Fostering self-regulated learning: From clinical to whole class interventions

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***Aim**: We describe the theoretical model underlying our interventions in metacognition and self-regulated learning (SRL). Our studies are the only ones in which all SRL components are trained in various learning domains and transfer between these domains is explicitly addressed, and that use both offline and online measures to evaluate the effects of the intervention.*
***Method:** Pre-experimental and quasi-experimental studies in regular classes were conducted. Offline and online measures were used to evaluate the effects of the interventions.*
***Findings:** Self-regulated learning can be enhanced in students with learning difficulties and intellectual disabilities, as well as in typically developing students. Improved SR behaviours are accompanied by improved academic performance.*
***Limitations:** Typical problems associated with data collecting using questionnaires (offline) were encountered. On the other hand, online measures require an important investment of resources. Therefore, the number of participants was limited in the observational studies, which makes generalisation more difficult. Furthermore, it must be acknowledged that quasi-experimental studies are difficult to realise in a natural context.*
***Conclusions:** Interventions based on metacognition and self-regulated learning can be effectively implemented in various natural settings. The results of our first series of studies are very positive, but more studies with control groups and delayed post-test to assess maintenance of the learned skills are needed.*
***Keywords:** Metacognition; self-regulated learning; clinical intervention; strategy instruction.*

Introduction

IT HAS BEEN WELL ESTABLISHED that metacognition plays a central role in learning and academic achievement (Bryce et al., 2015; Haberkorn et al., 2014; Ludwig et al., 2013; Veenman & Spaans, 2005). Metacognition refers to two separate but interrelated components (Brown, 1987; Pintrich, 2002). The first is metacognitive knowledge, i.e. the knowledge people have about their own cognition (strength, weakness, learning habits), about tasks (characteristics, difficulties), and about strategies (when, where and how to apply them). The second component refers to metacognitive processes that allow monitoring and regulation of one's own cognition. The latter processes are generally divided into three subcategories: planning, monitoring and evaluation. Metacognition helps students to learn efficiently: before starting a task, the students will set learning goals, anticipate possible obstacles, and define the problem solving steps. Knowledge of tasks' characteristics, as well as their own strengths and difficulties in the particular domain, will guide the students during this process. Strategies can be employed to deal with anticipated difficulties, help understanding the tasks' demands, gather and organise relevant information, or to regulate attentional processes. Knowing when a specific strategy is helpful allows the students to select the appropriate one at the right moment and adapt it when necessary. All along the problem solving process, the students will monitor ongoing activities and progress: control understanding and memorisation, correct and revise their production, adapt strategies, and adjust their plan. Once the task has been accomplished, the evaluation process will enable the students to compare the outcomes with the tasks demands or their own learning goals, and reflect on the way the task was dealt with, as well as the effectiveness of the strategies used. This in turn will reinforce metacognitive knowledge about the self, the task, and the strategies.

Metacognition is part of the broader construct of self-regulated learning (SRL; Boekaerts & Corno, 2005; Pintrich, 2002; Zimmerman, 2000). Whereas metacognition is restricted to the regulation of cognition, SRL includes the regulation of motivation and emotion. Self-regulated learners are active, strategic, self-conscious, reflective, and motivationally driven in pursuing their learning goals. Students with low school achievement and people with intellectual disability (ID) are characterised by poor SRL skills (Händel et al., 2014; Lichtinger & Kaplan, 2015; Nader-Grosbois, 2014): they have inaccurate metacognitive knowledge or do not use it appropriately to regulate their actions, and they fail to plan, monitor, and evaluate their learning activities. They not only use fewer learning strategies, but often these are also unsophisticated or inadequate. Furthermore, these students frequently present impeding motivational feelings and beliefs (Baird et al., 2009; Lichtinger & Kaplan, 2015; Schwab & Hessels, 2015).

Although teachers play a prominent role in fostering SRL, only few of them explicitly teach strategies or create learning environments that promote SRL in students (Dignath-van Ewijk et al., 2013; Spruce & Bol, 2015). Unfortunately, many students do not spontaneously develop their metacognition and this is even more evident for students with special educational needs (SEN). Consequently, several authors plead for explicit teaching of metacognitive skills. A large body of research, synthesised in several meta-analytic studies (de Boer et al., 2014; Dignath & Büttner, 2008; Donker et al., 2014; Higgins et al., 2005), demonstrates that strategy instruction and more general SRL training are effective and also lead to improved academic performance.

