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A plea for self-regulated learning as a process: Modelling, measuring and intervening

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Abstract

Self-regulated learning is regarded as a necessary prerequisite for life-long learning. Some of the existing models consider self-regulated learning as a process (e.g. Zimmerman, 2000; Schmitz & Wiese, 2006). Taking a process perspective on self-regulated learning gives us new insights in self-regulation processes, which allows using suitable methods for measuring self-regulation processes and allows evaluating the effectiveness of training programs more precisely. In this article, we want to advocate the process view on self-regulated learning by explaining its possibilities and advantages. We present a process model, show methods of measuring processes and ways to analyze processes. Specially, we present empirical examples for studies performing a process approach which try to enhance self-regulated learning. Finally, we offer practical advice on developing effective interventions and instruments from a process perspective.

Key words: self-regulated learning; process; intervention; diary; ARIMA; time-series analysis

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1. Introduction

The competence of self-regulated learning is regarded as a necessary prerequisite for lifelong learning (Wirth & Leutner, 2008). It is important throughout the whole lifespan and can be used in a great variety of areas of life (Schmitz, Schmidt, Landmann & Spiel, 2007). From kindergarten until retirement age self-regulation as well as self-regulated learning is necessary because the demands of the environment change rapidly in our times.

Different models of self-regulated learning have been developed, which can be differentiated by the perspective the authors take on self-regulated learning. Winne and Perry (2000) categorize those different models of self-regulated learning as component models, like the one of Boekaerts (1997) for example, which distinguishes between cognitive, metacognitive and motivational aspects of self-regulation and process models like the one of Zimmerman (2000), which consists of three cyclical phases of self-regulation, or the one of Stöger, Sontag and Ziegler (2009), which describes six cyclical steps in self-regulated learning. As outlined by Wirth and Leutner (2008), component models describe self-regulated learning in terms of different learner competencies that foster self-regulated learning and that are considered as relatively enduring attributes of the person. However, process models take into account the cyclical character of self-regulation with phases of learning that follow each another and subsequent learning states in which the learning behavior can be adapted.

In the following sections we will present the theoretical background of process studies on self-regulated learning. Namely, we will describe the concept of a process, present a process model of self-regulated learning and its measurement by Schmitz and Wiese (2006), enlighten the role of self-monitoring in self-regulated learning, and explain how to analyze processes, specially with respect to interventions. With regard to interventions we argue for the usefulness of quasi-experimental designs in that field and address the topic of different possible target groups and forms of intervention.

2. Theoretical background

2.1 The concept of self-regulated learning as a process

According to Zimmerman (2008) self-regulated learning is viewed as proactive processes that students use to acquire academic skills, such as setting goals, selecting and deploying strategies, and self-monitoring one's effectiveness, rather than as a reactive event that happens to students due to contextual forces. Self-regulated learning is considered as a sequence of states in contrast to the more trait-oriented component approach. Following Hertzog and Nesselroade (2003), a state is a relatively changeable attribute of an individual. Schmitz, Klug and Schmidt (2011) give an example for the concept of self-regulated learning as a sequence of states. A single learning state includes, for example, the completion of assigned material at a single point in time. In such a learning session, various aspects of self-regulated learning may be relevant for students. The single learning state

is their learning behavior y_t measured at a particular point of time (t) in this special situation. A state starts when students begin their learning session and ends when they finish it. The dynamic study of self-regulatory processes deals with a sequence of those learning states. Students will probably learn over a longer period of time in order to prepare for an exam. Each learning session represents a learning state, which influences the consecutive learning state. Examined over time, successive learning states provide a dynamic picture of the learning process. As became apparent, the process perspective on self-regulated learning seems to fit the real learning situation very well which leads to a high ecological validity of studies that take the process approach into account. How the measurement of states instead of the commonly investigated traits can be applied in a study will be explained in the methodology section as well as in the description of exemplary studies that used the process approach.

2.2 An extended process model of self-regulated learning

Schmitz (2001), following the models of Zimmerman (2000) and Kuhl (1987), developed a process model of self-regulation that regards a three-phase cyclical nature of one learning state as well as the accumulation of consecutive learning states in terms of a process. Figure 1 shows the extension of that process model of self-regulation as reported by Schmitz & Wiese (2006).

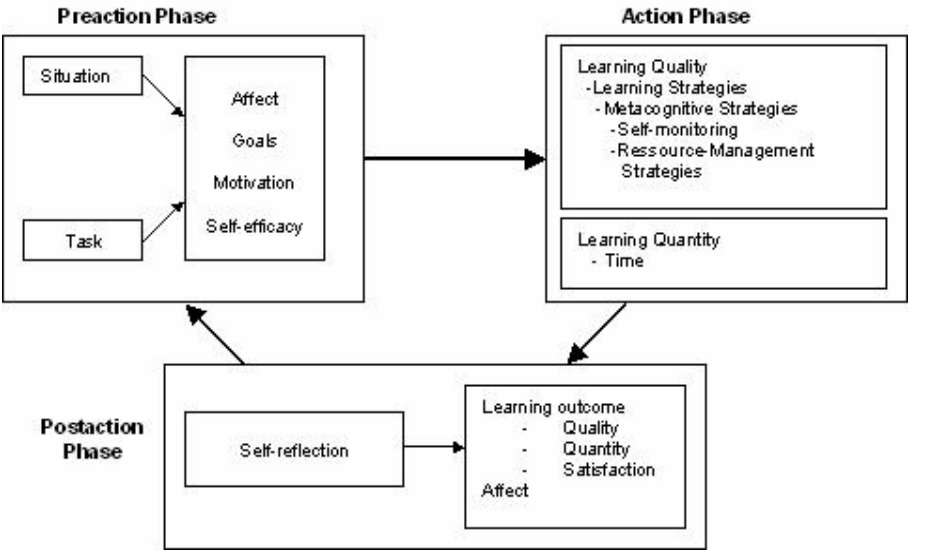

Figure 1:
Process model of self-regulated learning (Schmitz & Wiese, 2006)

