European Journal of Psychology of Education
2009, Vol. XXIV, nº 1, 17-31

Is it possible to improve mathematical achievement by means of self-regulation strategies? Evaluation of an intervention in regular math classes

Franziska Perels
Technical University of Darmstadt, Germany

Charlotte Dignath
Goethe-University Frankfurt, Germany

Bernhard Schmitz
Technical University of Darmstadt, Germany

After the effectiveness of self-regulation training outside school was demonstrated, a self-regulation intervention was developed to foster the learning achievement in regular math classes. Based on the theoretical framework of self-regulated learning, self-regulation training was integrated into a math class unit. The evaluation of the intervention concerning 53 sixth-grade students took place in a pretest/ posttest-control-group design. One teacher taught one class (control group) merely mathematical topics and another class (experimental group) in the same subject combined with self-regulative strategies. The results revealed that it is possible to support self-regulation competencies and mathematical achievement by self-regulation interventin within regular mathematics lessons of 6th-grade students.

Today students are faced with new demands on their learning abilities because of the increasing knowledge and the consequent necessity for lifelong learning. Therefore, it is necessary for students to be able to acquire new knowledge and to adapt existing knowledge to new requirements. For this reason, the recent discussion about education has led to a different view of learning, considering learners as active instead of rather passive during the learning process. Students have to be qualified to be active learners to prepare them for these demands. Therefore, the development of self-regulated learning is one of the main aims of education, besides the instruction of factual knowledge (PISA, 2004). In Germany, students' self-regulation competence is rather low compared to that of international students and the need for the support of self-regulation is obvious: The PISA – survey (Program for International Student Assessment; e.g., PISA, 2004) addressed the problem of deficits in cross-curricular academic competencies, which included general self-regulatory strategies. The results of this study revealed the need for students to learn self-regulated. Consequentially, several concepts to support students' self-regulated learning have been developed in Germany (see for example Perels, Gürtler, & Schmitz, 2005). These trainings mostly take place outside the classroom with nearly no correlation to regular classes. Although the evaluation of most of these programs has proven positive results, the transfer of training contents into school context was difficult because of the separation of training and teaching in regular classes.

Self-regulated learning is an important factor for effective learning, following many studies that have demonstrated the relevance of this competence for school-based learning and academic achievement (e.g., Zimmerman & Martinez-Pons, 1986). The concrete relationship between self-regulation competence and achievement is analyzed well in different studies, but most of these studies' results are based on correlation (e.g., Zimmerman & Martinez-Pons, 1986) without the possibility of testing specific intervention effects.

The aim of this study is to improve self-regulated learning of students so as to support their learning achievement in regular classes. Thus, it investigates the effects of training students' self-regulatory competence in math classes on self-regulated learning as well as on mathematical achievement (as a mathematical topic we chose division and multiplication) by conducting an intervention study. In order to effectively support self-regulated learning, we tried not only to include single components of self-regulation, which is often done in studies trying to support self-regulation by enhancing one single component. Our aim is to support the overall self-regulation cycle. This adds to research, because the few intervention studies which investigate the support of students' self-regulated learning in order to improve academic achievement often include only one component in the training program (e.g., learning strategies, Weinstein, Husman, & Dierking, 2000). By means of this integrated approach, we are able to analyze and compare the impact of these different self-regulation components on student self-regulated learning and their learning results; in this case, their mathematical achievement.

With respect to the content of our intervention, our study is based on self-regulation theory (see e.g., Boekarts & Corno, 2005; Boekaerts & Niemivirta, 2000; Pintrich, 2000; Zimmerman, 2000). For the intervention concept, we refer to the process model of self-regulation by Schmitz and Wiese (2006, see also Perels, Gürtler, & Schmitz, 2005), which provides many important components for the training of self-regulatory strategies. This process model is based on the self-regulation model by Zimmerman (2000, see also Zimmerman, 1998; Zimmerman, Bonner, & Kovach, 1996) and of Heckhausen and Kuhl (1985). They differentiate between three phases during the process of learning: the preaction phase/forethought, the action phase/performance and volitional control, as well as the postaction phase/reflection.

The preaction phase (forethought) mainly focuses on *goal setting*. At the beginning of the self-regulation process there is a predefined task given in a specific situation. With respect to the task and the situational and personal circumstances (e.g., the affective condition of the learner, e.g., being happy), the learner sets individual goals. Students choose their goals considering the kind of exercise at hand and their situational background (e.g., the learner's *attitude* to learning which influences the approaching to the task). This goal setting is connected to the motivation of the student to handle the task. Following Ryan and Deci (2000), we differentiate between intrinsic and extrinsic motivation. These authors define intrinsic motivation "as the doing of an activity for its inherent satisfactions rather than for some separate consequences" (Ryan & Deci, 2000, p. 56). In contrast, extrinsic motivation "is a construct that pertains whenever an activity is done in order to attain some separate outcome" (p. 60). According to self-regulated learning the ability to apply *self-motivation* strategies is also important. Thereby, self-motivation can be described as the ability to reach a goal without being influenced to do so by another person (self-motivation strategy e.g., self-rewarding) with an accentuation of personal responsibility. As another key concept, our model includes self-efficacy, defined as an individual's sense of his or her abilities, of his or her capacity to deal with the particular sets of conditions that learning puts before him or her. It has often been shown that self-efficacy has positive effects on important self-regulatory parameters such as effort, persistence, and achievement (Schunk & Ertmer, 1999). These components affect the *planning* of the given task starting with goal setting.

