Metacognition Learning
DOI 10.1007/s11409-010-9055-3

Promotion of self-regulated learning in classrooms: investigating frequency, quality, and consequences for student performance

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Received: 23 December 2009 / Accepted: 26 April 2010

Abstract An implication of the current research on self-regulation is to implement the promotion of self-regulated learning in schools. Teachers can promote self-regulated learning either directly by teaching learning strategies or indirectly by arranging a learning environment that enables students to practise self-regulation. This study investigates teachers' direct and indirect promotion of self-regulated learning and its relation to the development of students' performance. Twenty German mathematics teachers with their overall 538 students (grade 9) were videotaped for a three-lesson unit on the Pythagorean Theorem. Students' mathematics performance was tested several times before and after the observed lessons. A low-inferent coding system was applied to assess the teachers' implicit or explicit instruction of cognitive strategies (e.g., organisation), metacognitive strategies (e.g., planning), and motivational strategies (e.g., resource management). High-inferent ratings were used to assess features of the learning environment that foster self-regulation. Results reveal that a great amount of strategy teaching takes place in an implicit way, whereas explicit strategy teaching and supportive learning environment are rare. The instruction of organisation strategies and some features of the learning environment (constructivism, transfer) relate positively to students' performance development. In contrast to implicit strategy instruction, explicit strategy instruction was associated with a gain in performance. These results reveal a discrepancy between the usefulness of explicit strategy instruction and its rare occurrence in classrooms.

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Published online: 23 June 2010

Keywords Self-regulated learning · Learning environment · Video observation · Instructional effectiveness · Classroom research

In many situations people are faced with new knowledge and skills they want to learn or have to learn. When there is no external guidance, a learner has to regulate his learning process himself. He has to carry out activities like setting a learning goal, planning the steps to go, choosing adequate learning strategies, monitoring his progress, and checking the learning outcomes. In a society that requires lifelong learning, the ability to regulate one's own learning is getting more and more important to be successful in academic as well as in non-academic contexts. Therefore, a lot of educational research has focused on self-regulated learning during the last decades (Zimmerman 2008). In this regard, various theories, models, trainings, and studies on that construct have emerged. For this reason it is difficult to find a common definition of self-regulated learning. Combining the core features of the different models, Wirth and Leutner (2008) define self-regulated learning as "a learner's competence to autonomously plan, execute, and evaluate learning processes, which involves continuous decisions on cognitive, motivational, and behavioural aspects of the cyclic process of learning" (p. 103). Concerning the role of metacognition in self-regulated learning, there are two different perspectives on the relation of these concepts (Veenman 2007; Veenman et al. 2006). Some researchers regard metacognition as a superordinate or equated concept to self-regulation (e.g., Winne 1996). Others conceptualise self-regulation as a superordinate concept, including for example cognitive, metacognitive, and motivational components (e.g., Boekaerts 1999; Zimmerman 1995). Following the latter perspective, in this study we focus on self-regulated learning and consider metacognition to be subordinate and embedded into that concept.

Models of self-regulated learning

Wirth and Leutner (2008) suggest distinguishing process models of self-regulated learning from component models (Winne and Perry 2000; see also Thillmann 2007). These two model types are not mutually exclusive but represent different perspectives on self-regulated learning. Process models focus more on the phases of events that constitute the ideal process of self-regulated learning and their typical requirements on the learner (e.g., Otto 2010; Schmitz and Wiese 2006; Winne and Hadwin 1998; Zimmerman 1998, 2000). Typically, process models differentiate between phases before, during, and after learning. For example, Zimmerman (2000) defines the phases forethought, performance or volitional control, and self-reflection, which consecutively repeat. In contrast, component models describe competencies that enable learners to study in a self-regulated way. These competencies can be seen as relatively stable learner attributes (e.g., Boekaerts 1996, 1999; Pintrich 1999).