As shown in the model, each learning state consists of three cyclical phases that influence each other while exerting an impact on the subsequent learning state. The phases are named using the labels of Heckhausen and Kuhl (1985): preaction phase, action phase, and postaction phase. Schmitz, Klug and Schmidt (2011) describe each phase as follows:

The preaction phase precedes learning. In this phase, the situation and the assigned task are the source from which the students set goals, develop various attitudes towards learning, such as intrinsic and extrinsic motivations to learn (Ryan & Deci, 2000), and develop self-efficacy for managing tasks. Self-efficacy also affects important self-regulatory aspects such as effort, persistence, and achievement (Schunk & Ertmer, 2000). These sources of motivation and affect (Pekrun, Goetz, Titz, & Perry, 2002) are conceptualized as predictors of learning processes in the proximate action phase.

During the action phase, the quantity and quality of learners' performance matter. Concerning learning strategies, the model focuses on metacognitive and resource management strategies, such as regulation, effort, time and attention management, or learning with peers (see e.g. Pintrich, Smith, Garcia, & Mc Keachie, 1991). Self-monitoring plays an important role during this phase (see section 2.3).

The postaction phase focuses on students' metacognitive and affective reactions to the quantity and quality of their learning outcomes. These outcomes refer to that special learning session at one point of time t_1 and they in turn influence the components in the following learning state $t_{2,}$ via a feedback-loop.

In the following, the special role of self-monitoring in self-regulated learning will be enlightened.

2.3 The role of self-monitoring in self-regulated learning

Self-monitoring ability is the capacity to observe one's own learning behavior on a meta-level during the whole process of learning. Lan (1996) defined self-monitoring as "deliberate attention to some aspect of one's behavior" (p. 101). That attention to the aspect of one's learning behavior is of particular importance during the action phase in the described model because this is the phase where actual learning takes place. In the actual learning situation one has to be aware whether he is still attentive or whether his thoughts zone out. Due to self-monitoring the learner can notice when he works in an ineffective way and therefore can adapt his learning behavior in the actual learning state e.g. by focusing his attention on the task. This adaptation of behavior due to self-monitoring corresponds to Bandura (1982, p. 6) who cautioned, "People cannot affect the direction of their actions if they are inattentive to relevant aspects of their behavior". Furthermore, self-monitoring helps to adapt learning behavior in a consecutive learning session. Owing to the awareness of what one did while learning, ineffective strategies can be detected and again adapted in consecutive learning states. In that sense, self-monitoring helps to become a better learner and simultaneously to achieve better learning outcomes.

For our purposes it seems to be important to recognize that self-monitoring can occur on different levels. E.g., one can observe and eventually record one's own self-regulation

behaviour across the years of one's life. One can also monitor one's self-regulation behaviour daily for the duration of one or two months. If one self-monitors self-regulation behaviour across two months, for example, it could include observing one's behaviour each day. With respect to self-regulation: If a student monitors the self-regulation of his homework behaviour for one day, self-monitoring is located on a higher level as this kind of self-regulation. But within the self-regulation of homework for that day, the student could monitor, for example, the application of certain task specific math strategies this day. That means: self-monitoring can be performed at a higher level of self-regulation as well as a part of self-regulation and therefore, it can be seen as just one component of the self-regulation cycle but also as an operation on a higher level. The use of diaries as self-monitoring procedure can be seen on a higher level as the self-regulation cycle.

Korotitsch and Nelson Gray (1999) report of the so-called reactivity effect of self-monitoring which, adapted to self-regulated learning, says that the mere application of self-monitoring leads to better learning results. In some of our studies we fostered self-monitoring by using standardized diaries, which helped to reflect on one's behavior in sequenced learning states. The reactivity effect occurred in an impressive way. Solely due to the use of learning diaries students did better in a mathematical problem-solving test. We will address the topic of learning diaries in a later section of methodology. In addition to self-monitoring from a higher level, it is of a special importance due to that reactivity effect.

2.4 The use of quasi-experimental intervention studies in process research on self-regulated learning

When self-regulated learning is seen as a process, it seems obvious that a study design should best be planned longitudinally, most suitably with a big amount of measurement points which leads to gathering process data. The question is, whether the description of the trajectory is of interest or whether changes fostered by an intervention shall be measured in a longitudinal way. Intervention studies are common and useful for students and other target groups (see section 2.5) in the field of self-regulated learning. Most methods for analyzing process data can be applied in both cases whether there is an intervention or the original process shall be observed, but there is an additional way of analysis for intervention studies called interrupted time-series analysis (see section 3 on methodology).