During the action phase (performance and volitional control), when the task is actually dealt with, the amount of learning time, the use of internal resources (e.g., concentration) and the application of learning strategies (e.g., MSLQ; Pintrich, Smith, Garcia, & McKeachie, 1991) are important to achieve desired outcomes, e.g., good performance. In line with Pintrich, Smith, Garcia, and McKeachie (1991), we differentiate between three kinds of strategies: cognitive, metacognitive and resource-oriented strategies. Metacognitive strategies include planning, regulation and monitoring. With regard to resource-management strategies, two groups are distinguished: internal and external strategies. Internal strategies are effort, time management and attention management. An example of an external strategy is the act of seeking social support. Besides metacognitive and resource-management strategies, we also refer to volitional strategies (see Kuhl & Fuhrmann, 1998) which are not explicitly included in most learning strategy inventories. Volitional strategies are necessary, if problems arise during the task (see Corno, 1989; Kuhl & Fuhrmann, 1998). Corno (1994) describes volition "as the tendency to maintain focus and effort toward goals despite potential distractions" (p. 229). In this connection volitional strategies can be defined as a student's use of established work habits such as concentration strategies or the elimination of any kind of internal and external distraction. During the learning process the learner monitors his or her own behavior (self-monitoring). In our studies, we support the self-monitoring procedure by the use of standardized diaries. The efficacy of this kind of instrument has been well demonstrated in several studies (see e.g., Schmitz & Wiese, 2006).

After having completed the task, the so-called postaction phase (self-reflection) begins. The learner *evaluates* the result of his or her effort and draws conclusions for further learning processes (e.g., *dealing with mistakes*). The comparison of the result with the goal has implications of the learner' *affect* (e.g., content/discontent), leads to implications for further learning processes and is influenced by an adequate *attribution* (a person ascribes a learning result to oneself or to another person; see e.g., Reber, 1995) of the learning results. In this connection it is important that success and failure are attributed to internal, variable factors such as effort, because this kind of attribution leads to an assumption of responsibility for the learning outcome. The comparison of setting goals and learning results for the given learning process has implications on the goal setting and the strategy used for the following learning process. The theoretical background is depicted in Figure 1. The components of the three phases of self-regulation, as postulated in the model, were integrated in terms of strategies into an intervention implemented in regular mathematics classrooms.

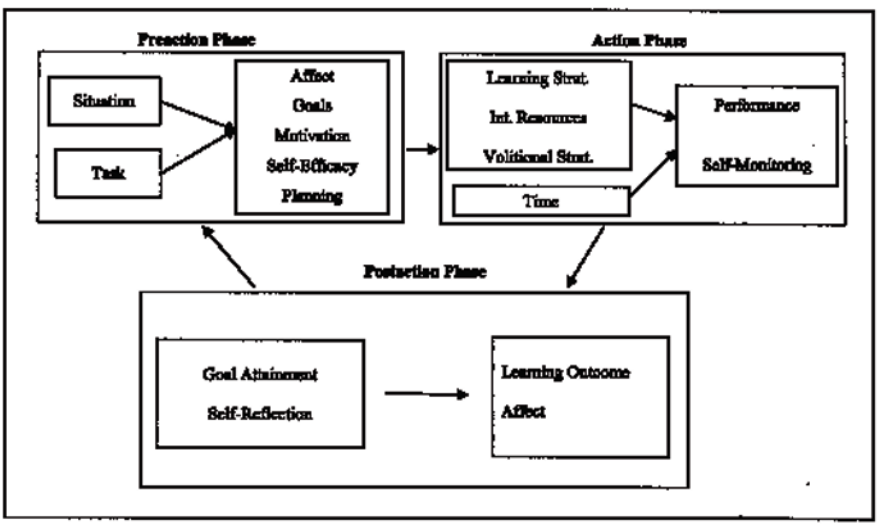

Figure 1. Process model of self-regulation (see Schmitz & Wiese, 2006)

To reduce complexity we choose important variables from each learning phase to measure before and after the training: Regarding the preaction phase we choose the components “goal-setting”, “self-efficacy” and “motivation”, for the action phase we choose the variable “volitional strategies” and as learning strategies “problem-solving strategies” (cognitive learning strategy), “resource-oriented strategies” and “self-monitoring”. Regarding the postaction phase we choose the components “handling mistakes” and “attribution” for training evaluation. These variables were the basis for the evaluation of the intervention.

Inclusion of self-regulation into mathematics lessons

In order to facilitate the transfer of the trained self-regulation strategies, the instruction of self-regulation strategies should be included directly into subject-oriented education. In line with De Corte, Verschaffel and Op’t Eynde (2000), interdisciplinary self-regulation skills as well as an issue-related attitude have not yet been sufficiently taught. As demonstrated by Hamman, Berthelot, Saia, and Crowley (2000), teachers use only 9% of all communication segments of a lesson for the discussion of such strategies. A study with elementary school teachers conducted by Moely, Santulli, and Obach (1995) revealed that less than 10% of the observed teachers taught their students how to self-regulate their cognitive activity while working on an exercise. In addition, the introduction of self-regulatory strategies seems to be even less frequent than the introduction of cognitive strategies (Santulli, 1992).

According to a meta-analysis by Hattie, Biggs, and Purdie (1996), the direct and isolated instruction of self-regulated learning strategies has turned out not to be very efficient. Instead, the authors rather argue that direct instruction of strategies ought to be linked to factual content in order to apply them in a natural setting. Training which combines the teaching of strategies with mathematics mostly focus on cognitive strategies – mathematical problem-solving strategies – but rarely on self-regulatory, metacognitive learning strategies. There are a few studies (e.g., Fuchs et al., 2003; Perels, Gürtler, & Schmitz, 2005), which combine the instruction of mathematical problem-solving strategies with multidisciplinary self-regulation strategies. These combined training sessions have proven to be more efficient than training covering just one of the two strategy domains. With regard to mathematics classes, it should also be possible to train self-regulation strategies on the basis of the curricular contents. New training programs trained students in their natural learning environment at school. However, the students were instructed by external trainers and not by their regular teachers as in our study. According to the results of their meta-analysis, Hattie et al. (1996) argue that intervention should be integrated into the actual classroom, because existing learning strategy training suffers from a lack of transfer.