Assessing metacognition

The evaluation of metacognition and SRL processes is quite complicated. Most often used are self-report questionnaires and interviews (so-called offline measures), because of their easy administration and analysis (including in large samples). However, little correspondence exists between the strategies individuals declare to apply in self-report questionnaires and their actual problem solving behaviours, which seriously compromises construct validity (Anthony et al., 2013; Cromley & Azevedo, 2006; Shamir et al., 2008). The low correlations with learning performance also question predictive validity (Bannert & Mengelkamp, 2008; Cromley & Azevedo, 2006; Shamir et al., 2008). An important explaining factor, above and beyond bias caused by memory distortion and social desirability, is students' incomprehension and wrong interpretation of the questions asked (Berger & Karabenick, 2016). This problem is even more critical for students with SEN or ID. Another critical issue is related to the items' generality-specificity and context (Schellings, 2011). Most questionnaires address very general situations ('What do you do before starting a task?'), but even with domain specific items ('What do you do before starting a math task?'), students' answers vary according to the particular situations they use as frame of reference. Use of a particular strategy is always conditional to its own specificity and task context, as well as the student's state of knowledge and beliefs. Finally, Ludwig et al. (2013) criticised that questionnaires measure the quantity or frequency of strategy use, but neither their adequacy nor effectiveness in a given situation.

Online measures, such as observations, think aloud protocols or trace data, record SRL behaviours during task execution. These methods allow capturing self-regulation as a dynamic and situated process in natural contexts with rich and in-depth behavioural data (Cleary et al., 2012; Lichtinger & Kaplan, 2015; Ludwig et al., 2013) and, importantly, assess what individuals actually do, rather than what they think or recall they do (Winne & Perry, 2000). Unsurprisingly, online measures display higher construct, concurrent and predictive validity than offline methods (Bryce et al., 2015; Cromley & Azevedo, 2006; Ludwig et al., 2013; Shamir et al., 2008). However, their disadvantages are time consuming and labour-intensive individual administration and data analysis, which exclude their use in large samples.

Metacognitive intervention in clinical practice

Development of SRL skills in low performing students is crucial for improving their learning and thinking. Therefore, the aim of our Learning Centre (Atelier d'Apprentissage) in the department of Special Education at the University of Geneva is to foster, stimulate or remediate cognitive and metacognitive processes, cognitive strategies, metacognitive knowledge, and motivational feelings and beliefs in children, adolescents and adults with unspecified learning difficulties, learning disabilities or intellectual and developmental disabilities. In our working model (Hessels-Schlatter, 2010), which is based on the theoretical considerations discussed previously and which serves as a framework for assessment and intervention, SRL is conceptualised as a dynamic and recursive process, in which the different components interact with one another. Metacognitive processes (planning, monitoring, evaluation) are employed for goals setting, selecting cognitive strategies, defining problem solving or learning steps, monitoring and regulation of ongoing actions and cognitive activities, evaluating outcomes as well as reflecting on the problem solving processes. Cognitive strategies (e.g. activation of prior knowledge, summarising, self-questioning, collecting information, using external memory) enable the individual to learn and solve problems more efficiently. They are at the same time the vehicle for metacognitive processes as they are determined by them. Jointly, metacognitive processes and cognitive strategies support and guide cognitive processes such as working memory, attentional processes and logical reasoning (e.g. by applying an external memory strategy to avoid cognitive overload). Likewise, metacognitive knowledge (about the self, task and strategies) are both interdependent and related to the other components. They are activated during planning and monitoring, allowing the selection or accommodation of appropriate strategies that fit the learner's needs and task characteristics. The final reflection during the evaluation phase allows adjusting and enriching metacognitive knowledge. Finally, motivational beliefs, such as self-efficacy, causal attributions and achievement goals, will equally determine the implementation of metacognitive processes and strategies, and are in return affected by the (meta)cognitive activities and learning outcomes.

The specificity of our clinical interventions is that all SRL components are addressed and that SRL competences are developed in all learning domains, and not in just one particular academic domain. Therefore, principles promoting transfer guide our metacognitive interventions (alternating the teaching support and tasks content, developing metacognitive knowledge and motivational beliefs) and transfer is taught explicitly (Hessels-Schlatter, 2010). Teaching methods include metacognitive questioning and modelling.

Alternating the teaching support (tasks content). Many students we see in our Learning Centre have experienced repeated failure in school and have developed negative emotions, such as displeasure, anxiety and boredom, associated with specific learning contents or domains. Consequently, they often are very passive and resistant to instruction. They also are hindered by low self-efficacy and expectancy beliefs. By starting our interventions with neutral tasks, without any specific academic content (curriculum unrelated), unfavourable effects of negative emotions and/or inadequate motivational beliefs are avoided, allowing the learners to regain confidence in their capacities. Furthermore, strategic learning activities should neither be hindered by a lack of content knowledge, nor by complex task processing or cognitive load (Fitzsimons & Bargh, 2004). As curriculum unrelated tasks require little academic background knowledge, learners can devote their cognitive resources to discovering, applying, and reflecting on strategies.

