

Self-regulation and Computer-aided Instruction

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L'auto-apprentissage est défini comme un apprentissage au cours duquel un étudiant construit lui-même son programme. Vingt et une fonctions d'apprentissage sont décrites qui pourraient soit être accomplies par les étudiants eux-mêmes soit par les professeurs (ou leurs substituts, par exemple des ordinateurs). Les étapes de l'apprentissage (par exemple l'orientation, les plannings, les examens, le contrôle) sont considérées comme aussi importantes dans un système avec professeur qu'en auto-apprentissage. Trois manières de remplir les fonctions d'apprentissage sont définies: action, activation et stimulation. De plus, sont présentés quatre programmes d'entraînement essayant d'enseigner à des étudiants comment utiliser les modes d'emploi d'ordinateur. Ces études essaient de montrer que l'entraînement peut avoir un effet non seulement sur la performance d'apprentissage mais aussi sur les processus d'enseignement. Ainsi furent étudiés les changements dans l'expression de la pensée à voix haute après entraînement. Dans une seule étude sur les quatre, on trouve à la fois des changements dans la performance et dans les processus. La partie finale de l'article décrit comment la stimulation des fonctions d'apprentissage avec un programme d'aide linguistique pour ordinateurs peut être accompli. Les fonctions de stimulation d'apprentissage conduisent à de meilleures performances seulement quand on apprend aux étudiants à s'auto-former.

Self-regulated learning is defined as learning in which students perform teaching tasks themselves. Twenty-one learning functions are described that should be accomplished either by learners themselves or by teachers (or their replacements, for instance computers). Regulation of learning (e.g. orientation, planning, testing, monitoring) are thought to be important both in teacher- and self-regulated learning. Three ways are defined in which learning functions can be fulfilled: taking over, activation and stimulation. Moreover, four training studies, trying to teach students how to learn through computer-aided instruction, are reviewed. These studies aimed to show that training can have an effect not only on learning performance, but also on learning processes, and so changes in thinking aloud as a consequence of training were studied. In only one out of the four studies were changes found in both performance and processing. The final part of the paper describes how the stimulation of learning functions through a computer-aided

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vocabulary learning program can be accomplished. Stimulating learning functions only led to better performance when students were taught how to fulfil the learning functions themselves.

INTRODUCTION

In this paper studies are reviewed with respect to their effectiveness, in which the self-regulation skills of students from secondary schools and adults, were trained using computer-assisted learning to learn courses. The studies and the training programs took a theory of self-regulated learning and the relations between teaching and learning functions as their starting point.

TOWARDS A THEORY OF SELF-REGULATION IN LEARNING

This theory or framework integrates research findings from our own department, findings of other institutes, and cognitive and affective theories on independent learning, thinking, and problem solving. In our opinion self-regulated learning pertains to being able to prepare one's own learning, to take the necessary steps to learn, to regulate learning, to provide for one's own feedback and judgement, and to keep oneself concentrated and motivated. The five tasks underlying these abilities can also be executed by teachers. This happens in many highly structured forms of teaching. Teachers, then, prepare the learning of the students, let them make learning steps (through assignments or the presentation of information), regulate the students' learning through testing, questions, observations, etc., judge the learning progress and provide feedback, and try to keep students motivated and concentrated. In other situations, however—where there are no teachers, where teachers function incompletely or inadequately, or in situations where teachers decide to hand over responsibility to students—the students have to execute these steps themselves. One might also say that under these kinds of circumstances students should be able to be their own teacher.

The main characteristics of the self-regulated learning theory we depart from were formulated by Shuell (1988, pp. 277–278):

... learning is an active, constructive, cumulative and goal-directed process
 It is *active* in that the student must do certain things while processing incoming information in order to learn the material in a meaningful manner. It is *constructive* in that new information must be elaborated and related to other information in order for the student to retain simple information and to understand complex material. It is *cumulative* in that all new learning builds upon and/or utilizes the learner's prior knowledge in ways that determine what and how much is learned. It is *goal-oriented* in that learning is most likely to be successful if the learner is aware of the goal (at least in

a general sense) toward which he or she is working and possesses expectations that are appropriate for attaining the desired outcome.

Shuell (1988) defined learning functions as psychological functions to be performed during learning by the learner. It is, in his opinion, not so much *how* the function is performed that is important, but *that* it is accomplished. There are, for instance, different ways to get attention: by physically pointing, by using different colours, or by means of a verbal prompt. Furthermore, learning functions can be initiated by the teacher and by the learner. For example, expectations can be specified by the teacher through instructional objectives, or they can be initiated by the learner identifying their own purposes. Shuell distinguishes 10 functions: expectation, attention, encoding, comparison, hypothesis generation, repetition, feedback, evaluation, monitoring, and combination/integration/synthesis.