This study focuses on training self-regulatory learning strategies during regular mathematics lessons. For this purpose, a teaching unit consisting of nine lessons with the topic “divisors and multipliers” as well as self-regulation contents was developed and introduced in a sixth-grade classroom. It was evaluated by a longitudinal design including pretesting and posttesting of the experimental and control group. The training contents are based upon a training program developed by Perels, Miethner, and Schmitz (submitted) within the context of a larger project of the German Research Association (DFG) aiming at the improvement of school quality (“BIQUA-Bildungsqualität von Schule”; quality of education and literacy at school).

For the self-regulation instruction concept Schunk and Ertmer (2000) recommend that beyond modeling, participants should be given greater responsibility for their own learning and self-regulation should be taught in content areas. They also suggest intensifying self-reflective practice to improve transfer. We tried to incorporate these recommendations in our intervention: Our training attempts to enhance the application of self-regulation content in actual mathematics lessons and we combined self-regulative strategies with the learning contents “divisors and multipliers”. The students’ mathematics teacher, who was instructed to behave as a self-regulation model in the self-regulation units, taught the lessons. Finally, self-reflected practice was supported by our self-monitoring procedure. The students received standardized goal diaries to self-monitor their goal achievement.

Research questions and hypotheses

The aim of the study was to improve self-regulated learning and mathematical achievement of 6th-grade students. Therefore, in-class student training was carried out to investigate its impact on student self-regulated learning and mathematical achievement concerning the content "divisors and multipliers". The following assumptions were made: For self-regulation we expected a specific effect of the intervention according to the results of the knowledge test and the answers to the self-regulation questionnaire (overall scale "self-regulation" and its scales goals, motivation, self-efficacy, volition, monitoring, learning strategies, attribution, and handling mistakes). We also expected an effect of the intervention on the mathematical achievement according to the contents of the teaching unit measured by a mathematics test.

Method

Design

The study was conducted following a quasi-experimental control group design with repeated measures. One mathematics teacher who taught two parallel classes participated in the study. One class served as a control group. The students of this class were examined before and after a conventional teaching unit with the topic "divisors and multipliers". The second class served as experimental group. This class participated in a teaching unit with the same topic but with the additional instruction of self-regulation strategies. For this class testing also took place before and after the teaching unit.

Participants

The voluntarily participating teacher taught mathematics to two sixth-grade classes at the same time. At the time of the intervention she was 52 years old and had been teaching for 27 years. Thus, she represented some of the characteristics of the average teacher in Germany today. The two classes consisted of 55 students (28 students in the intervention class and 27 students in the control class) who had moved on to the sixth-grade at the time of the intervention. Data sets of 53 students (26 of intervention class and 27 students in the control class) could be used in the pre /post data analysis and evaluation. The mean age in the intervention class was 11.15 (*SD*=.37) and 10.92 (*SD*=.39) in the control class. 45 students were eleven years old when the intervention took place, three children were ten, and five children were already twelve years old. 28 girls (14 in the control group) and 25 boys (13 in the control group) participated in this study.

Procedure

The procedure will be depicted separately for the control and the experimental group, for reasons of clarification. The head of the school was informed about the project and agreed to its terms. Then the *control group* took a pre-test consisting of a self-regulation questionnaire and a mathematics test during a mathematics lesson at the end of the school year. After that, the mathematics teaching unit without any special intervention took place before the summer holidays. In the fifth, the sixth and the seventh lesson, the control group additionally learned three strategies for handling mathematical word problems. This was not directly connected to the contents of the teaching units but served to ensure that the intervention of control group and experimental class lasted the same amount of time. The three strategies were selection (discrimination of relevant from irrelevant information, see e.g., Cook & Rieser, 2005), segmentation (subdivide a complex problem into its components and solve these components to solve the complex problem) and display formats (e.g., figure or table). All lessons were recorded on video. A posttest took place after that teaching unit. Both pretest and posttest consisted of a questionnaire on self-regulated learning as well as a mathematics test about the teaching unit. We did not use the self-regulation knowledge test for the control group in order not to discourage the students.

The *experimental group* finished the pre-test at the same time as the control group. However, this group didn't participate in the conventional teaching unit "divisors and multipliers" but worked on another unit of the curriculum. The children of the intervention group took part in a second pre-test measurement after the holidays, they were then trained in mathematics and self-regulation and then passed a post-test immediately after the end of the intervention. The mathematical contents were the same in both groups. The lessons of the intervention group were also videotaped. Seven weeks after the post-testing, stability and transfer of the trained self-regulation competencies were measured. The children and the teacher of the experimental class as well as the teachers who taught other subjects to this class participated in this follow-up measurement. The students of the experimental group kept diaries concerning their self-defined goals in order to support self-monitoring during the intervention.

Intervention

The intervention aimed at improving self-regulation of students in their regular mathematics class. Therefore, a teaching unit of nine mathematics lessons (lasting three weeks) was modified to teach and exercise eight self-regulation strategies in order to apply them to specific mathematics exercises. The training concept was meant to create a learning environment that supports self-regulated learning. The mathematics topics were based on the regular schoolbook for the school's fifth and sixth grades. Table 1 gives an overview of the training contents of the intervention group, including the contents of the control group's lessons for comparison. The control class only received instruction concerning mathematics. In order to guarantee an equal instruction time, control students additionally learned mathematical problem-solving strategies (selection, segmentation and display formats) which were not connected to the mathematical contents of the learning unit. To ensure that the mathematical contents were instructed in parallel to the two classes, the video-analyses of the control group lessons were evaluated before the instruction of the experimental group started.

All of the experimental group's lessons were designed to follow the same procedure: The teacher began every lesson with a short repetition of the last lesson's contents. The rest of the class consisted of 1/3 self-regulation strategies and 2/3 mathematical contents. At the end of each class, the teacher was asked to repeat the new contents and to give homework for the following lesson.