Nevertheless, since interventions with curriculum unrelated tasks generate very little transfer to academic achievement (Higgins et al., 2005), most researchers now agree that teaching strategies should not be separated from the learning context. This implies that either curriculum related tasks are used or that interventions are integrated in regular school activities. Both ways, transfer remains a critical issue: either strategies are too task or subject specific (e.g. mathematics, reading) which renders them inapplicable to other domains, or, when strategies can be transferred, students do not generalize them because they are anchored to the context in which they were initially learned. Therefore, we developed a model in which curriculum unrelated (CU) and curriculum related (CR) tasks are alternated (Bosson et al., 2010; Hessels et al., 2009). Cognitive and metacognitive processes and strategies are first trained with CU-tasks, such as games (Hessels-Schlatter, 2010) or visuospatial tasks. These are then followed by CR-tasks to allow the students to directly apply the trained processes and strategies in various regular school activities. We then return to CU-tasks to teach new processes and strategies, and so forth. Not only does this procedure allow explicit transfer, it also optimises the students' perceived utility of the trained competences for their school learning.

Developing metacognitive knowledge and motivational beliefs. Applying learning strategies effectively and efficiently requires appropriate metacognitive knowledge. Learners need to be aware of their own difficulties in order to select strategies that help them. This self-awareness is also essential in planning and monitoring, e.g. by paying more attention to mistakes one often makes. Similarly, knowledge of a particular task's characteristics will guide the choice of strategies. An assignment entailing much and unorganised information will be best addressed by planning steps for processing information sequentially and hierarchically, and by using external memory strategies such as underlining information or presenting information in a table. Finally, the utility of particular strategies and conditions for their application must be known to be able to select the most useful. Accordingly, SRL skills must be taught simultaneously with the promotion of metacognitive knowledge (Boekaerts & Corno, 2005; Donker et al., 2014; Pintrich, 2002).

The role of motivation in learning and its relationship with SRL processes is also often underlined (Bereby-Meyer & Kaplan, 2005; Lichtinger & Kaplan, 2015; Zimmerman, 2000). Cognitive engagement, task persistence and active and strategic behaviour require that learners feel capable to execute a task or learn a particular topic, to perceive the benefits of applying strategies, and to attribute success or failure to controllable causes, such as effort and strategic behaviour. In return, motivation is also affected by metacognition. As learners develop their repertoire of strategies and become more efficient, self-efficacy beliefs, control over learning, and confidence are boosted.

Metacognitive questioning and modelling. Our intervention method relies on metacognitive questioning that targets all components of our SRL model (Hessels-Schlatter, 2010). Before the learners start executing a task (planning phase), they are asked to think about the task's characteristics and difficulties, as well as their own strengths and weaknesses when dealing with such tasks. The learners are prompted to recall strategies, or to discover new ones to face difficulties, and to plan the problem solving process. During execution (monitoring phase) the learners are guided and encouraged to monitor ongoing activities and adjust the plan and strategies, if necessary. When finished (evaluation phase), the learners are asked to reflect on task performance (how did I do, what worked well and why), including motivational beliefs about causes of success and self-efficacy experiences. With less able learners, the intervention is completed by modelling: Strategy application is demonstrated explicitly and the way strategies can be adapted to specific tasks, as well as their utility, is verbalised. Thus, self-regulation strategies are taught indirectly or directly, allowing learners to actively and strategically engage in tasks, as well as to reflect on their own cognitive activities.

Assessing self-regulated learning in our clinical service

In a remediational context, it is important that evaluation is linked to intervention. In order to capture SRL processes as they dynamically unfold in actual task execution, we conduct continuous, online micro-analytic evaluation (Butler, 2011; Cleary et al., 2012). We directly observe behaviours, natural verbalisations, and answers to our metacognitive questioning. We note how the learners spontaneously tackle the tasks, how adequate and effective applied strategies are, and how thinking, metaknowledge and beliefs guide learners through task processing. We also evaluate changes in SRL behaviour during task performance as learners spontaneously adapt their processing, or following direct or indirect prompts, as well as changes from one intervention session to the other.

The CU- and CR-tasks used during the intervention serve both intervention and evaluation purposes. Our metacognitive questioning, too, is simultaneously an intervention method to teach strategies as well as a means to assess students' knowledge and processing. All intervention sessions are video-recorded. Master's students working in our Learning Centre make verbatim transcriptions of each session and are required to analyse all components of SRL as part of their training. The learner's progress guides us towards the next objectives, materials and mediation in order to best meet the learner's needs. This assessment methodology, obviously time consuming, assures an in-depth understanding with high construct and ecological validity as SRL is evaluated as a contextualised event occurring in authentic tasks.

From clinical practice to classroom intervention

Clinical observations show that our interventions allow students of different ages, ability levels, and presenting different types of SEN, to enhance their SRL skills and to improve their learning achievements. A study with a pre-test – post-test – delayed post-test design with waiting list controls, demonstrated that the students significantly improved strategic behaviour and metacognitive knowledge, as well as performance on curriculum-unrelated and academic tasks (Bosson et al., 2010). Not only do we believe that strategy instruction directly in the students' natural learning environment will exemplify the relevance for their everyday learning (thus fostering transfer to and the integration of SRL processes in their daily activities), we also think that in a European school context that is becoming more and more inclusive (Meijer, 2010), promoting SRL in class would be beneficial to all struggling students. Hence, the next logical step was to implement our approach in natural settings, adapting it to classroom teaching practices, as well as to learners with ID.