The "interrupted time-series design is one of the most effective and powerful of all quasi-experimental designs […] it is a particularly strong quasi-experimental alternative to randomized designs. " (Shadish, Cook & Campbell, 2002). First of all, there is the question of defining a time-series. Schmitz (1989, p. 1) defines a time-series as a sequence of measurements of one or more variables in consecutive points of time. Usually, a big amount of measurement points are needed. Shadish, Cook and Campbell (2002) recommend 100 measurement points, but in special cases with specific research questions results from a shorter period of time are sufficient and can be interpreted. A big advantage of process data is that it is often gathered in real life situations so that high extern validity is given (Hertel, Klug & Schmitz, in 2010). In addition to that, interrupted time

series designs allow assessing treatment effects. At the point of time when an intervention in self-regulated learning takes place the time series should show an interruption. The interruption can appear in different forms, permanence and immediacy. Shadish et al. (2002) describe six different designs of which we will present two: (1) Simple interrupted time-series, and (2) adding a no treatment control group.

A simple interrupted time-series design consists of a number of consecutive measurements within one group before and after an intervention takes place. O_1 until O_5 represent the measurements before the intervention, X stands for the intervention and O_6 until O_{10} represent the measurements after the intervention took place.

baseline measurements					intervention					post measurements
O_1	O_2	O_3	O_4	O_5	X	O_6	O_7	O_8	O_9	O_{10}

Concerning the internal validity of simple interrupted time-series designs, a threat is especially due to meanwhile events. Effects of meanwhile events and effects of the intervention can be confounded. Further sources of intern validity threats can be found in a systematic loss of participants, a possible change in the used instruments and a reactivity effect due to working with the instruments over a period of time (Shadish et al., 2002). Adding a no treatment control group to the interrupted time-series design helps avoiding some of these threats. Hence, data of the experimental group, which receives a treatment, can be compared to data of the control group, not receiving an intervention. In each group, baseline data and post intervention data is collected.

	baseline measurements					intervention					post measurements
EG	O_1	O_2	O_3	O_4	O_5	X	O_6	O_7	O_8	O_9	O_{10}
CG	O_1	O_2	O_3	O_4	O_5	–	O_6	O_7	O_8	O_9	O_{10}

The big advantage of adding a control group is due to the control of meanwhile events that could have an effect that can be confounded with the intervention. The interrupted time-series design with a control group is one of the most valid quasi-experimental designs.

2.5 Possible target groups and forms of intervention in process research on self-regulated learning

Considering life-long learning, interventions in self-regulated learning as a process are suitable for all kind of age groups. In order to illustrate both the necessity of self-regulated learning at all ages as well as the high bandwidth of forms of interventions, we will present some current studies beginning with the age group of school children up to the age groups of PhD students and teachers. Looking at the forms of intervention, many variations are possible and effective. An intervention can be directly addressed to the

target group which shall improve its self-regulated learning like students, but it can also take place in an indirect way, e.g. addressing teachers who in turn shall improve their student's self-regulated learning in class afterwards. Another variation lies in the context in which self-regulated learning is implemented (Dignath & Büttner, 2008) like in combination with mathematical problem solving or with text-learning strategies (Stöger & Ziegler, 2008).

As an example for fostering self-regulated learning at school, Perels, Dignath and Schmitz (2009) improved mathematical achievement by means of an intervention containing self-regulation strategies integrated into regular math classes. The same teacher taught one class, which served as a control group, merely mathematical topics and another class, the experimental group, in the same subject combined with self-regulative strategies. Results showed that it is possible to support self-regulation competencies and mathematical achievement by self-regulation intervention within regular mathematics lessons of 6th-grade students. Another example for fostering self-regulated learning within pupils is provided by Glaser and Brunstein (2007), who fostered 4th grade students' self-regulation procedures in a training combined with writing strategies in order to improve their composition skills. Students who were taught both self-regulation in conjunction with writing strategies, wrote more complete and qualitatively better stories in the post-test and in the follow-up test than students in the comparison groups who were taught writing strategies without self-regulation instruction and who received didactic lessons in composition. As these studies show, training in self-regulation for students shows significant effects on students' achievements even in different school subjects like math and languages. Otto (2007) addressed students in elementary school (4th grade, age 8 to 11), their parents and their teachers. Her focus was on improving the students' self-regulation and problem-solving skills. Here, direct and indirect ways of training were combined. The results show that students in direct training groups improved more than students in the indirect groups who in turn improved more than a control group. This study will be described more detailed in section 4 as an example for the ways of conducting and analyzing process studies in self-regulated learning.

Interventions in self-regulated learning are equally important in adulthood, e.g. in university studies (Schmitz, 2001; Schmitz & Wiese, 2006), PhD studies (Schmidt, 2009), or in the job (Landmann, Pöhnl & Schmitz, 2005). Peverly, Brobst, Graham and Shaw (2003) found that college students were not good at self-regulation, creating a special need for fostering college students' self-regulated learning. Furthermore, Landmann, Pöhnl and Schmitz (2005) created an intervention in self-regulation for women who wanted to return to their job after parental leave. The intervention aimed at a better achievement of objectives. Kramarsky and Michalsky (2009) conducted another study with adults as a target group. They investigated pre-service teachers' professional growth by comparing the professional growth of pre-service teachers in learning environments supported by self-regulated learning with pre-service teachers not supported by self-regulated learning. The group with self-regulation support outperformed the one without in all used measures of professional growth. As a result, the authors reason "the ability to self-regulate learning is essential for teachers' professional growth during their whole career as well as for their ability to promote these processes among students".

