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# Training of self-regulatory and problem-solving competence

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**Abstract**

The effects of different trainings on the acquisition of mathematical problem-solving and self-regulation were studied with 249 eighth-graders. The study was conducted with 4 different trainings in German grammar schools. Each training consisted of six 90-min sessions on a weekly basis. The results confirm that it is possible to improve mathematical problem-solving and self-regulation competence through this kind of short training. The evaluation shows that the combination of self-regulatory and problem-solving strategies leads to the best effects for the improvement of self-regulatory competences. Furthermore, it is possible to improve problem-solving by practicing problem-solving and self-regulatory strategies or a combination of both.


This article of the special issue investigates the possibility to foster self-regulatory competence relevant for school-based learning and academic achievement. It concentrates on the training of self-regulatory competence at eighth-grade students, which includes the training of motivational strategies as one part of the overall competence of self-regulation.

For our study we refer to the international comparative studies TIMSS (Baumert et al., 1997) and PISA (Baumert et al., 2001) which showed a relatively low

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performance level of German students, particularly with respect to self-regulation and mathematical problem-solving. The results of these studies revealed that many German students are able to solve only those mathematical tasks which require a high amount of automated computational skills.

The main goal of the study described in this article is to enhance students' self-regulation, as well as their problem-solving competence in mathematical word problems. For this we use different kinds of training, which consist of various combinations of self-regulation and problem-solving components. Our study is driven by two specific goals.

First, we want to test the effectiveness of a 6-week training period for eighth-grade students to improve their learning competencies and to lessen the deficits shown in TIMSS and PISA. These studies showed a relatively low performance level of German students, particularly with respect to self-regulation and mathematical problem-solving. Second, we want to know if a combined training of self-regulation and problem-solving components would lead to better results than teaching only one of these components.

## 1. Theory of self-regulation and problem-solving

Our training concepts are based on ideas from self-regulation theory as well as on theories of problem-solving. Thus, we describe these two theoretical frameworks and try an integration at the end of the theory section. Because our assumptions regarding self-regulation theory contain some of our own developments, our model of self-regulation is introduced first. In our theoretical assumptions, we rely on our model of self-regulated learning. Because daily learning must be regarded as a cumulative process our framework is entirely a process model.

### *1.1. A process model of learning*

We define the learning process as a sequence of learning states observed over time. Learning states can only be operationalized by individual state measures of behavior or cognition. To gain insight into the process of learning, however, multiple consecutive assessments have to be conducted. In our study, the learning process consists of a sequence of daily learning episodes. Each learning episode can be further divided into subphases, which will be described later.

#### *1.1.1. Zimmerman's model of self-regulation*

Zimmerman (1998, 2000) has developed a model of self-regulation which relates to the social-cognitive perspective formulated by Bandura (1986). According to Zimmerman (2000), "self-regulation refers to self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals." (p. 14). It is important to know that Zimmerman explicitly regards this definition as a process definition. Schunk and Zimmerman (1998), Zimmerman, Bonner, and Kovach (1996) and Zimmerman (2000) derived a phasic model of self-regulation that includes forethought, performance and volitional control, and self-reflective processes. The forethought phase refers to the processes that precede action. The performance phase includes processes which relate to action and to the application of volitional strategies. Self-reflection occurs after performance. Self-reflection, in turn, influence the next self-regulatory cycle. As labels for these phases of self-regulated learning, we prefer the widely-used terms of Heckhausen and Kuhl (1985): preaction phase, action phase and postaction phase. Fig. 1 displays our process model (see Schmitz, 2001).

### *1.1.2. Preaction phase*

In our process model of learning, the task is at the beginning of the self-regulation process. With respect to the task the students set *goals*. The environment is included at the beginning of the learning process as the influence of the situation under starting conditions. Whereas the Zimmerman model focuses on the influence of self-motivational beliefs which can be assumed to be highly stable, we prefer to concentrate on state aspects of *motivation*. 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).