The first two studies outside the Learning Centre were individual interventions (case studies) with one and two participants with ID, respectively. The first case study concerned an individual intervention with a 9-year-old girl with a hearing impairment and a severe developmental disability (mainstreamed in first grade of primary school), both in a clinical setting and in school. The intervention[1] addressed the aspects discussed earlier and consisted of 10 sessions of 30 minutes in the clinical setting and an equal number of presences of the researcher in class, also with a duration of 20–30 minutes each time. In school, the main objective was reminding the student to use the learned strategies during the regular school tasks. Assessments took place before and after the intervention, both in the clinical setting and in school and were completed by a maintenance test ten months later. Measures concerned Mathematics word problems (clinical setting), Mathematics achievement tests (school) and direct observations of SRL behaviours. The mathematics tests used in the clinical setting were parallel tests; those in school followed the curriculum and became progressively more complex. The observations made during task completion were coded into distinct SRL categories. Planning comprised identifying aim of the task, anticipating actions and following a plan. Monitoring comprised controlling one's own activity, controlling comprehension and verifying results. Cognitive strategies comprised e.g. analysing, using external memory, paraphrasing, naming and describing. The observations showed that the girl only very rarely exhibited planning and monitoring behaviours at the beginning of the intervention and did not use any strategies. However, such behaviours were frequently observed immediately after the intervention and were largely maintained after ten months, both in the clinical setting and in school. Unsurprisingly, the strategies relying on language (describing, naming, and paraphrasing) were the ones least used, because the child presented very limited spoken language due to her hearing loss. We also observed that when a task involved knowledge or skills she did not master well, such as subtractions, she would apply fewer strategies, which might be due to a cognitive overload. The improvement in SRL skills was accompanied by an improvement in school performance and this, too, was maintained over time (although at a somewhat lower level). We further observed that the student progressed in autonomy and motivational aspects: she stayed more on task, was less reliant on external help, and exhibited more perseverance in face of difficulty.

The second case study concerned an individual intervention in a special school for persons with ID. The two participants were aged 17 years and their mental age was estimated at about 6 years. The design comprised a pre-test, a post-test and a delayed post-test eight weeks later. The intervention consisted of 19 individual sessions of 45 minutes each and included many games. The measures concerned SRL behaviours and performance in analogic reasoning, picture arrangement, selective visual attention, drawings to complete, geometry, and mathematics problems. The behaviours and verbalisations of the participants were video-recorded and coded into distinct SRL categories: planning, monitoring, evaluation, cognitive strategies, regulation of attentional processes, and motivational aspects (e.g. task persistence, on-task behaviours). The teachers also filled in questionnaires to estimate whether SRL behaviours improved during regular class work, allowing us to evaluate whether SR behaviours were transferred to everyday work in class. Both students showed progress in SRL behaviours in most of the post-test tasks and this was accompanied by improved performance. The delayed post-test eight weeks later showed that one of the participants not only maintained, but improved even further on several measures. Her SRL behaviour in class improved considerably, she transferred most of these skills to the classroom context, and showed to maintain these after eight weeks. The other participant showed little change in his approach to class work. He did not perceive

[1] The content of the intervention and the measures will be presented in the methods section, as the general principles are the same. Differences generally concern the actual tasks used and their level of difficulty.

much utility in learning all these strategies, did not show mastery goals, and often exhibited avoidance behaviours when confronted with difficulty or cognitive effort. The latter illustrates the interplay between SRL components and the impact of motivational variables on strategic behaviour.

The next two studies concerned multiple-case studies based on whole class interventions in special classes. The first was implemented by the regular teacher in a special education class with 5 students with SEN, aged 12 to 13 years (see Hessels et al., 2009). The teacher enriched the regular school activities with a metacognitive intervention with CU-tasks during the morning hours and CR-tasks during the afternoon. Strategy application and the children's metacognitive knowledge were evaluated through self-report questionnaires (both general and task specific), and their behaviours and verbalisations were observed by the teacher. Metacognitive behaviours were further evaluated with visuospatial processing tasks (CU-tasks) and Mathematics word problems (CR-task). These tasks also allowed calculating a performance score. The students progressed in SRL behaviours in both types of tasks, and this was accompanied by an improvement in their overall performance. Interestingly, the student's self-evaluations in the general metacognitive questionnaire decreased (as did the teacher's evaluation of the students). This was attributed to a metacognitive adjustment occasioned by repeated reflection on their cognitive and metacognitive behaviours, resulting in a more realistic evaluation of these behaviours. The teacher also reported to have overestimated the students SRL behaviours at the beginning of the intervention, but to have adjusted these during the repeated precise observations of the students.