Obviously, interventions in self-regulated learning are relevant at all ages for coping with the rapidly changing environment and the intervention can effectively take place in different contexts and in different directness.

3. Methods for assessing and analyzing self-regulated learning

Following the description of the history of self-regulation and motivation by Zimmerman (2008), a number of instruments that assess self-regulated learning were developed in the 1980s. These instruments were commonly based on self-reports like questionnaires and standardized interviews. Popular examples for questionnaires are the Learning and Study Strategies Inventory (LASSI; Weinstein, Schulte & Palmer, 1987) and the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich, Smith, Garcia & McKeachie, 1991). Based on these two questionnaires, the German LIST (Inventory for Recording Learning Strategies in Academic Studies) was developed by Wild and Schiefele (1994). It distinguishes between cognitive, metacognitive and resource management strategies. Additionally, Zimmerman and Martinez-Pons (1986) developed a structured interview for measuring self-regulated learning based on self-reports: the Self-Regulated Learning Interview Scale (SRLIS). These questionnaire and interview methods showed to be reliable and valid in studies that tested their internal consistency as well as criterion validity by correlating their results with objective outcomes like test performance (e.g. Pintrich et al., 1993; Boerner, Seeber, Keller & Beinborn, 2005; Zimmerman & Martinez-Pons, 1986). However, Winne and Perry (2000) classified them as aptitude measures of self-regulation, which reflect the approach of self-regulated learning as a trait in the way it is realized within the earlier mentioned component models. Yet, regarding self-regulated learning as a process, further methods for measuring consecutive learning states were needed. Other methods assessing self-regulated learning as an event (Zimmerman, 2008, p. 169), "which is defined as a temporal entity with a discernable beginning and an end [and] is demarcated by a prior event and a subsequent event", are e.g. think-aloud protocols, direct observations, log-files during web-based learning and structured diaries. We now focus on structured diaries as a method for measuring self-regulated learning as a process.

3.1 Structured Diaries as a method for measuring self-regulated learning as a process

Diaries have proven their usefulness in research on self-regulated learning due to their application as an instrument for recording learning processes and for evaluating the results (e.g., von Eye & Bergman, 2003). Due to their structuring influence on the learning sessions, they serve as a self-instructional tool for documenting and reflecting learning processes. They help self-diagnosing learning behavior and therewith initiate adaptations in learning behavior that lead to better performance. In other words, filling out structured diaries helps to self-monitor the learning process, thus leads to the before mentioned reactivity effect (Korotitsch & Nelson Gray, 1999). Furthermore, if they are combined

with self-regulation training, diaries can improve students' transfer of training contents to new tasks.

Concerning quality criteria of diary data, Kanfer, Reinecker and Schmelzer (1996) validated diary data by correlating personal diary data with that of external observers, and the results confirmed high accuracy and reliability. In addition, diaries are attractive as measures of learning due to their high ecological validity, which in turn is due to their completion in a natural environment on a daily basis (Schmitz & Wiese, 2006). Consequently, this allows the computation of Cronbach's Alpha for each individual. Furthermore, if there are individuals with low Alphas, a subgroup can be identified which has high Alphas for each individual. The same holds for the factor structure. Whereas for cross-sectional data, factor structure can be computed for groups or subgroups, for diary data of samples, one can compute the factor structure for each individual separately. With respect to this information, it is possible to select a subsample of individuals who have similar structures. However, for validity one can compute individual coefficients, e.g. for criterion related validity.

Imagine having collected data measuring self-efficacy within a learning diary with effort being the predictor. This allows for computation of individual validity coefficients for effort with respect to self-efficacy. Again it is possible to select a subgroup of individuals for which the individual validity coefficients are high.

In sum, although it could seem that diaries lack the strength of other well established cross-sectional instruments, the major advantage is the possibility of testing the quality of diary data for the whole sample as well as for each individual. This allows a combination of idiographic and nomothetic analyses following Allport (1937).

Diaries can be constructed based on the process models of self-regulation so that they cover the whole self-regulation cycle. Variables of the preaction phase can be measured just before each learning state begins, whereas action and postaction variables are assessed immediately after finishing each learning session. Hence, they permit real-time recording of learning processes without reminiscence errors or palliations and show a great ecological validity.

The items in the structured diary are verbalized as states so that a measurement of consecutive learning states is possible. Trait-items from existing instruments that measure self-regulated learning can be taken and changed with respect to time. An example for the aspect planning of strategy application would be: "I think about how to proceed effectively" (very seldom to very often) in the trait version, which was adapted to "Today, I think about how to proceed effectively" (strongly disagree to strongly agree) in the state version of the diary. When we present studies that apply the methods in section 4, we will present an excerpt of items of a used diary for more information about a possible diary structure and formulation of the items (see table 1).

Diaries provide us with time-series data, which offer the possibility of conducting analyses with more sophisticated methods. We present some of these methods in the following.