As another key concept, our model includes *self-efficacy*. It has often been shown that self-efficacy has positive effects on important self-regulatory parameters such as

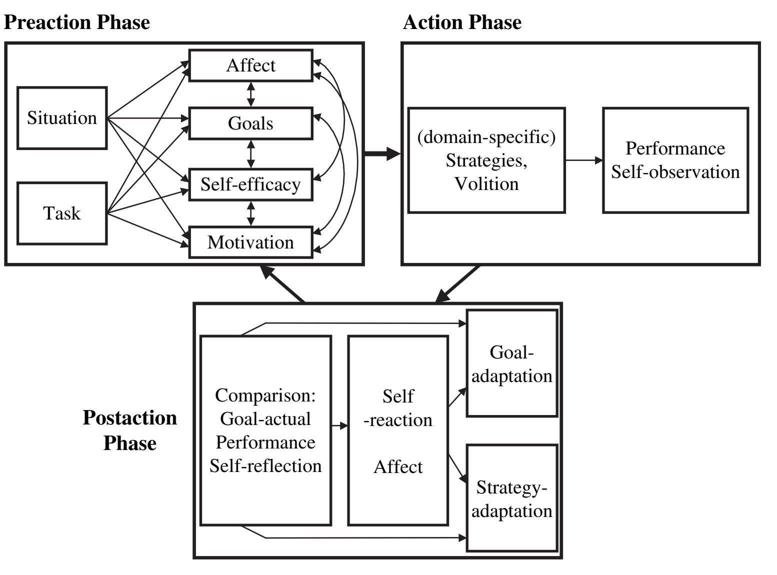


Fig. 1. Process model of self-regulation.

effort, persistence, and achievement (Schunk & Ertmer, 1999). Therefore, in line with Schmitz and Skinner (1993) we apply a state self-efficacy concept.

#### 1.1.3. Action phase

*Learning strategies* are important during the action phase. Following general lines of research regarding learning strategies, for example, the MSLQ (Pintrich, Smith, Garcia, & McKeachie, 1991), we differentiate between three kinds of learning strategies: cognitive, metacognitive and resource management strategies. We also explicitly refer to *volitional strategies* for learning (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). Usually, the main aim of learning is to achieve desired outcomes, e.g. good performance. Finally, as in the Zimmerman model, self-observation is located in the performance phase. In our study, we encourage self-observation by the use of standardized learning diaries.

#### 1.1.4. Postaction phase

Following Bandura (1986) and Zimmerman (2000) the postaction phase mainly contains *self-reflections* that can be distinguished between self-judgment and self-reactions. Self-judgment includes self-evaluation of one’s performance as well as causal attributions. Self-evaluation is based on comparing the observed behavior with a standard or goal. The result of self-judgment can be self-satisfaction or dissatisfaction and is related to a postaction positive or negative affect. The final part of the self-regulatory cycle is self-reaction. In our adaptation of the Zimmerman model (see Fig. 1), we are focusing on intentions which are formed with regard to learning behaviors considered for the next day. We incorporate the differentiation between the adaptation of goals and/or strategies.

As can be seen in Fig. 1, there is a time order of the phases. We assume that each phase influences the next. In addition, a basic assumption is that one learning episode influences consecutive learning episodes.

### 1.2. Theory of problem-solving

For our concept of the problem-solving training we focus on heuristic strategies for mathematical problem-solving which can be seen to be a part of mathematical problem-solving. We refer to Lompscher’s concept of problem-solving theory (1985) who postulates a theory of thinking (mental activity), which allows implications for problem-solving.

Bruder (2000) specified and transferred this theory to a mathematical context. She describes *reduction* (simplification of the problem situation), *reversibility* (reversion of ways of thoughts and problem-solving steps), *attention to aspects* (pay attention to a couple of aspects at the same time/recognition of the dependence of things and its targeted variation) and *change of aspect* (change of assumptions and criteria, restructuring of a fact) as aspects of mental flexibility transmitted to the mathematical context. According to Bruder (1993), a high mathematical problem-solving competence can be achieved by a greater method consciousness and the acquisition of different heuristic strategies, which can be regarded as "active principles of heuristic education" (Bruder & Stein, 1999, S.13, translated by the author) and basic characteristics of mental flexibility. This theory proposes that problem-solving can be taught by relying on a class of heuristics. For our purpose of training which focuses on the instruction of heuristic strategies to solve mathematical word problems for eighth-grade students, the following heuristic strategies were applied: (a) "working for- and backwards" is important to improve one's ability to use reverse problem-solving steps (reversibility) and to change the aspects of a problem-solving task (typical questions: what is sought? what is given?). These strategies are trained with the help of problems like this: "Two cubes of different sizes (length of edges $x$ and $y$) are put together to make one larger cube. How big is the surface area of the new cube?"; (b) the "principle of invariance" is important to improve one's ability to pay attention to a special aspect (the invariance) of the problem-solving task (typical question: what remains constant?). The principles are trained, for example, by problems which require the completion of predetermined numerical orders; (c) tables, figures, and equations are important to improve one's ability to simplify the problem-solving task (reduction). These implements are useful for every problem-solving task given in the training session.