A widely accepted example for component models is Boekaerts' (1999) self-regulation model which serves as basis in the present study. This model consists of three layers that are embedded into each other and represent the cognitive, metacognitive, and motivational aspects of self-regulation. The inner layer stands for cognitive regulation and deals with learning activities that directly refer to information processing. The middle layer (metacognitive regulation) focuses on the whole learning process as well as on the learner's knowledge and skills to regulate it. The learning process is again embedded into the "self", the learner's own goals, needs, and expectancies, represented by the outer layer (motivational regulation). Self-regulated learning strategies can be grouped according to the layers of this model. Organisation, elaboration, and problem solving strategies are typical examples for cognitive strategies. On the metacognitive layer, strategies such as planning, monitoring, and evaluating the learning process play an important role. Concerning the motivational regulation, strategies involve aspects such as resource management, causal attribution, action control, and feedback.

Ways of promoting self-regulated learning in classrooms

There is much empirical evidence that self-regulated learning is of great importance for academic achievement (Zimmerman 1990; Zimmerman and Schunk 2001). Several studies indicate that self-regulation goes along with better performance, showing that high-achieving students can be characterised as highly self-regulated learners (e.g., Nota et al. 2004; Purdie and Hattie 1996; Zimmerman and Martinez-Pons 1986, 1988). Moreover, numerous intervention studies reveal that trainings on self-regulated learning enhance students' academic performance (Dignath and Büttner 2008; Dignath et al. 2008; Fuchs et al. 2003; Masui and De Corte 2005; Perels et al. 2005; Schunk and Ertmer 2000). Accordingly, students should practise self-regulated learning throughout their whole school career. Thus, teachers have to cope with the task to foster their students' self-regulated learning behaviour (Waeytens et al. 2002).

These conclusions consequently lead to the question: What can teachers do to foster self-regulated learning in their students? In order to promote self-regulated learning two alternatives can be distinguished: direct promotion and indirect promotion (Otto 2010). Teachers can promote self-regulated learning *directly* by teaching learning strategies. There are two ways of strategy teaching: implicit and explicit instruction.

A teacher can *implicitly* induce his students to show certain behaviour, for example by modelling the use of a strategy. He can do this without mentioning that this behaviour can be an effective learning strategy. In this case, the students are not informed about the significance of this certain activity. This implicit kind of strategy teaching is called blind training (Brown et al. 1981). Implicit strategy teaching can for example involve a teacher acting as a role model applying a strategy and verbalising his thought processes (Collins et al. 1991). Or a teacher activates his students to engage in strategic behaviour by asking questions.

On the other hand, a teacher can *explicitly* tell his students to show a certain activity, for example by explaining that this activity is a learning strategy and can improve their performance. The students are given some information about the meaning and importance of that strategy. Brown et al. (1981) call this explicit strategy teaching informed training. They conclude from their training studies that blind training can enhance students' use of a particular strategy but fails to maintain generalisation of this activity. In contrast, informed training results also in maintenance of the activity when students are faced with subsequent similar problems and so contributes to the transfer of strategy application to appropriate settings. Especially for weaker students, teachers should explicitly explain the use of self-regulated learning activities, that is, the what, when, why, and how (Veenman 2007). Similarly, Pintrich (2002) postulates a need for explicit teaching of metacognitive knowledge. At the same time he points out that in most cases teachers instruct metacognition in a rather implicit way, assuming that students will acquire knowledge and skills autonomously. In conclusion, students should be informed about the significance of a strategy and about how to employ, monitor, and evaluate this strategy.

Another possibility for teachers is to foster self-regulated learning in an *indirect* way by arranging a supportive learning environment (Otto 2010). The learning environment is not only made up of student and teacher characteristics but also of the learning contents, the tasks, and the teaching methods. An important prerequisite for practising self-regulation in classrooms is a learning environment that enables and encourages students to learn in a self-determined way. In their CLIA-model (Competence, Learning, Intervention, Assessment), De Corte et al. (2004) provide a framework for designing learning environments that are conducive to fostering students' self-regulatory skills. For the design of these powerful learning environments they identify several major guiding principles. They stress the importance of social interaction among students (cooperation), active construction of knowledge (constructivism), learning embedded in authentic situations in order to foster transfer (situatedness), and the development of self-regulatory skills (self-direction). Various studies provide empirical support for the positive effects of powerful learning environments based on the CLIA-model. For example, the implementation of CLIA-based learning environments enhanced students' problem solving competency (Verschaffel et al. 1999), increased students' self-regulation activities and resulted in better academic performance (Masui and De Corte 1999, 2005).