3.2 Analysis of single cases on the basis of process data

The analysis of diaries is of great importance since it allows studying trajectories and relationships for individuals as well as for groups and subgroups. Learning process data can be depicted graphically even for individuals. The values of the dependent variable are plotted on the ordinate while time is plotted on the abscissa. Schmitz (2000) discussed the distinction between nomothetical and ideographic analyses of single case study data. He cautions that, in general, it is not possible to draw conclusions about individual courses from a sample course. But, using process data gathered with the help of diaries, processes of self-regulated learning can be described more precisely and analyzed using inferential statistics even with individual cases (Schmitz, 1990). Schmitz (2006) described several questions about an individual's learning process that cannot be answered without process data: Is the learning continuous or discontinuous, with one or more jumps? Are there plateaus or drawbacks? Does the amount of knowledge follow a simple trend, e.g., linear or quadratic? Is the learning behavior characterized by high or low variability over time? Are there phases of learning that exhibit qualitatively different learning behaviors? Does the learning behavior show some regularity or rhythm (e.g., a daily rhythm)? All of these questions can be answered using time-series data, which can provide insights into an individual student's self-regulated learning trajectory. Similar to the analysis of a single process over time, the relation between two or more processes can be studied using a time series analysis. When e.g. testing for the presence of a linear trend, a simple linear regression is estimated whereby the points of measurement serve as predictors. A linear trend can be positive or negative. An example of a linear trend will be given in section 4 when exemplary studies are presented.

3.3 Multivariate ARIMA models on the basis of process data

Process data on self-regulated learning also allows studying bivariate relations between two variables over time. Firstly, they can be graphically illustrated, but the method of choice to test for relations are multivariate ARIMA models. ARIMA stands for autoregressive integrated moving average models. These models are fitted to time series data either to better understand the data or to predict future points in the series (forecasting). If the data shows non-stationarity at the beginning, a differentiating step is needed, where e.g. linear trends are detected and eliminated. That is the integration part (I). The residuals can be further analyzed for autoregressive processes, which means that by means of values of earlier points in time, the values of later points in time can be predicted (AR). Additionally the time series is checked for moving average processes (MA). It is generally a linear regression of the current value of the series against previous (unobserved) white noise error terms or random shocks. Multivariate time-series analyses address the case of two or more variables of which process data is at hand. Similarities in the courses of the two variables can be studied. For example the relation between setting goals and motivation can be studied over time.

It is well known, that correlations do not allow causal interpretation. Nevertheless, applied to time-series, the term 'cross-correlation' is used for a relation between two time courses (Schmitz, Klug & Schmidt,2011). By using cross-correlations, it is possible to detect dynamic interactions and therewith to discover references for the directions of causality. The assumption is that what happens earlier in time can have an effect on what happens later. Lagged cross-correlations can be used to provide such references of causality due to temporal sequence. To illustrate a dynamic interaction, we pick up the example of the intraindividual relation between a students' goal setting before learning and his motivation to learn. Figure 2 shows the possible cause-effect relations schematically.

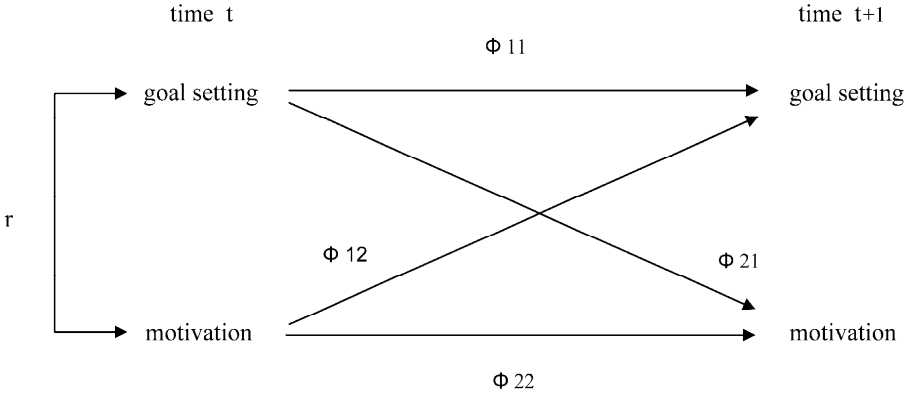

Figure 2:
Schematic diagram of the dynamic interaction between a students' goal setting and motivation

If the students' goal setting at the point of time t predicts his motivation at the point of time t+1, it shows the temporal sequence and seems plausible that goal setting is causal for motivation. Although the causal interpretation of time-lagged relations is correct for many cases, time lag does not necessarily prove causality. Schmitz (1989) discussed the issue of time-lagged relations and causality in detail. The ϕ-coefficients in the figure represent the type of the time-lagged path coefficients of the bivariate process. The ϕ-coefficient is a measure of association for two binary variables. It is similar to the Pearson correlation coefficient in its interpretation, but it does not range from -1 until +1. Its maximum value is determined by the distribution of the two variables. By estimating the ϕ-parameters, one can describe how the dynamic system works (Schmitz, 2006). Figure 3 shows the possible resulting ϕ-matrices which can be interpreted as follows.