The *first* and *second lesson* in the experimental group were based on group work in order to make the students familiar with the learning strategies supporting self-regulated learning. To warm up, the students thought about how they had dealt with learning problems in the past. Then they worked on different strategies (positive attitude towards mathematics and learning, motivation, goal-setting, planning, dealing with distractions (internal and external), concentration, handling mistakes) in so called "expert groups" (jigsaw learning). The students designed a poster for the strategy in each group. Then all the students walked around and were instructed by the experts of each group about the strategy described on the poster. The lessons ended with the assignment of the strategies to the preaction, action and postaction phases, whereby the students received a first impression of the self-regulation model. In the *third lesson*, the teacher introduced the topic "divisors and multipliers". Apart from this mathematical content, the lesson's goal for the students was to become aware of their positive and negative "attitudes towards mathematics". The children were supported in developing a constructive and positive attitude towards the subject. In addition, they learned about the importance of correct "goal setting" as well as distinguishing between main and subgoals. The contents of the *fourth lesson* concerned the consolidation of the topic “goal setting”. The students were told how to reach a long-term goal by planning small, precise steps. They practiced how to set goals and were introduced to a worksheet that can help them to set goals in class and monitor their progress. Regarding the mathematical contents they learned about the “divisibility of sums”. The *fifth lesson* dealt with the mathematical subject “rules of divisibility for the numbers 2, 4, 5, 8, 10 and 20”. Additionally, the students talked about personal experiences with “self-motivation”: Which strategies did they use to motivate themselves? The lesson aimed at making them aware of their own strategies and how to learn from their peers. The teacher also distributed a handout with a summary of self-motivation strategies. In the *sixth and seventh lesson*, the teacher introduced the topic “multipliers”. Based on an example exercise, the children learned how to proceed in a well-structured manner while working on a mathematical problem (“planning”). Another self-regulation topic of the lesson was “concentration”, starting with a discussion about “How does a lack of concentration show? What can be done?” The students received concentration exercises and practiced them. In the *eighth lesson*, the teacher talked about “dealing with internal and external distractions” as well as about “divisor rules for the numbers 3, 6 and 9”. The topic “distractions” was introduced with reference to previous lesson’s content (concentration). The students discussed what could disrupt their concentration. The teacher explained strategies for dealing with external distractions (e.g., sign for the room door “Please do not disturb!”). Then she presented possibilities for stopping bothersome thoughts (“stop sign” for interfering thoughts) and for reformulating them (self-instruction). For example, instead of thinking “This task is too difficult for me”, they could say, “Maybe I can find a small part of the task which is interesting and easy to solve”). The *last lesson* of the teaching unit contained the topic “divisors”. Additionally, the students learned how to “handle mistakes”, a strategy which takes place during the postaction phase. They learned how to use a standardized protocol pattern for noting mistakes and learning from them.

Table 1

Topics of the intervention groups

Topics of the experimental groups’ math lessons		
lesson	mathematical contents	self-regulative contents
1st & 2nd lesson	-	expert round: introduction of learning strategies
3rd lesson	introduction to the topic: divisor and multiplier	attitude towards math and goal-setting
4th lesson	divisibility of sums	goal pursuit and goal control
5th lesson	divisibility rules for the numbers 2, 4, 8, 5, 10 & 20	self-motivation
6th & 7th lesson	lowest common multiplier	planning how to solve a problem and how to concentrate
8th lesson	divisibility rules for the numbers 3, 6 and 9	dealing with internal and external distraction
9th lesson	greatest common divisor	handling of mistakes
Topics of the control groups’ math lessons		
lesson	mathematical contents	problem-solving contents
1st lesson	divisor and multiplier derivation and rules	
2nd lesson	divisibility of sums	
3rd lesson	last digit rules for divisibility: memorizing aids	
4th lesson	divisibility by 3 and 9 check sum	
5th lesson		problem-solving strategy: introduction to selection
6th lesson		strategy how to solve a problem: repetition selection, segmentation
7th lesson		problem-solving strategy: display formats transfer of strategies to other domains
8th lesson	lowest common multiplier	
9th lesson	greatest common divisor	

Instruments

The intervention was evaluated by using several instruments (questionnaire on self-regulated learning, diary for goal setting, mathematics test, and transfer measurement). In this article, we will focus on the measurement of self-regulation competence by means of a questionnaire for self-regulated learning, the knowledge test on self-regulation strategies and the mathematics test. The *self-regulation questionnaire* was constructed on the basis of an instrument used and evaluated in a study with 5th-grade students with the aim of improving self-regulated learning by training students and their parents (see Perels, Miethner, & Schmitz, submitted; Perels et al., 2005) during training outside regular classes. Both, the control group and the intervention group had to fill in this questionnaire before and after the intervention. The response categories of the self-regulation questionnaire ranged from 1 to 4 (1=I don't agree at all, 2=I don't agree, 3=I agree, 4=I agree completely). An overall scale "self-regulation" (α=.82) was designed in order to get an overall measure of the trained self-regulation competencies. The sub-scales included were *goal setting* (α=.63, 7 items, e.g., "If I want to reach an important aim I try to reach it step by step."), *motivation* (α=.71, 17 items, e.g., "After having completed an exercise I reward myself."), *volition* (α=.70, 12 items, e.g., "If I have to learn something difficult I prefer starting at once."), *learning strategies* (problem-solving and resource based strategies; (α=.69, 10 items, e.g., "I can easily find my materials on my desk."), *monitoring* (α=.61, 3 items, e.g., "During learning I evaluate whether my proceeding makes sense."), *attribution* (α=.66, 6 items, e.g., "If I don't succeed in doing my homework it is because I haven't made enough effort."), *handling mistakes* (α=.67, 3 items, e.g., "By analyzing my mistakes I can learn what to improve.") and *self-efficacy* (α=.67, 4 items, e.g., "I can manage to solve even difficult problems.").