Assessing the promotion of self-regulated learning

Obviously, there are several ways to foster students' self-regulation behaviour. However, it is not quite sure what teachers actually do during regular lessons. In order to investigate this question, two kinds of studying self-regulated learning can be distinguished: online measures and offline measures. One way is asking students and/or teachers by means of questionnaires or interviews about their self-regulated learning activities respectively their instructional behaviour concerning the promotion of self-regulated learning. These so called *offline measures* are usually self-reports which are collected before, after, or independently from a specific learning task (Desoete et al. 2003; Wirth and Leutner 2008). However, these measures are often criticised as having low validity (Artelt 2000; Spörer and Brunstein 2006). In fact, the results of many studies indicate that offline measures hardly correspond to the actual behaviour (Veenman 2005). Alternative assessment methods, which are taken during the learning situation, can be described as *online measures* (Wirth and Leutner 2008). There is evidence that online measures highly predict learning outcomes, whereas offline measures do not (Veenman 2007). Typical examples for online measures are thinking-aloud protocols, systematic observation, or the tracking of eye-movements. To assess teachers' instructional behaviour during regular lessons, systematic observation seems to be the adequate method.

Although observing teachers' promotion of self-regulated learning in naturalistic classroom settings seems to be a promising approach, studies that make use of this method are still rare. Moely et al. (1992) used an observation instrument to investigate elementary school teachers' promotion of learning strategies in language and mathematics lessons. Hamman et al. (2000) focused on the middle school level and applied a similar observation scheme to examine strategy instruction in lessons of different subjects. The results of both studies indicate that teachers spend only a small amount of their instructional activity on teaching students how to learn effectively. Nevertheless, Hamman et al. (2000) could show that teachers' strategy instruction is positively related to students' use of strategies. However, these studies did not differentiate between implicit and explicit strategy instruction. Furthermore, the arrangement of the learning environment was not taken into account.

Aim of the study

This study aimed at getting insights into teachers' promotion of self-regulated learning in regular classrooms. Furthermore, it was intended to investigate how different kinds of promotion of self-regulated learning relate to students' performance development.

Particularly, the following research questions were examined:

1. How much strategy instruction do teachers provide?
2. Which specific cognitive, metacognitive, and motivational strategies do they instruct?
3. In which way do teachers instruct strategies (implicit or explicit)?
4. To what extent do teachers realise features of the learning environment that enable and encourage students to practise self-regulation?

Additionally to those research questions, following hypotheses were investigated:

1. Teachers' direct and indirect promotion of self-regulated learning is positively related to students' gain in performance over time.
2. Explicit strategy instruction goes along with an increase in performance over time, whereas implicit strategy instruction does not.

Method

This article draws on data from the video study "Quality of Instruction, Learning, and Mathematical Understanding" which investigated instructional quality in mathematics lessons and the effects on student learning and motivation (Klieme et al. 2009; Klieme and Reusser 2003). In the present study the video data was reanalysed within the theoretical framework of self-regulated learning.

Sample

In the present study a subsample from the German–Swiss video study "Quality of Instruction, Learning, and Mathematical Understanding" (Klieme et al. 2009; Klieme and Reusser 2003) was reanalyzed. The total sample of the video study consisted of 20 German and 20 Swiss mathematics teachers. We analysed the complete subsample of 20 German mathematics teachers and their overall 538 secondary school students from the academic-track "Gymnasium" and the intermediate-track "Realschule" (grade 9). The 20 classes were equally distributed over the two school tracks; the mean number of students per class was 27 (SD=3.1). The students' (54% female, 46% male) mean age was 14.9 years (SD=0.58). At the time of the video recordings the teachers were already instructing the students in mathematics for at least 1 year. Overall, the teachers (25% female, 75% male) had a mean teaching experience of 16 years (SD=10.45). Participation was voluntary and students' parental consent was required.

Measures and procedures

Video recording

Each teacher was videotaped in his classroom for three lessons (each approximately 45 min), which dealt with an introduction to the theorem of Pythagoras. Teachers were advised to prepare and conduct their lessons as usual and to carry out one proof for the Pythagorean Theorem during the videotaped lessons.