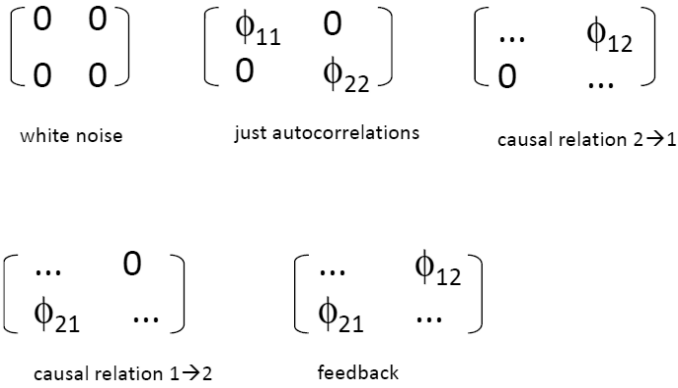

Figure 3:
Possible resulting phi-matrices from ARIMA models

The parameters ϕ_{11} and ϕ_{22} give information about the autocorrelations in the single time-series. If, for example, ϕ_{11} was significantly positive, the earlier goal setting would influence the goal setting later in time. The parameters ϕ_{12} and ϕ_{21} in turn give information about the time-lagged dynamic interactions of the two time-series. ϕ_{12} shows the effect of goal setting on motivation, whereas ϕ_{21} denotes the effect of motivation on goal setting. The synchronous correlation r on the contrary does not tell us anything about the cause-effect relation. For further information on ARIMA models see Schmitz (1987).

3.4 Interrupted time-series analysis on the basis of process data

Interrupted time-series designs were already introduced when talking about the benefits of time-series designs. So, which information do we get from interrupted time-series studies? Interrupted time-series analysis can provide answers to questions about if an intervention works and on how an intervention works (see Yaffee and McGee, 2000). Intervention effects can be examined either for an individual or for an aggregated sample. If the intervention is effective, the values of the dependant variable, gathered by diaries, show a change in the designated direction. Interventions can lead to different effects like (a) a change in level or intercept, (b) a change in drift, trend or slope, (c) continuous or discontinuous changes, which means it persists over time or not and (d) a change that starts immediately or delayed (Shadish, Cook, & Campbell, 2002).

To conduct this method of analysis, the variable of interest needs to be measured for a certain time before the intervention starts. This pre-training period is called the baseline phase. After this phase, the intervention starts and the measurement of the dependent variables continues. The post-training period of measurement is called the intervention phase. By means of interrupted time-series analysis, the baseline and the intervention phase are to be tested for significant differences. An example will be presented within the exemplary studies which will be illustrated in the next section. Finally, we will draw

some conclusions and discuss the pros and cons of studying processes in the field of self-regulated learning.

4. Studies on fostering and measuring self-regulated learning

We now present examples of self-regulation interventions and diaries following the process model of self-regulated learning (Schmitz & Wiese, 2006). Firstly we focus on an intervention study by Otto (2007) who aimed at 4th graders' self-regulation and mathematical problem-solving skills. We also touch on the implemented diary by Otto. Secondly we present another diary in more detail. In contrast to the first study it was designed for Ph.D. students in a training program by Schmidt (2009).

In a recent study Otto (2007) addressed students in elementary school (4th grade, age 8 to 11), their parents and their teachers. Her focus was on improving the students' self-regulation and mathematical problem-solving skills. She realized direct and indirect training programs. One direct experimental group received the most extensive training program consisting of lessons for students, parents and teachers (TG1). Another direct experimental treatment consisted of lessons for students and teachers (TG2). The two indirect training groups consisted of parents and teachers (TG3) and of teachers alone receiving the training (TG4). The control group (CG) received no training sessions.

Description of questionnaires and tests

Student-data was collected pre, post and four weeks after the training program to evaluate the stability of the effects. The questionnaire contained the following scales: Mathematical self-efficacy, goal-setting, time planning, strategy planning, intrinsic and extrinsic motivation, self-motivation, volition (concentration, procrastination, effort), monitoring and dealing with failure. Moreover Otto applied scales on the use of problem-solving strategies and a mathematical problem-solving test.

Description of the Diary

Students filled out a learning diary during the intervention period (42 days). It had to be filled out at home before and after homework. The diary was divided into four parts: preaction phase, action phase, postaction phase and problem-solving. Preaction items included positive and negative emotions (e.g. "Just now I feel sad."), self-efficacy ("Today I did understand everything."), intrinsic motivation ("Math-class was fun today."), motivation ("I'm looking forward to doing my homework."), planned use of strategies ("I think about how I will approach homework.") and planned time ("How much time do you think you'll need to do your homework?"). Action items included procrastination (e.g. "I started doing my homework immediately."), homework enjoyment ("Homework was fun today."), concentration and volition ("Today I could concentrate well while doing homework."), use of trained strategies ("Which of the following exercises did you use?"), effort ("I worked hard on my homework today.") and characteristics of homework-assignment (e.g. "Homework was easy today."). Postaction items included the time

needed for homework ("How much time did you need to do your homework?") and the afterwards calculated difference between planned and needed time for homework, goal-attainment ("I did the homework I wanted to do."), contentment ("I am contented with my results.") and reflection ("Where would you like to do better with your next homework-assignment?"). Mathematical problem-solving items included the strategies selection, sketch, estimate, decomposition and proof.

Description of the Training

Students were trained in seven weekly 1.5-hour sessions during teaching time, the first and the last session served as introduction and as recapitulation. Parents and teachers received five weekly 2.5-hour sessions in the evening. Students, parents and teachers learned about procrastination (self-motivating, structuring, goal-setting), preaction problem-solving, concentration and volition (handling distraction), action problem-solving and in the last session they learned about dealing with failure and reflection (individual reference standards, modification of strategies).