In addition to the measurement of strategy application, the students of the intervention group had to finish a *knowledge test* on self-regulation. This test measured the knowledge on self-regulation with the help of several questions with an open response format (e.g., "What can you do to learn from your mistakes?") as well as multiple-choice questions and a case example. For the multiple-choice questions, three to five possible answers were provided. The scales of this knowledge test were *goal setting*, *planning*, *self-motivation*, *concentration*, volitional strategies (e.g., *dealing with distractions)* and *dealing with mistakes*. Since the students in the control class did not receive self-regulation training, one can assume that their knowledge on self-regulation did not change. Therefore, only the students of the experimental group had to take part in the knowledge test in order to analyze the effects of the intervention in detail. The evaluation of the test results was realized by counting the number of correct answers on the multiple-choice questions and by grading the open answers with a maximum possible score of 26.5 points.

In addition, the students had to work on a *mathematics test*. This test consisted of five tasks including two word problems. The first and the second exercise dealt with divisibility. Example: "Is it possible to divide 132 by 12? Give reasons for your answer!" In the third task (word-problem) the students had to deal with multipliers. Example: "Martin has a stride of 60cm, Uwe of 80cm. Which distance does Martin/Uwe cover after 1, 2, 3... 10 steps? After which distance do Martin and Uwe's strides come together? How many steps does Martin have to take to reach Uwe's step?" The fourth task tested the content "divisibility by 3" and check sum. Example: "Is it possible to divide 423 by 3? How can you find out without calculating?" The last word problem was designed to measure the knowledge on the divisibility of sums. Example: "The teacher of class 5a wants to give several bags of sweets to 18 students. There are exactly 558 sweets. Can all students get the same amount of gummy bears without leaving any remaining bears?" In this test the students could reach a maximum of 19 points.

Results

The differences between the experimental group and the control group were calculated by means of analyses of variance, with time as a repeated measurement factor. There were no significant pretest differences between the groups before the intervention in the scales, except for the scale "monitoring" (t=-3.34, p<.01): The students of the experimental group rated higher in this scale. In the case of pretest differences, analyses of covariance were conducted with the pretest as a covariate (for pretest-posttest analyses). The results, as well as the means and standard deviations can be seen in Table 2. The results reveal significant interactions between time and group for most self-regulation scales – as expected in favor of the experimental group.

Table 2

Means (standard deviations) and results for the interaction Time x Group

DV	Group	Time				
		Pretest *M (SD)*	Posttest *M (SD)*	*df*	*F*	Eta^2
Self-regulation overall β	CG	2.85 (0.31)	2.73 (0.29)	9/37	5.09**	.55
	EG	2.90 (0.39)	3.19 (0.36)			
Goals	CG	2.94 (0.43)	2.83 (0.36)	1/45	9.84**	.18
	EG	3.01 (0.46)	3.39 (0.49)			
Self-efficacy	CG	3.10 (0.41)	2.47 (0.50)	1/45	31.12***	.41
	EG	3.02 (0.43)	3.17 (0.50)			
Motivation	CG	2.50 (0.40)	2.73 (0.40)	1/45	2.73	.06
	EG	2.60 (0.40)	3.03 (0.47)			
Volition	CG	3.12 (0.37)	2.76 (0.50)	1/45	16.75**	.37
	EG	3.16 (0.36)	3.28 (0.34)			
Problem-solving strategies	CG	2.55 (0.69)	2.78 (0.40)	1/45	0.00	.00
	EG	2.79 (0.86)	3.03 (0.46)			
Resource oriented strategies	CG	2.99 (0.60)	2.79 (0.35)	1/49	7.58**	.13
	EG	3.19 (0.48)	3.30 (0.54)			
Monitoring α	CG	2.81 (0.64)	2.88 (0.60)	1/49	4.47*	.09
	EG	3.33 (0.49)	3.40 (0.39)			
Attribution	CG	2.88 (0.43)	2.79 (0.38)	1/45	3.06#	.06
	EG	2.99 (0.42)	3.16 (0.39)			
Handling mistakes	CG	3.29 (0.58)	2.75 (0.37)	1/45	11.41**	.20
	EG	3.39 (0.49)	3.49 (0.47)			
Math test	CG	7.20 (2.43)	7.74 (2.95)	1/52	3.28#	.06
	EG	7.16 (2.90)	9.00 (2.73)			

Note. #p<.10; *p<.05; **p<.01; ***p<.001. α Because of pretest differences for the students an analysis of covariance with the pretest as covariate was conducted. The presented *M* and *SD* are not adjusted; β Multivariate analysis of variance.

The analyses of the self-regulation questionnaire show positive effects regarding the overall scale "self-regulation" and its sub-scales "goals", "volition", "learning strategies: resource-oriented strategies", "monitoring", "attribution" (10%-level), "handling mistakes" and "self-efficacy". The intervention group stated significantly more self-regulated behavior in the posttest than the control group, whereas the control group showed a small but statistically significant drop. There were no significant pretest-posttest differences between the experimental group and the control group in the scales "problem solving" and "motivation". Figure 2 shows the significant result for the overall scale "self-regulation".

Since the experimental class had to fill in a knowledge posttest on self-regulation, descriptive analyses according to this instrument were possible. The results of the test showed that the students of the experimental group reached almost half of the possible maximum score (11.24 of maximum possible 26.5 points). The students had a considerable knowledge of the topics goal setting (criterions for goal setting [1.19 of 1.5 points] and control of aim pursuit

[0.34 of 0.5 points]), concentration (0.85 of 1 point), and shifting of negative thoughts about learning situations and competencies into positive ideas (0.9 of 1 point).

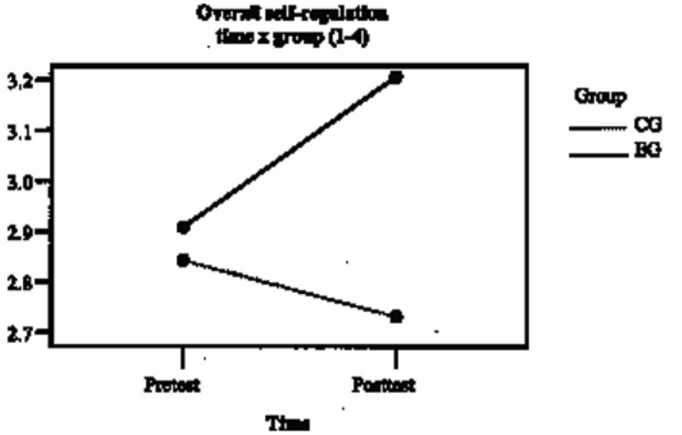

Figure 2. Significant interaction Time x Group in relation to "Overall Self-regulation"

Concerning the mathematical competencies on multipliers and divisors, an analysis of variance regarding an overall measure (sum over all exercises of the test, max. score: 19) was conducted (result see Table 2). Figure 3 shows the result of this analysis.