### 1.3. Integration of problem-solving and self-regulation

We integrate heuristic strategies for solving mathematical word problems in the process model of self-regulation as a domain-specific learning strategy belonging to the action phase, which can be trained in addition to general learning strategies. With respect to the integration of self-regulation and problem-solving, our assumptions are in line with De Corte's framework for learning mathematics from instruction (De Corte, 1990; De Corte, Verschaffel, & Op't Eynde, 2000). In his theory of expertise, which is part of this framework, they postulate that both problem-solving and self-regulation competence are essential to achieve expert ability in mathematical problem-solving. But our concept differs from theirs concerning the importance of self-regulation within the integration of problem-solving and self-regulation. Whereas De Corte's framework assumes self-regulation to be one part of mathematical expertise, we assume heuristic strategies to be one domain-specific strategy of the action phase of the self-regulation process. In this respect our assumption is more general, because it allows the transfer to other domain-specific contents (e.g., text processing) besides mathematical problem-solving, if corresponding domain-specific strategies are integrated.

### 1.4. Training

Interventions regarding self-regulation are described very well in Schunk and Ertmer (2000). In their summary for future research they strongly recommend (a) not only relying on modeling but also giving students greater responsibility for their own learning, (b) that self-regulation should be taught in content areas (c) viewing the issue of transfer as relevant and (d) that greater research attention be given to self-reflective practice. We try to incorporate all these recommendations: (a) our training attempts to enhance the application of training content in real homework situations. Therefore, students have to take responsibility for their learning. (b) As training content for self-regulation, we investigate mathematical problem-solving. We compare pure training in self-regulation with pure training in problem-solving, and with a combination of problem-solving and self-regulation. (c) We explicitly deal with the question of transfer. Because there are many different methods of transfer, we define which kind of transfer we want to support, namely the transfer of the training content presented in extracurricular lessons to application in homework situations. (d) Self-reflective practice is supported by our self-monitoring procedure. We want to enhance self-monitoring by means of standardized diaries. These diaries contain questions related to homework tasks. The kind of questions in the diary is related to the components of our self-regulation model.

### *1.5. Aims*

Based on the theoretical assumptions of self-regulation and problem-solving, different training forms were developed. The following assumptions were made: for the problem-solving training we expected strong effects for the problem-solving measure and effects only for such self-regulation variables which are connected with problem-solving (e.g., self-reflection/handling errors). For the self-regulation training we expected effects for important self-regulation variables: goals, motivation, volition, self-efficacy, learning strategies, and self-reflection/handling errors. Under the condition of the self-regulation training we expected little effects for the problem-solving measure, because of the transfer which has to be made from the more general self-regulation strategies to mathematical problem-solving (in our case the application of heuristic strategies for word problems). For the combined training we expected effects for the self-regulation variables (goals, motivation, volition, self-efficacy, learning strategies, and self-reflection/handling errors), as well as for the variable of the problem-solving test.

## 2. Method

### *2.1. Participants*

Two-hundred and forty-nine eighth-grade students (106 boys and 143 girls) ages 13 (67%), 14 (31%) and 15 (2%) from three German grammar schools (Gymnasium) participated in this study. Because of nine incomplete or incorrect filled out questionnaires only 240 data were integrated in the analyses. After informing the headmaster and the class teachers about the project, the parents of all eighth-grade students were invited to a parent–teacher conference. At this meeting the aims of the study were presented. To participate in our study the students needed a parent's written consent. For all students, participation in the training was voluntary.