Shuell's ideas resemble ours considerably (see Table 1) and his list of functions has some overlap with our list of self-regulatory abilities. Expectations and attention correspond to our preparatory abilities. Encod-

TABLE 1
List of Learning Functions

<i>Main Category</i>	<i>Subcategories</i>	<i>Shuell's Category</i>
1. Preparation of learning	orientation on goals and actions	expectation
	choice of goals	—
	relevance of goals	expectation
	promoting self-confidence of learner	expectation
	planning of learning activities	—
	motivating students to learn	—
	getting started	attention
	getting attention	attention
2. Learning steps	recalling prior learning	—
	comprehension	encoding
	integration	comparison, repetition, hypothesis generation combination/integration/ synthesis
	application	—
3. Regulation processes	monitoring	monitoring
	testing	monitoring
	revision	—
	reflection	—
	evaluation	evaluation
4. Performance judgement and feedback	feedback	feedback
	judgement	—
5. Motivation and concentration management	upholding motivation	—
	upholding concentration	—

ing, comparison, hypothesis generation, repetition, and combination/integration/synthesis resemble our learning steps to be taken. Feedback, of course, corresponds to our performance and feedback category, Evaluation and monitoring fit into our regulation processes category.

Though the two approaches do show some agreement, there are some important differences, too. First, we do not believe, as Shuell does, that it does not matter how, or by whom, the function is accomplished. It may be the case that this does not matter in the short run. In the long run, however, it does make a difference: when teachers accomplish all functions, students will not learn how to do it on their own. In addition, some ways of accomplishing the function are better than others: we believe active forms of learning and regulation lead to better learning results than passive ones. Furthermore, we think that our list is more complete and more differentiated than Shuell's. In our system the two phases of learning (before and during) are better distinguished. Finally, our system has more room for motivational, volitional and emotional aspects of learning (cf. Keller & Kopp, 1986; Paris, 1988).

On the other hand, the concept of learning functions seems to be a useful one, that can easily be integrated in our approach. Therefore, Table 1 presents the list of learning functions we think necessary in any learning situation, being initiated and accomplished either by the teacher or the learner.

Table 2 presents examples of teacher and learner initiations of the various categories of the model. Instructional systems differ in the extent to which they provide for explicit help, structure, or advice for the various learning functions. Some systems take care of almost all the functions, leaving only few possibilities for the student. Other systems let students fulfil many of the functions themselves. We think there are three ways instructional systems can have an influence on the learning functions of students: taking over, activation, or stimulation (cf. Wittrock, 1974). *Taking over* a learning functions means that the system initiates and fills the learning function. This happens, for instance, when students are obliged to answer multiple-choice questions provided by the teacher, or when a teacher presents information (see Table 2). *Activating* a certain function pertains to forcing students to use certain functions in a specified way, for instance by assigning that they should make a scheme of the concepts discussed in a text book. *Stimulating* students to use certain functions concerns either general advice to execute certain learning activities and leave out some others, or training students in the learning functions (see Table 2). Stimulation occurs, for instance, when teachers advise students to learn in a meaningful way, or when they teach them to use certain learning strategies or self-regulation skills.

There are advantages and disadvantages connected to the three ways of

TABLE 2
Examples of the Categories, when Initiated by Teachers and Learners

<i>Teacher Initiated Example</i>	<i>Learner Initiated Example</i>
TEACHER:	LEARNER:
1. Preparation of learning <ul style="list-style-type: none"> Presents information on goals Chooses goals for students Explains why goals are relevant Reassures students that the goals are within their reach Chooses learning activities and their sequence Makes learning look interesting by telling a story Gives the sign to start Attracts students' attention through raising voice Gives an overview of prior learning that has relevance 	<ul style="list-style-type: none"> Thinks of possible goals and activities Chooses personal learning goals Realises why goals are relevant Is self-confident; promotes own self-confidence Plans and chooses learning activities (e.g. underlining) Is motivated to learn; promotes self-motivation Has adequate starting strategy Pays attention
2. Learning steps <ul style="list-style-type: none"> Presents information in a structured way Relates new information to old; presents a scheme Demonstrates how one can apply a certain principle in practice 	<ul style="list-style-type: none"> Reads, listens, analyses Relates, makes a scheme Applies to a new situation, thinks of possible applications
3. Regulation of learning <ul style="list-style-type: none"> Observes whether students understand Poses a question Presents information a second time in a new way Tells students why they learned in a certain way Judges the process of learning 	<ul style="list-style-type: none"> Consults own feeling of knowing Paraphrases in order to test comprehension Tries a new strategy Thinks of possible reasons for succeeding this time Evaluates the process of learning
4. Performance judgement and feedback <ul style="list-style-type: none"> Gives feedback on student response Judges students' performance 	<ul style="list-style-type: none"> Uses external feedback possibilities; attributes Judges own performance
5. Motivation and concentration management <ul style="list-style-type: none"> Promises a reward Stimulates students to keep on 	<ul style="list-style-type: none"> Thinks of future rewards Takes a break

coping with learning functions. The following seems to be applicable to the 'taking over' of learning activities: Taking over learning activities that students could perform themselves decreases the active participation by students (sometimes interference effects may even occur, see Simons, 1980). A consequence may be that students work and learn below their

qualitative level—their prior knowledge and intellectual abilities are not exploited as much as they might have been. Furthermore, when this ‘taking over’ happens all the time, students will not develop their learning skills any further. On the other hand, when students are not able to execute and regulate learning activities themselves, taking over forms the only feasible short-term solution.