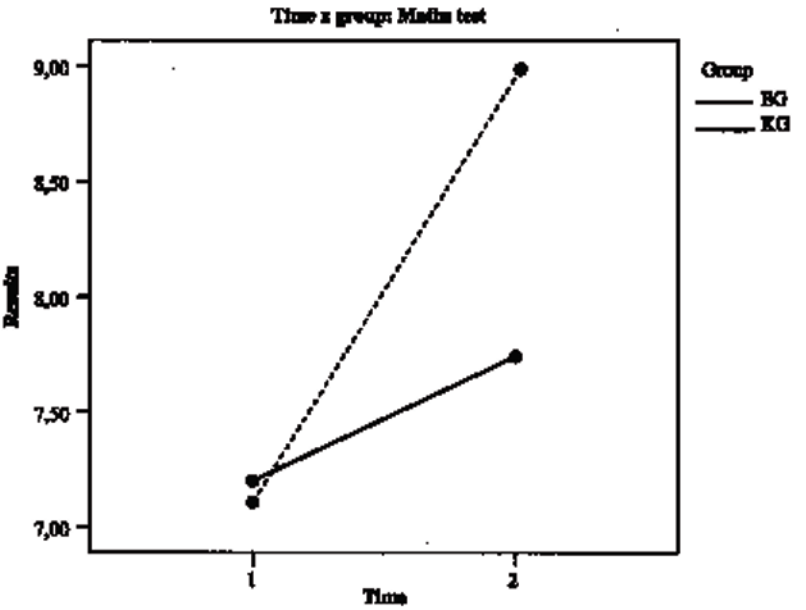

Figure 3. Interaction Time x Group in relation to the result of the math test

As illustrated in Figure 3, both classes improved after the intervention regarding their mathematical competencies. However, there are significant differences (10% level) between the groups. Only the students of the experimental class showed a significant increase (t=3.72, p<.01).

Discussion

The results of the pretest-posttest evaluation reveal that it is possible to support self-regulation competencies and mathematical achievement by a self-regulation intervention within regular mathematics lessons of 6th-grade students. The students who received self-regulation instruction during their mathematics class showed knowledge on the trained self-regulation strategies as well as higher assessments in the self-regulation questionnaire at the posttest. Both the results of the overall-scale "self-regulation" and the separate analyses of the included self-regulation strategies indicate this. Yet there are no effects regarding the scales "motivation" and "problem-solving strategies". Relating to "problem solving", the lacking interaction effects could be explained by the fact that the control group learned mathematical problem-solving strategies instead of self-regulation during the intervention time. Therefore, both groups thought they were learning strategies to support the learning of mathematical contents and therefore showed an increase in their statements for this scale in the questionnaire. Regarding motivation, there are effects for the experimental class but they are not statistically significant. Maybe there was no additional self-motivation needed during the training period that was interesting and new for the students. A further measurement after a retaining period of a few weeks or months could help to detect any effects of the intervention regarding self-motivation.

Pertaining to mathematical achievement, we measured the results of the mathematics test of the "experimental" students and compared them with the results of the "control" students. We found that it is also possible to support mathematical performance by training self-regulatory strategies during regular classes. The students of the experimental group showed higher improvement in their mathematics skills concerning "divisors and multipliers" in the pre/posttest comparison.

Our approach of combining self-regulation with subject-related strategies was successfully conducted by Perels et al. (2005), who improved the competencies of 8th-grade students by means of training outside school which combined self-regulatory and mathematical problem-solving strategies. In this context, our study adds to research as it realizes this combination in a regular classroom situation, so that it is possible to directly influence school-based learning with cross-curricular self-regulation strategies.

In our study, we successfully combined general (self-regulation) strategies with mathematical contents. This procedure should ensure a direct transfer of self-regulation training contents to the subject related tasks on divisors and multipliers. According to Waeytens et al. (2002), the approach of combining the instruction of self-regulated learning with regular subject contents as well as the idea of creating learning environments which make self-regulated behavior necessary and that support it, in general do not always go well with existing teaching and learning strategies. The school organization does not yet sufficiently demonstrate an adapted learning and working behavior to students (e.g., Moely, Santulli, & Obach, 1995). In the consequence it is necessary for the intention to support self-regulation and as a result learning achievement to attach great importance to the self-regulation contents as well as to adequate methods and learning environments to support it as we did in our study.

In contrast to other trainings, which focus on the implementation of selected components of self-regulation (for an overview, see Schunk & Ertmer, 2000), our intervention implemented components of all phases of the self-regulation process. The combination of specific mathematical strategies and overall self-regulation for the students seemed to be beneficial for self-regulated learning as well as for mathematical achievement.

Nevertheless, there are still some limiting factors to this study: the items of the questionnaire only measure if a student claims to apply learning strategies. It is not possible to conclude any statements on how far the students can actually regulate their learning behavior. In this context, a behavior-related operationalization of the employment of learning strategies might be revealing, as for instance stated by Leutner, Barthel, and Schreiber (2001) relating to self-motivation of university students. With such an instrument, it would be possible to measure the results of strategy use, as it was possible to do with the mathematics test.

Another limitation of the study is that only one teacher participated which reduces the possibilities for generalization of the results. She taught both classes in the same topic one after the other (first the control class, then the experimental class). The contents of the teaching units of the experimental class were designed in parallel to those of the control class concerning the mathematical topics. To ensure parallelism of the mathematical parts of the learning units we used the video data. Between the two learning units (of the control class and the experimental class) the teacher received only little information about the aims of the intervention. She was informed in detail after the end of the study. This was necessary to prevent the teacher from influencing the arrangement of the lessons with her knowledge of the hypothesis.