### 2.2. Design

The participating students were randomly assigned to one of four experimental conditions. There were between 58 and 67 students assigned to each condition. The experimental conditions were based on a training factor with the following conditions: (a) self-regulation, (b) combined training (self-regulation and mathematical problem-solving), (c) problem-solving training, (d) control group (no training).

### 2.3. Procedure

A pretest was conducted consisting of a self-regulatory questionnaire and a problem-solving test. A similar problem-solving test and the same self-regulation questionnaire were conducted one week and then again four weeks after the intervention. The training program started shortly after the pretest and took place in six 90-min training sessions after school in the afternoon on a weekly basis. To ensure good training conditions the training was presented in subgroups of no more than 19 students (the control groups had up to 25 students, which were trained after the intervention). There were four subgroups per training condition. Two subgroups per training condition answered questions in a diary every day before and after their homework for six weeks. The learning diary should invite the students to observe and reflect upon their learning behavior outside school. We expected this self-reflection to support the training progress.

In our study three types of trainings are realized. In the self-regulation training only self-regulatory components (goal setting, motivation, volitional strategies, self-efficacy, and self-reflection) are included which are applicable for learning in general as well as for specific mathematical problem-solving tasks. The problem-solving training aims to instruct heuristic strategies (working for- and backwards, the principle of invariance, table, figure, and equation) for mathematical word problems. In this article we focus on the description of the combined training program which includes both heuristic strategies and self-regulatory components. Table 1 shows the contents of this program.

### 2.4. Training

In the combined training, every training session (with the exception of the first one) started with a written summary of the training content of the last session. At the end of each training session the students were given the possibility to give feedback on the trainer and the training content. At the end of all the training sessions (with the exception of last one) homework was given to the students.

The first training session started with an explanation of the model of the combined training. After that the students were instructed to consider their use of a strategy by solving a mathematical task which allowed different solving strategies (“*water-transfer-problem*” [Wasser-Umfüll-Problem]). Subsequently, the heuristic method “working forwards” (typical question: what is given?) was explained and

Table 1
Content of the combined training

| Unit | Problem-solving | Self-regulation |
|---|---|---|
| 1st unit | Working forwards | Strategy reflection, attention |
| 2nd unit | Tables, figures, equation<br>Working for- and backwards | Goals |
| 3rd unit | Working for- and backwards<br>Principle of invariance<br>Exercise | Volitional strategies |
| 4th unit | Tables, figures, equation<br>Exercise | Goals, self-reflection motivation |
| 5th unit | Principle of invariance<br>Exercise phase | Volitional strategies |
| 6th unit | Integration | Self-reflection/handling errors |

implemented based on two examples. The first session ended with a general reflection of problem-solving strategy use and how to regulate attention.

The main topics of the second unit were the heuristic methods "working for- and backwards" and the self-regulatory strategy "goal setting". In this training session the students had to solve a mathematical word problem. The solution required a combination of working for- and backwards (typical question for working backwards: what is sought?). With the help of this word problem, the students became familiarized with methods which support the problem-solving process (heuristical tools: table, equation, figure). In the second part of this training session, the students learned how to set goals and were taught about the importance of commitment to those goals.

The third training session focused on the self-regulatory strategies "goal setting" and "strategy use", as well as on the repetition and practise of the heuristic methods "working for- and backwards". In this unit the principle of invariance (typical question: what remains constant?) was introduced. At the end of this lesson the students had to develop different volitional strategies using teamwork. To support this process, the students could refer to different descriptions of volitional problems (distraction, procrastination, motivational problems, concentration problems) and how to handle them.

To support the impact of the training, the fourth training session was used to summarize the previous training content. In addition, the self-regulatory component "motivation" was focused on in more depth.

In the fourth training unit, as well as in the first part of the fifth training session, the students had to repeat and practise the training content. The heuristic method "principle of invariance" was worked on. In the second part of the fifth training session, the students were taught to use strategies to handle interfering/distracting thoughts during the solving of mathematical problems. Within this context the two strategies "stop negative thoughts" and "reformulation of negative thoughts" were introduced and practised.

The last training session started with a recap of the model of the training. After that, the topic "self-reflection/handling errors" was introduced and practiced by analyzing errors. To integrate the different training components, the students were taught how to build a semantic network of all the strategies they had learned.