Observation instrument

The videos were coded using the observation instrument ATES (Assessing How Teachers Enhance Self-Regulated Learning, Dignath and Büttner 2010). The observation instrument consists of two parts: (1) a low-inferent coding system to assess the quantity and quality of strategy instruction and (2) four high-inferent rating scales to assess features of the learning environment that foster self-regulated learning.

1. The *low-inferent coding system* is based on Boekaerts' (1999) self-regulation model and was used to assess the instruction of specified learning strategies. Low-inferent means that small units are analysed in detail. The observers coded minute by minute whether the teacher instructed cognitive strategies (elaboration, organisation, problem solving), metacognitive strategies (planning and systematic activity, monitoring and evaluation), and motivational strategies (resource management, causal attribution, action control, feedback). Teacher statements as well as non-verbal behaviour were taken into account. Table 1 gives some examples of teacher statements that were coded as instruction of strategies. If the teacher instructed different strategies within 1 min, it was possible to code more than one strategy for this minute. To account for the quality of strategy instructions, it was specified for each coded strategy whether the teacher promoted it in an implicit way (the teacher prompts the students to use a certain strategy without directly referring to it) or in an explicit way (the teacher tells the students directly to use a certain strategy). For example, the teacher question "What Do you already know and what are you looking for?", while the students are dealing with a mathematics task, would be coded as implicit instruction of an organisation strategy. On contrary, the teacher statement "While working on this kind of task, you should always ask yourself 'What do I already know and what am I looking for?'" would be coded as explicit instruction of the same organisation strategy.
2. The *high-inferent ratings* are based on the CLIA-model (De Corte et al. 2004) and were used to assess features of the learning environment that foster self-regulated learning. High-inferent means the analysis of a larger unit on a more abstract level. Four scales were completed after having observed a whole lesson. Each of the four scales on cooperative learning, constructivist learning, self-direction, and transfer consists of two or three facets, which are rated on a 4-point scale. For the assessment of *cooperative learning* the observers judged (a) the amount of cooperative learning in the classroom (quantity) and (b) the extent to which the teacher ensured that the students really work cooperatively (quality). The scale on *constructivist learning* comprised the facets (a) activation of prior knowledge, (b) embedding new knowledge into a meaningful context, and (c) working with complex problems. For the scale on *self-direction* the observers assessed (a) to which extent the teacher allowed his students to make free decisions and so to take responsibility for structuring their learning and (b) the balance between self-directed and teacher-directed learning. The scale on *transfer* required judgments on (a) the integration of learning in a real-life context and (b) the extent of dealing with the learning contents in diverse ways or in diverse contexts.

Table 1 Examples of coded strategy instructions in the low-inferent coding system

Strategy	Teacher statement
Cognitive	
Elaboration	"Now we will quickly summarise, so that we know what actually the point is."
Organisation	"While working on this kind of task, you should always ask yourself: 'What do I already know?' and 'What am I looking for?'"
Problem solving	"Look at this rectangular triangle: Which side do you chose as base and which as height to make life as easy as possible?"
Metacognitive	
Planning and systematic activity	"How could we proceed with this problem, which steps could we take?"
Monitoring and evaluation	"Please check your results again!"
Motivational	
Resource management	"I recommend you to share the work with your neighbour."
Causal attribution	"I am very confident that you will master this task."
Action control	"This is an important point, listen carefully!"
Feedback	"It's great that you work so accurately!"

Observation training and interrater reliability

For observation purposes the observation instrument was applied to the total of 60 videos. Before starting the coding procedure, two observers passed through a 60-hours observation training, during which they were introduced to using the instrument and practised coding. After that, 15 out of the 60 videos were coded by both observers to check the interrater reliability. Initially, interrater reliability was checked after the coding of the first ten videos. For the low-inferent coding system, which resulted in nominal data, Cohen's kappa was computed (kappa=.72). For each single facet of the four high-inferent rating scales (interval scales) generalizability coefficients were computed, which ranged between .70 and 1.00. Next, interrater reliability was calculated for five more videos in regular intervals throughout the coding procedure, which resulted in a kappa of .71 for the low-inferent coding system. For the facets of the high-inferent rating scales generalizability coefficients ranged between .64 and .97. An exception was the facet *extent of dealing with the learning contents in diverse ways or in diverse contexts* from the high-inferent rating scale *transfer*, whose generalizability coefficient was .00. Hence, this facet was excluded from further analyses.