Results for the pre-post comparison

Results show that students in direct training groups (TG1, TG2) reported better values on self-regulation as overall-scale. The exact rank order was TG1 > TG2 > TG3 > TG4 > CG. Concerning preaction scales only students of direct training improved significantly in motivation. Mathematical self-efficacy was improved in every training group in contrast to CG. Analysis of variance of action scales led to mixed results. Data indicated that student volition increased in every training group except for TG4. Among postaction scales only dealing with failure improved for every group compared to the control group. Concerning the results of the problem-solving test the groups did not differ. The follow-up test showed stability of effects only for the groups which were trained directly, indicating that stability of effects requires direct training.

Results for trends

Following the steps of a thorough process analysis, Otto first searched for trends. She found significant trends for most of the variables. We would like to highlight here the positive trends for self-efficacy, intrinsic motivation, planned time and reflection. Negative trends were found for procrastination and the difference between planned and needed time for homework. Figure 4 shows the trends for self-efficacy and intrinsic motivation before learning.

Results for the interrupted time-series

As a second step Otto (2007) carried out interrupted time-series analyses defining the period before a training session as baseline for the specific content trained afterwards. She also took the AR(1)-model as a basis for her analyses (Schmitz, 2001). She found improvement on associated variables after almost each of the training sessions. After the second training session students showed improved intrinsic motivation and decreased

procrastination. Figure 5 shows the time-series (continuous line) and phase means (broken line) for procrastination. The vertical bar on day 8 marks the date of the second training session. The decrease is apparent in both the course of the time-series and the difference between the phase means.

After the third training session referring to preaction problem-solving strategies students reported more frequent use of sketches. After the fourth training session, which dealt with concentration, diary data indicated better concentration and more frequent use of strategies promoting concentration. After the fifth training session dealing with action problem-solving skills there was no improvement in the diary data. After the sixth training session referring to dealing with failure and reflection students improved their reflecting skills marginally.

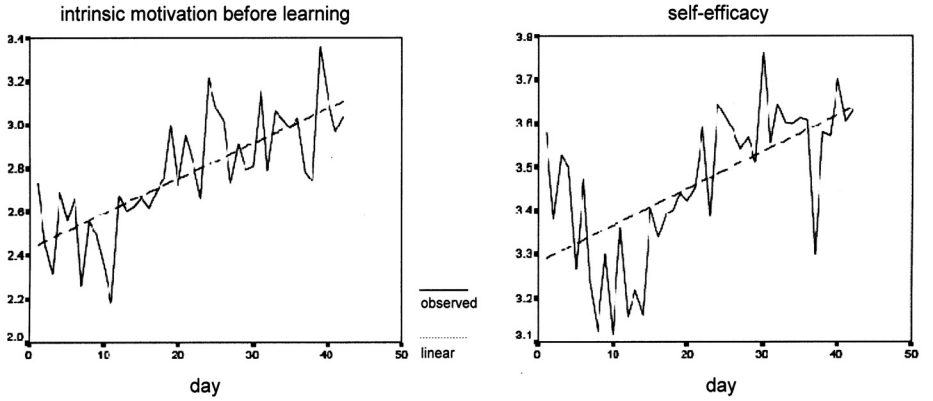

Figure 4:
Trends for intrinsic motivation before learning and self-efficacy

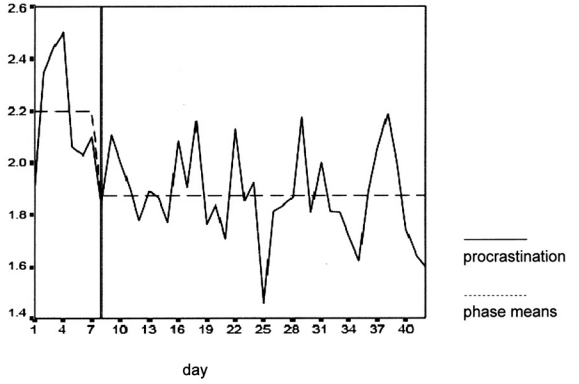

Figure 5:
Time-series for the variable procrastination

Results for the Validation

Otto also aimed at validating the process model of self-regulated learning (Schmitz & Wiese, 2006). She succeeded for synchronous diary data, i.e. variables of the preaction phase correlated with variables of the action and postaction phase. The validation was not possible for asynchronous diary data, i.e. postaction variables at time t did not correlate with preaction variables at time t+1.

In order to validate the learning diaries Otto (2007) correlated the data aggregated across time from the diaries with the pre and post data from the questionnaires. The highest correlations occurred for intrinsic motivation in the pretest ($r=.46$, $p<.001$) and for effort in the posttest ($r=.71$, $p<.001$). Many of the other variables also included in the learning diary correlated with the pre- and post-measures. Other variables showed weaker correlations such as reflection in the pretest ($r=.32$, $p<.05$) and procrastination in the posttest ($r=.44$, $p<.001$). These results indicate that longitudinal and diary data are interrelated but we also find discrepancies. The significant correlations Otto found, indicate validity of diary data, i.e. fewer items repeatedly measured over time included in the diary still measure the same variable as extended scales in longitudinal questionnaires. However, the differences in magnitude of the correlations indicate slight discrepancies between the two measurement methods.

A similar training program was carried out by Bruder (2006). She addressed students in grammar school. The 6th-graders received either a direct or an indirect training program from their parents concerning self-regulated learning and mathematical problem-solving. The pupils also had to fill out a learning diary. Similar training studies were carried out by Perels, Gürtler and Schmitz (2005) who trained 8th-graders in a German grammar school in mathematical problem-solving and self-regulated learning and also implemented a diary (Perels, Otto, Landmann, Hertel & Schmitz, 2007). Other studies by Schmitz (2001) and Schmitz and Wiese (2006) both had an adult target group of university students with the main focus on the diary data.