## 2.5. Instruments

### 2.5.1. Measurements of the pretest–post-test evaluation

For pretest–post-test evaluation, a problem-solving test and a self-regulation questionnaire were conducted before and after the intervention.

*2.5.1.1. Self-regulation questionnaire.* The topics of the self-regulation questionnaire were developed with respect to the components of the process model of self-regulation. The students were given statements to the topics of self-regulation. Responses were coded on a scale, with scores ranging from 1 to 4 (1 = I don't agree at all; 2 = I don't agree; 3 = I agree; 4 = I agree completely). The main topics of the self-regulation questionnaire are "goals", "motivation/volition", "learning strategies", "self-reflection/handling errors" and "self-efficacy". These scales are aggregated in an overall scale "self-regulation". Some of the subscales of these topics have been taken from established instruments. Selected scales have been newly developed. Reliability (Cronbach's alpha) was assessed for all scales. Only those scales which had an $\alpha > 0.6$ were included in the analyses. Table 2 gives an overview of the scales with their references and reliabilities.

*2.5.1.2. Problem-solving test.* The problem-solving test was conducted to assess the students' mathematical problem-solving competence. The two parallel tests (before and after the intervention) consist of 17 problem-solving tasks representing the subject areas of basic mathematics and heuristic strategies (working for- and backwards, principle of invariance, tables, figures, and equation). For example, to test the application of the principle of invariance, the following problem was presented: "Anne is 4 years younger than Eva. In 6 years they are together 34 years old. How old are the two girls today?" For each test, an overall measure of reliability was computed ($\alpha = 0.75$).

### 2.5.2. Measurement of the process evaluation

The process evaluation of the study was based on the *learning diaries*. The scales of this process measurement have been chosen in reference to the process model of self-regulation: self-regulation, effect before learning, motivation, goals, planning, volition, metacognitive learning strategies, time for homework, individual benchmarking, attribution, problem-solving strategies. Reliability (Cronbach's alpha) was assessed for all scales. Only the scales which had an $\alpha > 0.6$ were included in the analysis. This article focuses on the description of the results of the pretest–post-test evaluation. For this reason we omit the detailed description of the scales of the learning diary (measurement of the process evaluation).

Table 2
Scales of the self-regulation questionnaire

| Scales | Reference | Example (translated) | Reliability |
|---|---|---|---|
| Goals | Brandstädter and Renner (1988); SSI-K (Kuhl & Fuhrmann, 1999); self-provided | When I deal with new types of problems I often find ways and means for solving them. | 0.84 |
| Motivation/volition | Schiefele and Moschner (1997); LIST (Wild & Schiefele, 1994); Wild (2000); VCQ (Kuhl & Fuhrmann, 1998); Prenzel (2000); Baumert et al. (1997); self-provided | If I have to deal with unpleasant exercises I get it quickly behind me. I try to make myself deal with homework even though I do not like to do it. | 0.91 |
| Learning strategies | LIST (Wild & Schiefele, 1994); self-provided | I think up concrete examples for special learning content. | 0.90 |
| Self-reflection: handling errors | Self-provided | Mistakes show me what I can do in a different way. | 0.71 |
| Self-efficacy | WIRKALL-R (Schwarzer & Jerusalem, 1981) | If I try hard to solve difficult problems I am always successful. | 0.86 |
| Overall scale self-regulation | Aggregation of the above scales added with self-regulatory strategies (Schwarzer, 1999), self-reflection (self-provided), handling mistake (self-provided) | | 0.88 |

## 3. Results

Because there are no significant pretest differences the dependent measures were analyzed using a 2 (before/after the intervention) × 4 (training conditions) factorial univariate analysis of variance with time as repeated measurement factor. For pairwise comparisons we use LSD (least significant difference). Table 3 gives an overview of the results for the number of interaction time × training for the self-regulatory scales and the problem-solving measure. In our description we refer to significant (5%-level) and tendential (10%-level) results. Means and standard deviations for these interactions are shown in Table 4.

Table 3 shows for the measures of the self-regulation questionnaire that there was a tendential interaction time × training for the overall scale self-regulation ($p = 0.09$), as well as for "motivation/volition" ($p = 0.01$; significant), "self-efficacy" ($p = 0.06$; tendency), and "self-reflection/handling errors" ($p = 0.02$; significant). Fig. 2 depicts the result for the overall scale self-regulation.