Mathematical achievement tests

While the video coding and rating described above is an exclusive part of the present study, several tests that assessed students' mathematical achievement at different times during the study (see Table 2) have been borrowed from the study design and data developed by Klieme et al. (2006, 2009). In the beginning of the school year the students were given the initial test. The pretest was administered immediately before the videotaped three-lesson unit, the posttest immediately after this video unit. After the whole teaching unit on the Pythagorean Theorem (4 weeks to 5 weeks), the follow-up test was presented. At the end of the school year the final test was given. While the initial and final tests covered general

Table 2 Scales of the mathematical achievement tests

Scale	Initial test	Pretest	Posttest	Follow-up test	Final test
1	General mathematical achievement 10 items rel.=.60 M=−0.06 SD=1.21	Prior Pythagoras-theorem-related knowledge 10 items rel.=.64 M=0.29 SD=1.31	Understanding of the Pythagoras-theorem 16 items rel.=.78 M=−0.07 SD=1.41		General mathematical achievement 18 items rel. =.72 M=−0.02 SD=1.09
2	Understanding of proofs 10 items rel.=.74 M=0.03 SD=1.40			Understanding of proofs 8 items rel.=.65 M=0.14 SD=1.27	

rel. = reliability (EAP/PV, comparable to Cronbach's α)

mathematical achievement using curriculum valid tasks from a broad range of content areas, pretest and posttest dealt with knowledge and skills related to the theorem of Pythagoras. In addition, the initial test and the follow-up test each included a measure for understanding of proofs (scale 2), adapted from Healy and Hoyles (1998). For each test the individual achievement scores were estimated using item response theory. Data from the achievement tests were analysed based on a one-parametric item response model (Rasch model) using ConQuest (Wu et al. 1997). Warm's estimates were used as individual achievement scores.

Data analyses

As not all observed lessons were exactly the same in length, the observed number for each kind of strategy was standardised to 45 min. For every teacher, the observed numbers of strategies were averaged over the three lessons.

To investigate the long-term development in mathematical achievement, effect indicators on the classroom level calculated by Klieme et al. (2009) have been used in the present study, indicating the performance in the posttest, follow-up test or final test, corrected by the performance in the corresponding scale of the initial test or pretest. A regression was run for each student outcome measure, using the respective assessment of prerequisites as the predictor, and residuals were aggregated on the class level. Individual background variables (track, gender, social background, cognitive ability) were taken into account when calculating the residuals, providing adjusted effect indicators.

Results

Overview of teachers' direct and indirect promotion of self-regulated learning

In order to examine if and how teachers promote self-regulated learning in their classrooms, we first ask how much strategy instruction they provide (research question 1). In particular, how many strategy instructions were coded per 45-minute lesson? Results reveal that strategy instruction does indeed take place in classrooms. On average, 25 (SD=7.87) strategy instructions were observed per 45-minute lesson. However, there was a wide variation among teachers, with an average number of 10 up to 40 strategy instructions per lesson. Thus, teachers actually spend some time of their instructional activity on strategy instruction.

But which specific strategies are instructed (research question 2)? As Table 3 shows, teachers mostly instruct cognitive strategies, especially elaboration and organisation, followed by motivational and metacognitive strategies. Again, for the most frequently instructed strategies (elaboration, organisation, resource management), teachers differ widely in how often they instruct these specific strategies.

Next, we look at the quality of the strategy instructions. Do teachers instruct strategies in an implicit or explicit way (research question 3)? In particular, what is the percentage of implicitly versus explicitly instructed strategies? The results reveal that teachers mostly instruct strategies in an implicit way. 85% of the total number of strategy instructions were implicit, whereas 15% were explicit. On average, teachers gave 21 (SD=5.87) implicit and 4 (SD=3.78) explicit strategy instructions during a 45-minute lesson.