Another limitation pertains to the intervention duration: As mentioned earlier, the training lasted only three weeks. Greater effects regarding the learning behavior and the mathematical achievement should be expected in case of a continuous and fairly long-term instruction of self-regulation competencies in regular classes (e.g., Hilden & Pressley, 2007 according to increase students´ self-regulated use of reading comprehension strategies). From this point of view, the presented teaching unit of nine lessons is just a first introduction to the topic.

Learning strategies should be practiced regularly in further lessons. In order to place these concepts in schools in the long run, it seems to make sense to impart the knowledge and skill of how to instruct self-regulation strategies within the scope of teacher training. This is, of course, not limited to mathematics classes, because opposed to cognitive learning strategies that aim at facilitating the acquisition of a certain subject matter, self-regulatory learning strategies are more general and multidisciplinary, and can be applied during the whole learning process in different content areas. Further research should investigate how such training could be integrated into existing teacher training, and what kind of methods could evaluate whether transfer of the training contents was successful.

The present study implies practical consequences for schools. The results show that it is possible to support self-regulatory strategies in regular classes (6th-grade class). Therefore, teaching interdisciplinary self-regulatory and domain-specific strategies should already be integrated in regular elementary school lessons to support the development of advantageous learning behavior as early as possible. Therefore changes in teacher apprenticeship are necessary.

References

Boekaerts, M., & Corno, L. (2005). Self-regulation in the classroom: A perspective on assessment and intervention. *Applied Psychology: An International Review, 54*, 199-231.

Boekaerts, M., & Niemivirta, M. (2000). Self-regulated learning: Finding a balance between learning goals and ego-protective goals. In M. Boekaerts, P.R. Pintrich, & M. Zeidner (Eds.), *Handbook of Self-Regulation* (pp. 417-450). San Diego, CA: Academic Press.

Cook, J.L., & Rieser, J.J. (2005). Finding the critical facts: Children's visual scan patterns when solving story problems that contain irrelevant information. *Journal of Educational Psychology, 97*, 224-234.

Corno, L. (1989). Self-regulated learning: A volutional analysis. In B.J. Zimmerman & D.H. Schunk (Eds.), *Self-regulated learning and academic achievement. Theory, research and practice* (pp. 111-141). New York: Springer.

Corno, L. (1994). Student volition and education: Outcomes, influences, and practices. In D.H. Schunk & B.J. Zimmerman (Eds.), *Self-regulation of learning and performance: Issues and educational applications* (pp. 229-251). Hillsdale, NJ: Erlbaum.

De Corte, E., Verschaffel, L., & Op't Eynde, P. (2000). Self- regulation. A characteristic and a goal of mathematics education. In M. Boekaerts, P.R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 687-725). San Diego: Academic Press.

Fuchs, L.S., & Fuchs, D., Prentice, K., Burch, M., Hamlett, C.L., Owen, R., & Schroeter, K. (2003). Enhancing third-grade students' mathematical problem solving with self-regulated learning strategies. *Journal of Educational Psychology, 95,* 306-315.

Hamman, D., Berthelot, J., Saia, J., & Crowley, E. (2000). Teachers' coaching of learning and its relation to students' strategic learning. *Journal of Educational Psychology, 92,* 342-348.

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

Heckhausen, H., & Kuhl, J. (1985). From wishes to actions: The dead ends and short cuts on the long way to action. In M. Rese & J. Sabini (Eds.), *Goal-directed behavior: The concept of action in psychology* (pp. 134-159). Hillsdale, NJ: Erlbaum.

Hilden, K.R., & Pressley, M. (2007). Self-regulation through transactional strategies instruction. *Reading and Writing Quarterly: Overcoming learning difficulties, 23*, 51-75.

Kuhl, J., & Fuhrmann, A. (1998). Decomposing self-regulation and self-control: the volitional components inventory. In J. Heckhausen & C.S. Dweck (Eds.), *Motivation and self-regulation across the life-span* (pp. 15-49). New York: Cambridge University Press.

Leutner, D., Barthel, A., & Schreiber, B. (2001). Studierende können lernen, sich selbst zum Lernen zu motivieren: Ein Trainingsexperiment [Students can learn to motivate themselves to learning: a training experiment]. *Zeitschrift für Pädagogische Psychologie, 15,* 155-167.

Moely, B.E., Santulli, K.A., & Obach, M.S. (1995). Strategy instruction, metacognition, and motivation in the elementary school classroom. In F.E. Weinert & W. Schneider (Eds.), *Memory perfomance and competencies: Issues in growth and development* (pp. 301-321). Hillsdale, NJ: Erlbaum.

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

Perels, F., Miethner, S., & Schmitz, B. (submitted). Training program for secondary school students and their parents to improve self-regulated learning. *Contemporary Educational Psychology.*

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

Pintrich, P.R., Smith, D., Garcia, T., & McKeachie, W. (1991). *The motivated strategies for learning questionaire (MSLQ)*. Ann Arbor: University of Michigan.

PISA. (2004). *PISA. Learning for tomorrow's world. First results from PISA 2003*. OECD Publishing.

Reber, A.S. (1995). *Dictionary of psychology* (2nd ed.). London: Penguin Books.

Ryan, R.M., & Deci, E.L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology, 25,* 54-67.

Santulli, K.A. (1992). Teachers' role in facilitating students' strategic and metacognitive processes during the representational, solution, and evaluation phase of mathematics problem solving. *Dissertation Abstracts International, 52*, 55-59.

Schmitz, B., & Wiese, B.S. (2006). New perspectives for the evaluation of training sessions in self-regulated learning: Time-series analyses of diary data. *Contemporary Educational Psychology, 31*, 64-96.

Schunk, D.H., & Ertmer, P.A. (1999). Self-regulatory processes during computer skill acquisition: Goal and self-evaluative influences. *Journal of Educational Psychology, 91,* 251-260.