Fig. 2 shows an increase among the students of the combined training groups. In contrast, the improvements of the other groups were minimal. LSD showed

Table 3
Results of the self-regulation questionnaire and the problem-solving test

| Independent variable | Dependent variables | df | *F* | *d* |
|---|---|---|---|---|
| Time × training | Measure 1: overall scale self-regulation | 196 | 2.23# | 0.15 |
| | Measure 2: goals | 196 | 0.99 | 0.12 |
| | Measure 3: motivation/volition | 196 | 4.16** | 0.13 |
| | Measure 4: learning strategies | 196 | 0.51 | 0.07 |
| | Measure 5: self-efficacy | 195 | 2.52# | 0.23 |
| | Measure 6: self-reflection/handling errors | 196 | 3.32** | 0.18 |
| | Measure 7: problem-solving test | 233 | 3.94* | 0.37 |

*Note:* $^{\#}p \leq 0.10$; $^{*}p \leq 0.05$; $^{**}p \leq 0.01$.

a significant difference between the combined training and every other condition (with the least significant difference = 0.13) and no differences between the other training conditions. As Table 3 shows, there are significant effects for "motivation/volition", "self-reflection/handling errors", and a tendency for "self-efficacy". For all these variables, there was a significant increase among the students of the combined training group (least significant difference between the combined training and the other training conditions for the scale "motivation/volition" = 0.17; and between the combined training and the other training conditions for the scale "self-reflection/handling errors" = 0.21). In contrast, the improvements of the other groups for these scales were minimal with the exception of the self-regulation

Table 4
Dependent measure means and standard deviations

| Time × training | | Combined training | | Self-regulation training | | Problem-solving training | | Control group | |
|---|---|---|---|---|---|---|---|---|---|
| | | *M* | SD | *M* | SD | *M* | SD | *M* | SD |
| Measure 1 | Pretest | 2.90 | 0.36 | 2.98 | 0.41 | 2.98 | 0.45 | 3.00 | 0.40 |
| | Post-test | 3.03 | 0.43 | 3.01 | 0.51 | 2.99 | 0.46 | 2.99 | 0.45 |
| Measure 2 | Pretest | 2.86 | 0.53 | 2.91 | 0.56 | 3.02 | 0.51 | 2.92 | 0.57 |
| | Post-test | 2.91 | 0.60 | 2.89 | 0.64 | 2.94 | 0.61 | 2.97 | 0.56 |
| Measure 3 | Pretest | 2.78 | 0.40 | 2.85 | 0.45 | 2.85 | 0.42 | 2.88 | 0.41 |
| | Post-test | 2.94 | 0.45 | 2.84 | 0.47 | 2.82 | 0.42 | 2.86 | 0.45 |
| Measure 4 | Pretest | 2.81 | 0.44 | 2.91 | 0.42 | 2.90 | 0.46 | 2.88 | 0.47 |
| | Post-test | 2.98 | 0.44 | 2.95 | 0.56 | 2.95 | 0.48 | 2.92 | 0.46 |
| Measure 5 | Pretest | 2.67 | 0.43 | 2.70 | 0.58 | 2.78 | 0.48 | 2.79 | 0.47 |
| | Post-test | 2.80 | 0.50 | 2.81 | 0.52 | 2.76 | 0.57 | 2.76 | 0.53 |
| Measure 6 | Pretest | 2.99 | 0.56 | 3.19 | 0.49 | 3.06 | 0.60 | 3.21 | 0.47 |
| | Post-test | 3.25 | 0.46 | 3.14 | 0.61 | 3.10 | 0.60 | 3.20 | 0.47 |
| Measure 7 | Pretest | 14.41 | 4.33 | 14.80 | 4.56 | 14.37 | 4.48 | 15.69 | 5.51 |
| | Post-test | 15.08 | 5.49 | 16.06 | 5.68 | 16.40 | 5.83 | 15.04 | 5.82 |