The second multiple-case study was much like the previous one, except that the intervention was carried out by the learning support assistant instead of the teacher. Participants were two boys and one girl, aged 10, with learning difficulties. Their curriculum was at the level of 3rd to 5th grade. The intervention followed the same principles as the previous studies and consisted of 10 double lessons of 45 minutes, with pre-test and post-test measures. The measures were based on visuospatial processing tasks (CU-tasks), Mathematics word problems, stimulated-recall interviews and direct observations. The analyses showed that all SRL behaviours improved from pre-test to post-test, that the number of spontaneously reported strategies in both types of tasks augmented (as did their quality), and that this was accompanied by improvement in performance. However, in Mathematics performance, only one student really progressed, whereas the others did not show much change. On the one hand, we attributed this to the fact that the problems were too complex (due to the amount of information and misleading information to consider), and on the other hand by the students' engagement in (still non-automatised) SRL behaviours which together provoked a too high cognitive load.

The aim of this first series of studies was to develop SRL skills in students with SEN and ID in order to support their everyday learning. We subsequently engaged in a long-term (and still ongoing) research program aiming not only at promoting SRL in students, but also providing mainstream school teachers the tools to implement SRL in their daily classroom practices. Indeed, fostering SRL should not be a single activity amongst others. It should be fully integrated in ongoing instruction in order to promote SRL in all students, whatever the domain or context (Peeters et al., 2014). In the remainder of this article we will focus on two recent studies that illustrate the implementation of our interventions in primary school mainstream classes with students from disadvantaged socioeconomic backgrounds. To our knowledge, ours are the only studies (see also Hessels et al., 2009; Bosson et al., 2010) in which all SRL components are trained in various learning domains, in which transfer between these domains is addressed systematically and explicitly, and that use both offline and online measures to evaluate the effects of the intervention (cf. Butler, 2011; Lichtinger & Kaplan, 2015; Perels et al., 2009).

Method

The studies reported here were whole class interventions in regular classes with students from disadvantaged socioeconomic backgrounds. The studies are part of a larger project in two mainstream schools in metropolitan Geneva. The directors of the schools contacted us with the request to initiate a project that would allow teachers to incorporate metacognition and self-regulated learning in their daily teaching. The interventions were all carried out by research assistants. The first study has a pre-experimental design with pre-test and post-test, the second follows a quasi-experimental design with a control group. We will first present the intervention procedure and the measures used. We will then discuss the two studies, starting with details about the participants, followed by some major results. As our aim is to give a broad overview of the applicability and effects of our method in naturalistic class settings, and in the light of the restricted space available, only part of the data (especially the quantitative data of the CR-task) are presented.

Intervention procedure

The two studies aimed to develop students' SRL skills: metacognitive processes, cognitive strategies, metacognitive knowledge, and motivational beliefs. These were operationalised and adapted to the participants, depending on their age and aptitude level (class related). The strategies were introduced successively and only a few at a time. The students were trained on a CU-task in the morning during one period of 45 minutes (e.g. a game of deduction or a visuospatial task in which the student has to find pairs of incomplete drawings which together make up a complete drawing). Once the strategies had been explained by the research assistant, the students worked in dyads on the task with the instruction to apply the strategies. This was followed by a whole group discussion, intended to explicitly reflect on the strategies, their condition of application and their utility (How did you apply the strategies? Why are they useful, why do they help to solve the task? Could you also use these strategies in math, in language, in history? How would you do that?). The strategies were written on a poster that remained permanently visible in class. In the afternoon, children learned to apply these same strategies on a CR-task (e.g. vocabulary learning, geometry) that was part of the regular school programme. Again, they first worked in dyads, followed by a common discussion. The regular teachers were encouraged to refer to the strategies during their own teaching. Each set of strategies was trained during several weeks, after which new strategies were introduced and added to the poster. The training comprised a total of 12 double lessons of 45 minutes.

Measurements

Several offline and online instruments were used to evaluate the impact of the interventions on SRL skills (direct effect) and on task performance (indirect effect). As the tasks' domain specific competences were not trained, we can attribute improved performance to enhanced SRL skills. Parallel mathematic word problem tasks were applied at pre- and post-test in both studies. These were completed with several tools (specified below) allowing the measurement of different SRL competences. Testing sessions of a few selected students from each class were video-recorded. This allowed to gather multiple sources of data, including on the quality and effectiveness of the displayed SRL behaviours, and to triangulate the different sources (Butler, 2011; Boekaerts & Corno, 2005; Winne & Perry, 2000).

Trace data. We analysed traces of strategies the participants left on their worksheets. Trace data considered the use of external memory, organisation, and monitoring. External memory comprised behaviours such as underlining, crossing out or writing down information. Organisation indicates whether a student's worksheet showed that information was somehow organised (e.g. by putting the steps to be executed one above the other). Monitoring indicates that traces showed that the student had e.g. controlled that they had picked the right information.