Schunk, D.H., & Ertmer, P.A. (2000). Self-regulation and academic learning: Self-efficacy enhancing interventions. In M. Boekaerts, P.R. Pintrich, & M. Zeider (Eds.), *Handbook of self-regulation* (pp. 631-651). San Diego, CA: Academic Press

Waeytens, K., Lens, W., & Vandenberghe, R. (2002). Learning to learn: Teachers' conceptions of their supporting role. *Learning and Instruction, 12*, 305-322.

Weinstein, C.E., Husman, J., & Dierking, D.R. (2000). Self-regulation interventions with a focus on learning strategies. In M. Boekaerts, P.R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 727-747). San Diego, CA: Academic Press.

Zimmerman, B.J. (1998). Developing self-fulfilling cycles of academic regulation: An analysis of exemplary instructional models. In D.H. Schunk & B.J. Zimmerman (Eds.), *Self-regulated learning: From reaching to self-reflective practice* (pp. 1-19). New York: Guilford Press.

Zimmerman, B.J. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P.R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13-39). San Diego, CA: Academic Press.

Zimmerman, B.J., & Martinez-Pons, M. (1986). Development of a structured interview for assessing student use of self-regulated learning strategies. *American Educational Research Journal, 23*, 614-628.

Zimmerman, B.J., Boner, S., & Kovach, R. (1996). *Developing self-regulated learners: Beyond achievement to self-efficacy*. Washington, DC: American Psychological Association.

Envisageant la discussion sur l'effectivité d'entraîner l'autorégulation en dehors de l'enseignement scolaire, un programme d'intervention fut conçu à fin d'améliorer l'autorégulation académique des collégiens dans le cadre de l'enseignement régulier. Fondé à la théorie d'apprentissage autorégulé, une intervention qui se penche sur l'autorégulation fut intégrée dans une unité de leçons de mathématiques. L'évaluation de l'intervention pour 53 élèves de la cinquième eût lieu dans le contexte d'un design prétest-intervention-posttest avec un groupe contrôle. Dans une des deux classes (groupe contrôle), le professeur enseigna exclusivement des mathématiques; dans l'autre classe (groupe expérimental), elle enseigna la même matière ajoutant l'enseignement des stratégies d'autorégulation. Les résultats indiquent que les compétences de l'autorègulation et la performance en mathématiques peuvent être améliorées par une intervention d'autorégulation en classes régulières de mathématiques.

Key words: Mathematics, Self-regulation, Strategy training, Student training.

Received: September 2006
Revision received: February 2007

Franziska Perels. Department of Educational Psychology, Institute of Psychology, Technical University of Darmstadt, Alexanderstraβe 10, 64283 Darmstadt, Germany. E-mail: perels@psychologie.tu-darmstadt.de; Web site: www.paedpsy.psych.tu-darmstadt.de/

Current theme of research:

Self-regulated learning, evaluation methods, training, pre-school education, mathematical problem-solving, fostering meta-cognition and self-regulated learning among students by means of standardized diaries

Most relevant publications in the field of Psychology of Education:

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

Perels, F., Miethner, S., & Schmitz, B. (submitted paper). Training program for secondary school students and their parents to improve self-regulated learning. *Contemporary Educational Psychology.*

Perels, F., Merget-Kullmann, M., Wende, M., Schmitz, B., & Buchbinder, C. (in press). Improving self-regulated learning of preschool children. Evaluation of training for kindergarten teachers. *British Journal of Educational Psychology.*

Perels, F., Otto, B., Landmann, M., Hertel, S., & Schmitz, B. (2007). Self-regulation from the process perspective. *Journal of Psychology, 215*, 194-204.

Charlotte Dignath. Department of Educational Psychology, Institute of Psychology, Goethe-University, Senckenberganlage 15/HP 126, 60325 Frankfurt am Main, Germany. E-mail: c.dignath@paed.psych.uni-frankfurt.de; Web site: www.psychologie.uni-frankfurt.de/abteilungen_und_bereiche/pp/index.html

Current theme of research:

Promotion of self-regulated learning at primary and secondary school. Meta-analyses. Instruction of metacognitive strategies. Teacher observations. Video-based qualitative research. Fostering metacognition and self-regulated learning among university students by means of standardized log-books.

Most relevant publications in the field of Psychology of Education:

Dignath, C., & Büttner, G. (submitted). Developmental aspects of what makes interventions to promote self-regulated learning most effective. A meta-analytic comparison between primary and secondary school level. *Metacognition & Learning.*

Dignath, C., Büttner, G., & Langfeldt, H.-P. (submitted). How can primary school students acquire self-regulated learning most efficiently? A meta-analysis on interventions that aim at fostering self-regulation. *Educational Research Review.*

Bernhard Schmitz. Department of Educational Psychology, Institute of Psychology, Technical University of Darmstadt, Alexanderstraße 10, 64283 Darmstadt, Germany. E-mail: schmitz@psychologie.tu-darmstadt.de; Web site: www.paedpsy.psych.tu-darmstadt.de/

Current theme of research:

Self-regulated learning, counseling in school environment, time-series analyses, self-monitoring, self-motivation.

Most relevant publications in the field of Psychology of Education:

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

Perels, F., Otto, B., Landmann, M., Hertel, S., & Schmitz, B. (2007). Self-regulation from the process perspective. *Journal of Psychology, 215*, 194-204.

Schmitz, B. (2006). Advantages of studying processes in educational research. *Learning and Instruction, 16*, 433-449.

Schmitz, B., & Skinner, E.A. (1993). Perceived control, effort, and academic performance: Interindividual, intraindividual, and multivariate time series analyses. *Journal of Personality and Social Psychology, 64*, 1010-1028.

Schmitz, B., & Wiese, B.S. (2006). New perspectives for the evaluation of training sessions in self-regulated learning: Time-series analyses of diary data. *Contemporary Educational Psychology, 31*, 64-96.