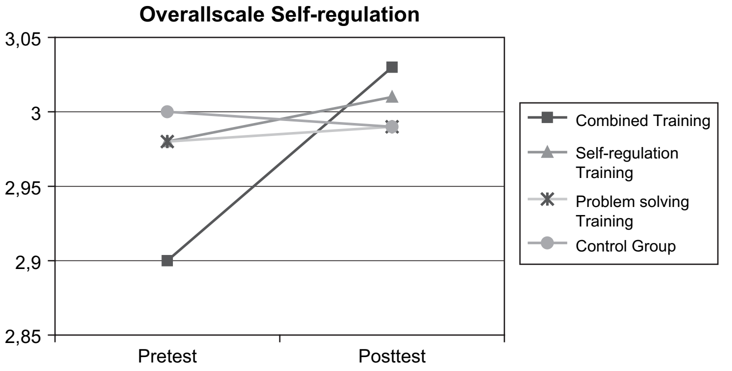


Fig. 2. Significant interaction time × training: overall-scale self-regulation.

training for the scale "self-efficacy". For this scale, both self-regulation training and combined training led to an increase.

The analysis of the problem-solving test showed a significant interaction time × training for the overall measure (see Table 3). As expected, the students of the problem-solving training group surpassed the problem-solving competence of all other training groups after the intervention (LSD revealed a significant difference between the training groups and control groups with the least significant difference = 1.91). Unexpectedly, the training of self-regulatory strategies improved problem-solving skills, too. There are no significant differences between the training groups. Fig. 3 shows the interaction time × training for the problem-solving measure.

Fig. 3 shows a significant interaction time × training for the problem-solving measure which emerges from the training groups compared to the control group. Possible explanations for this effect will be analyzed in the discussion section.

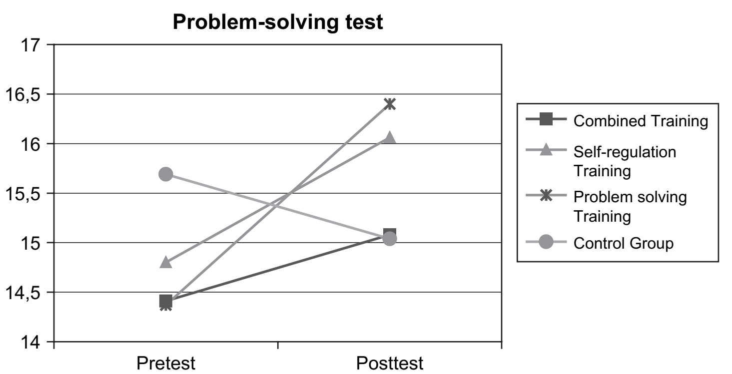


Fig. 3. Significant interaction time × training: problem-solving test.

Further analyses of the measures of self-regulation and problem-solving four weeks after the end of the interventions show a stability of the effects: The analyses of variance concerning post-test 1 and post-test 2 showed no significant differences for the significant dependent variables of the comparison between pretest and post-test 1.

In addition to the pretest–post-test comparison, a process evaluation based on the diary data has been made. For this, trend analyses were computed. Due to the limited amount of space in this article, we omit the detailed presentation of these analyses. Instead, an example of these kinds of results is provided. Fig. 4 shows the tendential linear trend for the variable "goals" in the combined trainings ($b_o = 3.31$, $b_1 = 0.003$).

Fig. 4 shows that, in the course of the training sessions, the students' ability to set goals increased steadily. It can be seen that the process evaluation identifies effects that the pretest–post-test comparison does not show.

## 4. Discussion

The results of the pretest–post-test comparison of the different training types revealed that a combined training of self-regulatory and problem-solving strategies is effective for enhancing self-regulatory competences. Further on, problem-solving competences can be improved by all three training types. The significant interaction time × training showed that students of the problem-solving training group