Task specific self-report questionnaire. Immediately after completing the mathematics task, a task-specific self-report questionnaire was administered. Items first of all targeted self-evaluation of task performance (I made no mistakes, I made few mistakes, I made quite a few mistakes, and I made many mistakes), which allowed for calibration (i.e. linking the participants' estimation of performance to their real performance). The higher the score, the better the evaluation. Next, metacognitive knowledge about the task was assessed: judgement of difficulty (students have to indicate which of the proposed relevant and irrelevant sources of difficulty were present for the task they completed), problem categorisation (identify which of several proposed word problems share the same underlining structure), problem representation (identify which schema represents the problem) and problem synthesis (identify which sentence correctly summarises the problem).

Math performance. The variables used are the number of steps (operations) correctly identified (but not necessarily correctly calculated) and the overall performance (correctly solved). As we discovered that the pre-test and post-test in 2nd and 6th grade were not perfectly parallel, we had to adjust the scoring. In 2nd grade the number of steps that needed to be executed to solve the problem was 3 and the maximum score for performance was 4, in 6th grade the number of steps was 9 and the maximum score for performance was 5. In the second study the maximum number of steps correct was equal to the maximum score on Performance.

Task specific interview (only study 2*).* The students tested individually participated in a stimulated-recall interview subsequent to task execution. With the completed task in front of them and observations as memory trigger, questions were asked about what they had done, how they did it and why. These questions elaborated on the same SRL components as those addressed by the questionnaire.

Observations (only study 2). Verbalisations and behaviours were video recorded during task engagement and analysed using a coding scheme that identified the various SRL behaviours. This data source allowed both quantification of SRL occurrences and in-depth analyses of the adequacy and efficiency of the applied strategies, as well as the interactions among SRL components. It also allowed inferring causal relations between strategic behaviour and performance.

Results

Study 1

The sample consisted of 18 students in 2nd grade (7 boys and 11 girls) with a mean age of 7;8 years and 21 students in 6th grade (12 boys and 9 girls), with a mean age of 11;10 years. The data regarding SRL behaviours of the two classes were analysed together. These are presented in Table 1, except for monitoring for which only data from 2nd grade can be presented. One-sided *t*-tests are presented to indicate if a difference is significant.

The results show that with regard to trace data, improvement was observed in the use of external memory and that monitoring improved in 2nd grade. Organisation of work was significant at the level of 10 per cent only. This must be attributed to the fact that this variable showed no change in 6th grade, whereas in 2nd grade the change was significant (t_{17}=2.380, p<.01). The results further show that self-evaluation was more correct after intervention, as was judgement of difficulty and problem categorisation. Problem representation did not change significantly. Concerning self-evaluation it is interesting to note that the students especially made calcu-

Table 1: SRL behaviours in mathematics at pre-test and post-test (*N*=39).

	Pre-test	Post-test			
	M (SD)	M (SD)	*t*	df	*p*
Trace data					
External memory (max=5)	1.66 (.81)	2.00 (.84)	1.880	38	.03*
Organisation (max=1)	0.58 (.50)	0.74 (.45)	1.526	38	.06+
Monitoring (max=1)°	0.10 (.40)	0.40 (.50)	2.051	17	.03*
Questionnaire					
Self-evaluation (max=2)	0.70 (0.85)	1.19 (.94)	2.165	36	.02*
Difficulty judgment (max=2)	1.35 (0.95)	1.62 (.79)	2.372	36	.01**
Problem categorisation (max=2)	0.95 (1.01)	1.42 (.92)	2.162	37	.02*
Problem representation (max=2)	1.47 (0.83)	1.61 (.75)	0.725	37	.24
Problem synthesis (max=2)	1.67 (0.75)	1.35 (.95)			

° 2nd grade only (*N*=18) $^{+}p \leq .10$; $^{*}p \leq .05$; $^{**}p \leq .01$

lation errors, but that their performance with regard to the steps to be executed and operations to be implemented was relatively good at pre-test, and even very good at post-test. It is very likely that the students referred themselves to the steps that had to be executed for problem solving and not their correctness of the solution when they evaluated how well they succeeded the task. This would explain their tendency to overestimate their performance. Problem synthesis improved significantly in 6th grade, but decreased even more in 2nd grade, making the overall result decrease. It appeared that 2nd grade students had not understood this question at all.

The results of the performance in the mathematics tests in both classes are presented separately in Table 2, because of the large differences in task complexity.

The students' performances in 2nd and 6th grade improved significantly from pre- to post-test, both for number of steps and performance (correctness of calculations). The tasks were relatively easy with regard to the steps to be implemented and operations to be applied, especially in 6th grade. The students above all made calculation errors.

