that they will be assigned throughout their schooling. For instance, a common task, but one that often causes difficulties for students, is writing summary texts based on the processing of multiple sources (e.g., FitzPatrick & McKeown, 2021; Harris et al., 2019; Raković et al., 2021, 2023). Extant studies have found positive effects from teaching strategies that were used to guide students in Grades 3–8 in preparing persuasive essays on scratch paper by selecting and organizing relevant information obtained from reading one or two texts (e.g., Collin et al., 2021; FitzPatrick & McKeown, 2021; Harris et al., 2019). However, high school and university students are faced with increasingly more complex writing tasks that require understanding many more documents and drafting longer texts (e.g., essays, dissertations, academic journal articles). In such cases, it often is not possible to retrieve a predefined schema from memory to drive the selection of information from multiple documents and the structure of the upcoming text. Students must be capable of switching to a constructive planning strategy that enables them to build their own representation of the task autonomously and generate their own subgoals and procedures (Flower et al., 1992). Thus, as Harris et al. (2019) argued, although these good results are encouraging, more instruction is needed to support students through the various writing assignments they will be assigned throughout their schooling.

Another study limitation concerns the data's generalizability. The present study revealed a beneficial effect from the French version of the SRSD intervention on students from disadvantaged backgrounds. These students revealed themselves to be particularly fragile in writing skills, producing texts well below expectations that the French Ministry of Education set. Thus, it remains to be demonstrated that the French version of the SRSD intervention produces similarly positive effects with students who have a higher starting writing level. Indeed, students with a higher level of writing ability before any form of intervention tend to use more planning strategies than students with difficulties (Bai, 2018). Consequently, the SRSD intervention's benefits to these students could be more limited.

Finally, more research is needed to understand SRSD's impact on students' self-regulated skills, as well as to identify the variables that moderate its efficacy. The study's results found that SRSD helped students produce a more accurate self-assessment of their texts, but certain aspects remain to be examined: (1) whether SRSD impacts spontaneous production of monitoring judgments during the task; (2) these judgments' consequences on the regulation

of cognitive activities; and (3) whether improvements in monitoring accuracy made possible by the intervention impact the revision strategies' quantity and quality. Furthermore, concerning development of planning strategies and their effects on text quality, mediation analyses on our data revealed a direct path from the SRSD group to the number of story parts included in students' stories, i.e., some students in the SRSD group wrote better-structured stories than those produced by the BAU group without needing to write down their mentally organized ideas on planning sheets. Thus, some students used more covert planning strategies that our study was unable to capture. One way of investigating students' mental states more reliably and providing deeper insights into students' self-regulation during writing tasks would be to use think-aloud data coupled with multi-channel trace data, including logs and eye-tracking devices (for a discussion on improving measurement and self-regulated learning, see Fan et al., 2023; Fan, Lim Fan et al., 2022b; Fan, van der Graaf Fan et al., 2022b). Studying these measures with process-mining techniques has been demonstrated to provide a better understanding of the dynamic nature of self-regulation processes unfolding during learning or writing tasks (Lim et al., 2021) and could make it possible to understand SRSD's effect on students' writing skills more accurately. For instance, it could allow for identifying when and how often students make metacognitive judgments (e.g., "My character is not sufficiently described to allow my reader to picture her"), as well as examining how students self-regulate their writing processes when the monitoring process yields a negative assessment (e.g., students returning to their planning sheets to read planned ideas on character descriptions before editing written texts). Thus, we argue that the recent significant development of research into the measurement of self-regulation skills (Fan et al., 2023; Fan, Lim Fan et al., 2022b; Fan, van der Graaf Fan et al., 2022b; Li et al., 2023; Lim et al., 2021, 2023; Raković et al., 2022, 2023; van der Graaf et al., 2023) has the power to (1) make students' self-regulation difficulties during writing tasks more visible, (2) improve current understanding about whether and how the SRSD teaching approach addresses these difficulties, and (3) provide recommendations based on these data on how to adjust SRSD interventions to students' needs optimally and how to design effective adaptive scaffolds.

Conclusion

Writing is an important but complex skill to master. Explicitly teaching writing strategies to students and accompanying them in their appropriation and implementation of these strategies is key to improving the quality of the texts they produce. The present study showed that a French version of the SRSD intervention can enable students from disadvantaged backgrounds to make substantial progress in their ability to produce and assess texts within a short period of time. Results indicated that an improvement in the quality of the texts they produced was explained by changes in the planning process, enabling students to write stories that were better structured and contained more ideas. However, results also showed that spending more time on a planning sheet before writing is not sufficient, and should prompt teachers who implement SRSD to carefully monitor their students' application of the writing strategies they are taught. Overall, the present study provides a better understanding of why, how, and for whom SRSD works, as well as providing guidance on the points that requires vigilance when implementing this kind of intervention, in order to guarantee its effectiveness. We believe that this knowledge (1) provides interesting avenues for research

to optimize SRSD effectiveness and (2) could help to improve the efficacy of emerging professional development programs aimed at training teachers to implement multicomponent strategy-focused writing instruction in class (for a recent review and perspective on the topic, see Harris et al., 2023).

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Data availability All data, analysis code, research materials and all the material for the writing intervention are available on the Open Science Framework: https://osf.io/gncm8/?view_only=f2731ecc6f8047079fb4b860830ed76a.

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