Finally, we investigate the indirect promotion of self-regulated learning by looking at the arrangement of the learning environment (research question 4). In particular, what are the high-inferent ratings for cooperation, constructivism, self-direction, and transfer? Results indicate that supportive features of the learning environment are hardly identifiable. The average ratings per lesson (scale ranges from 1 *does not apply at all* to 4 *applies fully*) for cooperation (M=1.71, SD=0.57), constructivism (M=1.74, SD=0.20), self-direction (M=1.60, SD=0.48), and transfer (M=1.87, SD=0.59) were rather low. Thus, supportive features of the learning environment which foster self-regulated learning seem to be hardly realised in regular lessons.

Promotion of self-regulated learning and performance development

Overall, it is expected that teachers' direct and indirect promotion of self-regulated learning is positively related to students' gain in performance over time (hypothesis 1). First, the instruction of strategies is expected to be positively related to students' gain in mathematical achievement. In particular, the observed numbers of instructions of the different kinds of strategies as well as the total number of observed strategies should

Table 3 Mean number of strategy instructions per teacher during a 45-minute lesson

Strategy	*M*	*SD*	*Min*	*Max*
Cognitive				
Elaboration	7.88	3.06	3.43	14.73
Organisation	8.28	4.17	3.79	20.26
Problem solving	0.12	0.34	0.00	1.40
Metacognitive				
Planning and systematic activity	0.93	1.08	0.00	4.26
Monitoring and evaluation	1.64	1.05	0.00	3.49
Motivational				
Resource management	2.65	2.42	0.00	10.71
Causal attribution	0.13	0.29	0.00	1.20
Action control	0.05	0.13	0.00	0.39
Feedback	2.74	1.47	0.63	5.83

correlate positively with the gain in performance from tests prior to the videotaped lessons (initial test, pretest) to tests after the videotaped lessons (posttest, follow-up test, final test), that is, with the adjusted effect indicators. Strategies that were observed less than ten times during the 60 videos (problem solving, causal attribution, and action control) were excluded from these analyses. Indeed, we could find some positive relations between the instruction of strategies and students' gain in mathematical achievement (see Table 4). The number of instructed organisation strategies correlated significantly with the gain in proof understanding from the initial test to the follow-up test (r=.47, p=.02). Thus, students whose teachers instructed more organisation strategies during the videotaped lessons showed a higher increase in proof understanding at the end of the teaching unit. However, for the other kinds of strategies (elaboration, planning and systematic activity, monitoring and evaluation, resource management, and feedback) we could not find a significant correlation with the learning gain. Overall, the total number of observed strategy instructions showed positive but nonsignificant correlations with the gain in proof understanding over the teaching unit (r=.33, p=.08) and with the general achievement development over the school year (r=.21, p=.19).

Next, a supportive learning environment is expected to be positively related to students' gain in mathematical achievement. Particularly, the scores in the four rating scales should correlate positively with the gain in performance from tests prior to those after the videotaped lessons (i.e., with the adjusted effect indicators). Results reveal that some features of a supportive learning environment are positively related to students' gain in achievement (see Table 4). The ratings of the categories constructivism (r=.71, p<.01) and transfer (r=.56, p=.01) correlated significantly with the gain in performance from pretest to posttest. Students who learned in a more constructivist and transfer activating learning

Table 4 Correlations with long-term performance development (adjusted effect indicators)

	TP	PU	GA
Direct promotion: strategy instructions			
Elaboration	.10	.15	.08
Organisation	−.12	.47*	.05
Planning and systematic activity	.18	.19	.19
Monitoring and evaluation	−.09	−.06	.21
Resource management	−.06	−.10	.17
Feedback	.26	.23	.21
Total	.00	.33	.21
Explicit	.09	.52*	.22
Implicit	−.03	.17	.16
Indirect promotion: learning environment			
Cooperation	.12	−.02	.09
Constructivism	.71**	.49*	.13
Self-direction	−.07	−.12	.08
Transfer	.56**	.33	.05

TP development of achievement related to the theorem of Pythagoras over the video unit (test scores in the posttest corrected for scores in the pretest), *PU* proof understanding development over the teaching unit (test scores in the follow-up test corrected for initial test scale 2), *GA* general achievement development over the school year (test scores in the final test corrected for initial test scale 1)