Study 2

This study followed a quasi-experimental design. The sample consisted of 32 students in 3rd grade (16 boys and 16 girls) with a mean age of 8;7 years and 40 students in 5th grade (19 boys and 21 girls), with a mean age of 10;6 years. The students in the control group (20 boys and 17 girls) followed the original curriculum, but completed all the pre-test and post-test measures; the students

Table 2: Performance in mathematics in 2nd grade (*N*=18) and 6th grade (*N*=20).

	Pre-test	Post-test			
	M (SD)	M (SD)	*t*	df	*p*
2nd grade					
Number of steps (max=3)	2.2 (1.1)	2.7 (0.8)	1.365	17	.03*
Performance (max=4)	2.3 (1.4)	2.8 (1.5)	1.311	17	.10+
6th grade					
Number of steps (max=9)	7.1 (1.4)	8.0 (1.3)	2.196	19	.02*
Performance (max=5)	2.1 (1.1)	2.8 (1.0)	2.942	19	.001**

+$p \leq .10$; *$p \leq .05$; **$p \leq .01$

in the experimental group followed the metacognitive intervention during class hours. Table 3 presents the SRL behaviour data (means and standard deviations).

All means (except problem categorisation) progressed more between pre-test and post-test in the experimental group than in the control group. Analyses of variance with repeated measures revealed that the differences were significant (with medium effect-sizes) for Monitoring ($F_{1,62}$=5.108, $p \leq .05$, η^2=.08), Self-evaluation ($F_{1,62}$=4.648, $p \leq .05$, η^2=.07), Strategy knowledge ($F_{1,62}$=6.503, $p \leq .01$, η^2=.10) and Planning ($F_{1,62}$=6.876, $p \leq .01$, η^2=.10). The differences on the other variables were not significant and the effect-sizes were small (.02-.04).

With regard to performance, the data were again analysed separately for 3rd and 5th grade because of the large differences between the tasks (see Table 4).

The performance scores equally progressed more in the experimental groups than in the control groups. Analyses of variance with repeated measures revealed that the differences were significant in grade 3 and showed large effect sizes: Number of steps ($F_{1,29}$=7.935, $p \leq .01$, η^2=.22) and Performance ($F_{1,29}$=12.718, $p \leq .001$, η^2=.31). In 5th grade, the differences were not significant: Number of steps ($F_{1,31}$=0.504, *ns*, η^2=.02) and Performance ($F_{1,28}$=0.075, *ns*, η^2=.00). This is probably partially due to a ceiling effect that was observed for both measures at post-test.

Next to the quantitative data, also video-recorded observations were made. Until now, these have been analysed for two students in 3rd grade. The first, considered as a 'high performing student' by the teacher, obtained almost the maximum score on the mathematics task at pre-test and used various strategies. Nevertheless, in the interview she could only vaguely and very generally describe what she had done and showed little awareness of the strategies she used. Yet, after the intervention she showed enhanced SRL behaviours for all observed categories. She was able to explain in a very precise way what she did and was able to justify the way she executed the task. She also spontaneously and elaborately described many strategies and why these were useful to her. The second

Table 3: Means and standard deviations of SRL behaviours in the experimental and control group (*N*=72).

	CG		EG	
	Pre-test	Post-test	Pre-test	Post-test
Trace data				
External memory (max=2)	.56 (.56)	.53 (.66)	.32 (.48)	.53 (.51)
Organisation (max=1)	.58 (.50)	.76 (.43)	.50 (.51)	.84 (.37)
Monitoring (max=1)	.69 (.35)	.78 (.30)	.53 (.42)	.82 (.27)
Questionnaire				
Self-evaluation (max=1)	.39 (.49)	.18 (.39)	.29 (.46)	.47 (.51)
Strategy knowledge (max=1)	.68 (.15)	.71 (.14)	.64 (.19)	.77 (.15)
Planning (max=1)	.69 (.47)	.59 (.50)	.42 (.50)	.63 (.49)
Problem categorisation (max=1)	.53 (.51)	.74 (.45)	.74 (.45)	.75 (.44)
Problem representation (max=1)	.72 (.45)	.68 (.75)	.61 (.50)	.78 (.42)

student was considered as having difficulties by the teacher. She scored 0 on both math performance measures at pre-test. After the intervention, large gains were obtained for planning activities (she now entirely read the instruction, showed to systematically explore the task and gather data, took the time to analyse the information before starting calculations, and showed to plan execution steps), monitoring (rereading instruction, asking herself questions, stopping at difficult information, comparing information, checking that the right numbers were used), and diverse strategies (external memories, gestures that support cognitive activity). This helped her in task performance with regard to the numbers and information that had to be considered for the calculations: all were correctly collected. However, when she started the calculations, ongoing monitoring diminished with time and she did not operate a final check of her work (going back to instruction, comparing answer with instruction, doing calculations again). As a consequence, overall performance did not improve much. As her verbalisations during task and interview revealed a good understanding of the diverse strategies and how these could help her, and considering that she was severely struggling with regard to mathematical knowledge and skills, the reduction in strategic behaviour in the course of the task may suggests a cognitive overload: the student's resources were not enough to maintain this strategic engagement during the entire task.