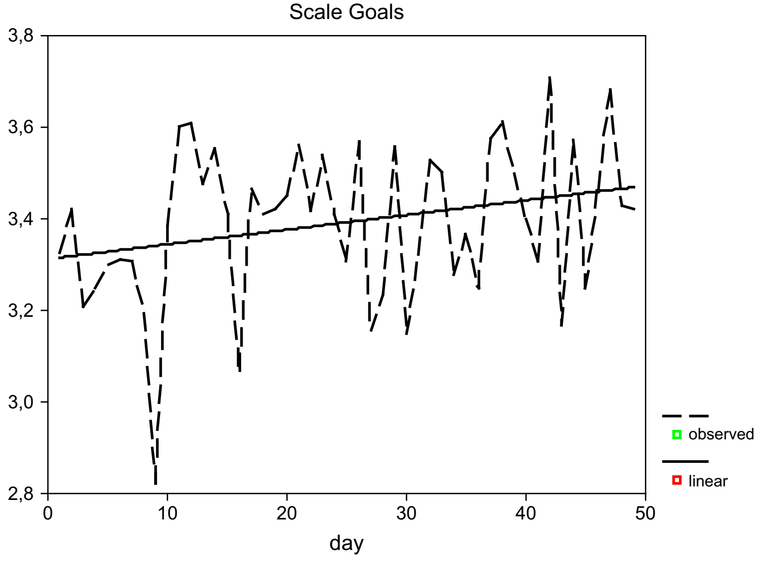


Fig. 4. Linear trend for the scale "goals" (combined training).

improved their skills most, but there are no significant differences between the three training groups.

The results for the self-regulation variables show that it seems to be more difficult to train self-regulatory compared to problem-solving competencies. Only the combined training leads to an increase, and the effect size ($d$) of the interaction time $\times$ training for the overall scale self-regulation is, compared to the problem-solving measure, small. The noticeable outcome of the combined training for the self-regulation measures can be explained by synergy effects of self-regulation strategies and problem-solving components. Thus, the ability to handle errors or to motivate oneself is related to mathematical problem-solving. If these strategies are used in the context of mathematical problems, their success in problem-solving may lead to the increased application of self-regulation strategies. The results show as well that it is possible to improve self-efficacy either by a combined training or by a self-regulation training. Maybe self-efficacy is more independent from the mathematical context. There are some open questions regarding the non-significant results for the scales "goals" and "learning strategies". Further research should investigate the requirements and possibilities to train these self-regulation strategies. The effect sizes ($d$) show that for the self-regulation measures the effects of the intervention are very small. Therefore, further research should investigate the improvement of the effectiveness of the training concerning the improvement of self-regulative competence.

As expected, the training of problem-solving strategies (problem-solving training and combined training) leads to an improved problem-solving competence. Unexpected was the significant effect of the self-regulation training on the problem-solving measure. This unexpected result can be explained by the assumption that in our model self-regulation is a domain non-specific competence which is able to facilitate learning processes independent of the learning content (but refer to Boekaerts (1997) for a converse concept). The ability to learn self-regulatorily influences the acquisition of new learning material. In our study the components of the self-regulation process (goals, motivation, volition, self-efficacy, learning strategies and monitoring) influence the learning of mathematical problem-solving strategies. In our analyses we only examine an overall measure for problem-solving competence. Maybe differentiated analyses could deliver more insight which trained problem-solving strategies are important to improve mathematical problem-solving competence.

The results of our study lead us to the conclusion that it is possible to enhance self-regulatory competence and problem-solving behavior by the training of self-regulatory components. For the self-regulatory competences, the improvement can be optimized by the combination of self-regulation and problem-solving strategies (combined training). For the training of problem-solving skills this effect was not explicit, because all types of training led to significant effects regarding the problem-solving measure. Thus, further research should investigate the development of combined training programs which focus on the improvement of self-regulatory, as well as problem-solving competences.

We realized our study with eighth graders who attend grammar schools (Gymnasium). In this school type the students have higher learning competences than students at school at a lower level (Realschule, Hauptschule). Consequently, we examined a very special sample. Further investigations should expand the training concept for students with lower learning competences.

In contrast to other training programs which focus on the implementation of selected components of self-regulation (for an overview see e.g. Schunk & Ertmer, 2000; for monitoring and goals see e.g. Schunk, 1983 or Schunk & Schwartz, 1993; for reattribution see e.g. Dweck, 1975), our training (the self-regulation training and the combined training) implemented the whole self-regulation process. Even though there are training methods which combine cognitive and motivational aspects (see for instance Rheinberg & Fries, 1998), the combination of mathematical problem-solving strategies (as part of the cognitive learning strategies) and self-regulation seems to be beneficial.

Our results entail implications for school-based learning and behavior. We showed that a relatively short training of a combination of mathematical problem-solving contents and self-regulatory strategies leads to an increase of self-regulated and motivated learning and in addition improves mathematical problem-solving.

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