**p<.01, one-tailed, *p<.05, one-tailed environment showed a higher increase in their understanding of the Pythagorean Theorem after the video unit. Additionally, the constructivism ratings were significantly correlated with the gain in proof understanding from the initial test to the follow-up test (r=.49, p=.02). Students who were taught in a more constructivist way showed a higher increase in proof understanding after the teaching unit. For the ratings in cooperation and self-direction there was no significant relation to performance development. In summary, there is evidence that some aspects of teachers' direct and indirect promotion of self-regulated learning are indeed positively related to students' gain in performance over time.

Explicit versus implicit strategy instruction and performance development

Finally, we expect the explicit strategy instruction to go along with an increase in performance over time, which is not expected for the implicit strategy instruction (hypothesis 2). In particular, the number of explicit strategy instructions should correlate significantly positive with the learning gain (adjusted effect indicators), whereas the number of implicit strategy instructions should not. As expected, results indicate that explicit strategy instruction is positively related to students' learning gain, whereas implicit instruction is not. As can be seen in Table 4, the number of explicit strategy instructions showed a significant positive correlation with the increase in proof understanding over the teaching unit (r=.52, p=.01). In contrast, the number of implicit strategy instructions was not significantly correlated with the learning gain in any of the performance measurements. Indeed, students whose teachers instructed a higher number of strategies in an explicit way showed a higher increased understanding of proofs after the teaching unit. On the contrary, students whose teachers instructed a higher number of strategies in an implicit way did not show an increased performance over time.

Discussion

How do teachers implement promotion of self-regulated learning in regular classrooms? We found that promotion of self-regulated learning occurs mainly by implicit instruction of strategies. Teachers differ highly in their amount of strategy teaching. Also, different kinds of strategies differ in the frequency they are instructed, with a main focus on cognitive strategies, especially elaboration and organisation. On the other hand, explicit strategy teaching is rare. Besides, teachers hardly create a learning environment that fosters self-regulated learning, although there is again a variation between teachers to some extent. The finding that explicit strategy teaching is rare corresponds to the results reported by Moely et al. (1992) and Hamman et al. (2000), who focused on teachers' explicit strategy instruction. They found that teachers spend only little time on strategy instruction. The same could be concluded from the present study when only looking at the explicit strategy instruction. However, when broadening the view and also considering the implicit strategy instruction, it becomes evident that teachers are more busy in strategy instruction than supposed up to now.

What is the relation between teachers' promotion of self-regulated learning and students' gain in performance over time? Results suggest that teaching certain kinds of strategies (organisation) as well as arranging a supportive learning environment (constructivism, transfer) is strongly related to students' improvement in mathematical knowledge and skills. These findings are consistent with our hypotheses. Particularly, with regard to the results of Hamman et al. (2000), which reveal that teachers' coaching of learning positively relates to students' use of strategies, and Zimmerman's (1990) conclusion that self-regulated learning is important for academic achievement, our results seem reasonable. Our longitudinal data indicate that students' learning outcomes can be seen as a consequence rather than a precondition of teachers' promotion of self-regulated learning.

However, the positive relationship between promotion of self-regulation and gain in performance does not apply for every kind of strategy and every feature of the learning environment. For most kinds of strategies (elaboration, planning and systematic activity, monitoring and evaluation, resource management, feedback) as well as for some features of the learning environment (cooperation, self-direction) we could not show any relationship to students' gain in performance. A problem with some of these strategies might be that they were rarely observed. The implicit assumption that underlies the hypotheses is that the teachers' promotion of self-regulated learning results in an enhancement of students' self-regulated learning which in turn leads to increased cognitive outcomes. If the lacking effects of rarely observed strategy instructions are interpreted against this background, it seems possible that students need more input on these strategies to apply them themselves and thus to profit from them. Within this study, however, it is not possible to verify the assumption of the mediating role of students' application of self-regulated learning in the relationship between teachers' promotion and gains in student performance. Hence, future research should focus on this mediation hypothesis and additionally assess students' self-regulated learning behaviour.