Table 4: Performance on the mathematics word problems in 3rd and 5th grade.

	CG		EG	
	Pre-test	Post-test	Pre-test	Post-test
3rd grade				
Number of steps (max=7)	5.2 (2.2)	5.1 (1.9)	3.6 (2.4)	6.0 (1.5)
Performance (max=7)	3.6 (2.3)	3.3 (2.1)	1.4 (2.2)	4.2 (2.4)
5th grade				
Number of steps (max=9)	7.0 (2.0)	7.4 (1.8)	7.7 (1.6)	8.6 (0.7)
Performance (max=9)	5.3 (2.8)	6.8 (2.2)	6.1 (2.4)	7.9 (1.2)

Discussion

In this article we presented our method to improve metacognition and SRL in students with learning difficulties or ID, as well as in typically developing students. Individual interventions were transformed into classroom interventions in order to foster learning in all students, and the accompanying studies evolved from individual case studies, via multiple case studies in special classes, to pre-experimental and quasi-experimental studies in regular classes. For reasons of space, we limited ourselves to presenting mainly quantitative data and only short summaries of the online measures (observations). Inevitably, this has reduced the more valid, finely grained, and informative data, regarding the adequacy and efficiency of applied SRL behaviours, as well as the consequential links between SRL and performance (Anthony et al., 2013; Cromley & Azevedo, 2006). We neither could present data regarding the effects on teachers' style of instruction, which also is an important factor (Dignath-van Ewijk et al., 2013).

Summarising the results, we can affirm that the interventions had an effect on SRL. The studies showed effects on many of the SRL behaviours and these were accompanied by increased performance. Since underlying components of the mathematics tasks were not trained, we may assume that improved performance is related to increased SRL behaviour and that the application of the learned strategies supports academic success. Observations and interviews provided more sensitive and in-depth understanding of SRL. In the interviews, the students had to explain spontaneously and in their own words what they did. Compared to the questionnaire, it allowed obtaining information about more diverse strategies, but also about the student's comprehension of the strategies (metaknowledge) and how and why they implemented them. Observations gave insight on the adequacy, quality, and efficacy of the implemented SRL behaviours and unveiled the influences between variables and the interplay with performance. At pre-test, the students used few strategies and these were generally not employed in an adequate and effective way. For example, external memory was often applied haphazardly, thus not allowing for efficient control of task execution. Monitoring, when applied, neither lead to error detection nor to changing to more appropriate strategies to deal with difficulties. At post-test, initial exploration and adequate use of external memory allowed collecting and organising all relevant information. Monitoring was supported by adequate traces, and, in case of problem detection, followed by more effective revision. Verbalisations also demonstrated that children became more analytical and reflective. Hence, improved SRL behaviours indeed led to improved performance.

Observations also evidenced inter-individual variability in strategy acquisition and use. Less confident students tended to show slower progress. In some cases, students' strategic behaviour, even if improved, was less effective, as if the newly acquired strategies were not yet well enough automatised and still demanded too much cognitive resources to be implemented, impeding task performance.

Of course, we were also confronted with the typical problems associated with data from questionnaires, including students' (mis)understanding of the intended meaning for some items. Even though the questionnaires were task-specific, a lack of correspondence existed for some items between what students declared to do and what they were observed doing. Moreover, in trying to elaborate more adequate items, we included some multiple-choice items requesting the students to apply strategies (in problem categorisation, representation, synthesis, and planning), but we experienced the same pitfall as Cromley and Azevedo (2006): These items rather assessed academic skills instead of strategy use. Furthermore, regarding metaknowledge about tasks, students often seemed to confound difficulty with low performance and vice versa (see e.g. Baird et al., 2009).

To conclude, we can state that the model appears to work well in clinical settings and when implemented in special and mainstream classes. Alternating between various tasks elicited the interest of the students and they perceived a high utility of what they were learning. The current article not only clearly shows the benefits of SRL, but also illustrates the need for including SRL in the school curriculum, as a means for improving learning in all students. The teachers, too, acknowledged the utility of the intervention and reported changes in the students' behaviours. Further studies, systematically including control groups, delayed post-tests and online evaluations of the students are under way. Furthermore, the effects on the teachers and the way in which they adapt their teaching, i.e. making it more metacognitive, is under investigation.

Acknowledgement
We would like to thank all the Master students in Special Education who contributed to this project: Yann Balli, Aurélie Benoît, Emilie Bonnefous, Susanne Dubois-Ferrière, Kirsta Erne, Sarah Grossniklaus, Cécile Masset, Aline Ravessoud, Annik Skrivan and Stefania Weber.

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