Another study implementing diaries in a group of adults was conducted by Schmidt (2009). She trained Ph.D. candidates in self-regulation skills. According to her process model of adults' self-regulation, she trained participants in three areas of self-regulation: subjective evaluation of the situation, (meta)cognitive self-regulation and affective/ motivational self-regulation. Her two groups received training with and without a diary. The control group did not receive any training or diary. Schmidt correlated pre-post measures and diary data and demonstrated a positive linear relationship between the self-regulation questionnaire and the diary.

Description of the diary

The diary Schmidt implemented will now be described in more detail as a recent example for an electronic diary. Considering the demands and possibilities of postgraduate students she realized an online diary version. The diary had to be filled out every day over a period of twelve weeks, starting one week before the first training session and ending six weeks after the last training session. It consisted of open questions and items coded on a six-point Likert-scale (scores ranging from 1 = *I strongly disagree* to 6 = *I strongly*

agree). Items were related to the three phases of self-regulation. The preaction phase was measured with the scales self-efficacy, planning, goal-setting and self-motivation. The action phase was realised with the scales self-monitoring and volition. The postaction phase was measured with the variables self-reflection, emotions and dealing with failure. Open questions contained specified questions in dependence of the days of the week. At the beginning of the week, participants were asked to write down a goal for the whole week. Furthermore, they had to specify a goal for every day. Preaction variables of the diary were supposed to be answered in the morning, whereas action and postaction phase variables should have been answered in the evenings. At the end of every day and at the end of the week, participants had to rate their goal-attainment (0% to 100%). Moreover they answered reflection questions with which they reflected on which things worked well and which things needed improvement. Table 1 shows the scales and items of the diary. These examples show the state perspective on self-regulated learning as they always ask for the actual occurrence of the variables in connection with actual tasks.

We have exemplarily described two studies which trained self-regulated learning and evaluated the training programs under a process perspective with the help of diaries. Otto's process analyses showed substantial effects for a lot of crucial variables like procrastination and intrinsic motivation. Schmidt's learning diary for postgraduate students was presented in more detail as an example on how diaries can be designed electronically, economical and related to self-regulation states. Based on their results, both studies encourage to implement diaries in training programs.

5. Concluding comment

Like cyclical models of self-regulated learning show, self-regulated learning builds a process with consecutive learning states that influence one another. The process point of view on self-regulated learning, which we support in this article, leads to a certain methodological approach in the examination of self-regulated learning: Process research and therewith process data is needed. As we pointed out, structured diaries are an appropriate and flexible instrument that can be used to gather process data in the field of self-regulated learning. Diaries can be used for every age group and in diverse contexts. They allow measurement of consecutive learning states and the consideration and analysis of courses on the individual level. Additionally, interrupted time-series analysis is a powerful method to evaluate training programs in self-regulated learning. Multivariate ARIMA models even allow indicating causality between two self-regulation variables due to temporal sequence. The quality criteria of process data from diaries are satisfied, notably their ecological validity is high. In addition to the mentioned advantages of diaries as a method for measuring processes, they can be used as intervention instruments that foster self-monitoring which in turn leads to a reactivity effect and they improve students' transfer of training contents to daily life.

Table 1:
Scales and items of postgraduates learning diary (Schmidt, 2009)

Preaction Phase		
Self-efficacy	I'm able to achieve my today's job-related demands.	Schmidt (2009)
Planning	Today I'm going to plan my tasks before I begin working on it.	Schmidt (2009)
Goal-setting	Today I have a concrete goal.	Schmidt (2009)
Self-motivation	I can motivate myself well for my today's tasks.	Schmidt (2009)
Emotion	Today I feel – Determined – Active – Distressed – Nervous	PANAS, adapted, Watson & Tellegen, 1988
Action Phase		
Self-monitoring	While I was doing my tasks today, I attended to keep my goals in view.	Adapted, Breutmann, 2006
Volition	Today I kept on fullfilling my tasks, even when difficulties accured.	Schmidt (2009)
Postaction Phase		
Dealing with failure	From today's mistakes I learn how to improve myself.	VCQ2, adapted, Kuhl & Fuhrmann, 1997
Goal-Attainment	My goal for the week is… My goal for the day is… What can you improve tomorrow? What can you improve the next week? What has worked well today? What has worked well this week? How do you assess the attainment of your goal for the day (from 0 to 100%)? How do you assess the attainment of your week goal (from 0 to 100%)?	Schmidt (2009)

Nevertheless, some limitations of diary data should be mentioned. It is important to consider that they depend on self-reports. Moreover, regularly completion of a diary implies great effort for the subject. A high level of compliance by the subjects is needed to avoid a high dropout rate, which can reduce external validity of the data. Furthermore, the results depend on the subjects' motivation and, if the diary is not standardized, on writing skills.

In our opinion, the advantages of using process data for measuring and analyzing processes of self-regulated learning exceed the obstacles by far. Hopefully the remarks of this

article help to motivate researchers investing effort in conducting more process studies in the field of self-regulated learning. If so, great proceedings for investigating and enhancing self-regulated learning processes in the future are due.

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