Which role does implicit versus explicit strategy instruction play? We found that explicit strategy instruction is associated with a gain in performance, whereas implicit instruction is not. This is consistent with the findings reported by Brown et al. (1981), who concluded that only explicit strategy teaching results in maintenance of a particular learning activity and its transfer to appropriate settings. It is assumable that exactly this maintenance and transfer is needed to ensure an impact of strategy instruction on student performance.

In conclusion, students seem to benefit most from explicit strategy instruction. However, it has to be noted that we only found a relation of explicit strategy instruction with the gain in understanding of proofs, but not with the gain in knowledge on the Pythagorean Theorem. Thus, this kind of instruction seems to be relevant for reflexive and challenging aspects of mathematical reasoning such as understanding mathematical proofs, but not for traditional achievement goals such as acquiring knowledge.

Also, this kind of informed training tends to be very rare in classrooms. These results reveal a discrepancy between the usefulness of explicit strategy instruction and its rare occurrence in classrooms. Possibly, teachers hold the assumption that implicit strategy instruction is sufficient to provide students with information about the use of self-regulated learning strategies. This assumption may be based on the belief that teachers' modelling of a strategic behaviour will lead students to draw inferences for their own learning and to adopt this behaviour. However, it seems more likely that teachers are not even aware of their implicit strategy teaching and do not consciously know that they are implicitly providing their students with information on self-regulated learning strategies. To clarify teachers' underlying assumptions on self-regulated learning and their intentions for their instructional behaviour, future research could enrich video studies in classrooms with interviews in which teachers comment on their instructional activities and report their underlying beliefs.

Another interesting question, which was not examined in this study, is whether there are differential effects of teachers' promotion of self-regulated learning on student performance in high-achieving versus low-achieving classes. Further analyses will deal with the issue whether some classes benefit more from this kind of instruction than others.

A limitation of the present study is certainly the relatively small sample of classes which is not representative for German schools. The small sample size also explains why we did not implement multilevel analyses, although the data are hierarchical in structure. Usually a sample of 30 groups is considered as a precondition for applying multilevel modelling (Maas and Hox 2005). The strengths of the study include the longitudinal performance data, which allowed us to examine relations with the gain in performance over time rather than with the mere posttest data. That way the study could provide evidence that students' performance is indeed a consequence of teachers' promotion of self-regulated learning.

In the context of the project "Quality of Instruction, Learning, and Mathematical Understanding" teachers' promotion of self-regulated learning can be seen as an alternative perspective on the quality of learning environments. Within this project, various publications have dealt with different aspects of mathematics instruction and their impact on students' cognitive outcomes (e.g. Lipowsky et al. 2009; Hugener et al. 2009; Rakoczy et al. 2008). Most of these studies were based on the three-dimensional model of instructional quality (Klieme et al. 2009) which distinguishes the three dimensions *cognitive activation*, *classroom management*, and *supportive climate*. For example, Lipowsky et al. (2009) found two dimensions of instructional quality, that is, cognitive activation and classroom management, to have positive effects on mathematical achievement. Within the three-dimensional model of instructional quality, the constructivism and situatedness aspects of the CLIA-model would be covered as elements of cognitive activation, while cooperation and self-direction are linked to supportive climate. In the video ratings and analyses presented by Lipowsky et al. (2009) only cognitive activation and classroom management explained students' performance gain, supportive climate did not. Our present results are in line with these findings. The theoretical and empirical framework applied here suggests that some effects of instructional quality discussed in previous publications are in fact based on the promotion of self-regulated learning. The findings emphasise the complex nature of instruction and learning environments, and contribute to the understanding of the multiple factors that influence student performance.

The given results do not just broaden our theoretical knowledge of the relationship between the promotion of self-regulated learning and student performance. They also have an important practical meaning. We identified a major need for more explicit strategy promotion in schools as well as for attempts to create a learning environment that supports the enhancement of self-regulated learning. To reach this aim, knowledge and skills how to foster self-regulated learning during regular lessons should be an inherent part of teacher education and training. Teachers need to know the categories implicit and explicit instruction and must be able to distinguish them. Especially, teachers and prospective teachers should be informed about the importance of explicit strategy instruction and should have the opportunity to practise this kind of self-regulated learning promotion in classroom settings.

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