The activation of learning activities and regulations has the following advantages and disadvantages: Activating regulations and/or activities mostly increases the effort expenditure by the students themselves. They have to execute the assigned learning activities and regulations. This way they may learn how to do it and develop their learning and regulation skills somewhat better than in cases where the teacher ‘takes over’. However, they do not learn when to initiate these activities and regulation processes (for instance, choosing and controlling their own learning goals and activities). Furthermore, they may often fail to exploit all the possibilities of integrating preconceptions and advance knowledge with new knowledge and skills. Perhaps self-chosen activities and regulation processes might lead to better results than the activated ones.

The stimulation of learning activities and regulation processes can be evaluated as follows: Stimulating students to use certain ways of learning and regulation, or teaching them how to learn, will, in our view, lead to the best learning processes eventually. In this way, the chances are best that learning proceeds actively, cumulatively, constructively, and in a goal-directed way. It can only be successful, however, when students are able to fulfil several of the necessary learning functions on their own. In the short term, therefore, this way of proceeding may result in lower performance, frustration, and resistance.

Thus, when teachers present a summarising scheme, students cannot (and will not) create their own structure. When teachers activate structuring activities by giving them an assignment to create a scheme of relations, students cannot (and perhaps will not) use their other structuring abilities. Finally, when teachers stimulate students to structure text information in too general a way, students who are unable to do so may reach lower results than if they had been activated instead.

What happens in many instructional situations is that teachers feel obliged to take over learning activities, because they observe that students are not able to execute them when activated. For instance, teachers expect their students to take their own notes using their schematising and structuring abilities. Soon, however, they discover that many of the students are not able to make adequate notes. Then they feel obliged to take over by literally dictating the notes. Because of this, these students never learn how to take notes independently and the circle closes.

When one wants to teach students how to learn independently (see

Vermunt & Van Rijswijk, 1988), one is usually forced to take over important learning activities as a first step. Gradually, the learning activities and regulation processes, once they have been learned, can be activated. Therefore, while taking over learning activities, a teacher should teach the students how to execute and regulate the learning activities on their own. When different learning activities and regulation processes have been practised and activated, the teacher should gradually replace activations with stimulations, depending on the developing learning and regulation skills. An important question is whether such learning to learn approaches can be given in separate courses or can only be successful in integrated domain-specific courses. General learning to learn courses have until now failed to succeed (Resnick, 1987; Simons, 1988). Overall, there was a complete lack of transfer to regular learning situations. Domain-specific approaches, however, seem to be more promising (see next section). Perhaps a combined general and domain-specific approach might form an acceptable compromise. One important question is whether such learning to learn approaches can be embedded into computer aided learning programs.

COMPUTER-AIDED LEARNING TO LEARN

In this section, we will review some of our studies on computer-aided learning to learn, in which the theory is applied to training programs. Finally, an illustration of the theory in research on the flexible use of a learning strategy will be described.

Learning to Learn From Text

During the last few years, in our department, several studies have been done (see De Jong, 1987; De Jong & Simons, 1988; De Jong & Simons, 1992; Simons, 1989; Simons & Lodewijks, 1987; Vermunt & Van Rijswijk, 1988) searching for individual differences in self-regulation processes that correlate with performance on tasks that have to be executed relatively independently. Parts of the theory presented earlier inspired the design of the studies. It became clear that such differences do exist, at least in the populations studied, namely, students beginning secondary education, and adult education. Differences in Testing, Monitoring, and Directing explained high percentages of variance in performance differences. Also, differences in regulation style (internal versus external regulators versus unregulated learners) and depth of processing (deep versus concrete versus surface processors) correlated with exam performance.

We also devised training programs aimed at changing the regulation processes of weak-performance students from secondary education, using

the theory presented as a point of departure. In designing training programs we had the following lines of thought: (1) we based the training on the differences in processes observed during a pretest session; (2) we stressed metacognitive awareness by letting students reflect on their own way of learning and that of other students; (3) we emphasised the importance of regulation processes by letting students practice with a set of questions one may pose to oneself during learning (e.g. Do I understand this part? What went wrong? Is this in line with the learning goal?), and techniques and skills one may find useful in answering these questions (e.g. paraphrasing, reflection, thinking of new examples, self-testing); (4) finally, non-cognitive variables like concentration, self-motivation, attributions, and mind orientations were also included when possible.

Typically and uniquely in our attempts, thinking-aloud protocols were used as the dependent measure in addition to the learning performance measure normally employed. The design of our studies was as follows. Subjects thought aloud, and filled in a pretest and some questionnaires. Based on these data (sometimes only on a preliminary and superficial inspection of the protocols, because of time constraints) the training programs were devised and executed, employing different learning materials. Then at a posttest session (parallel to the pretest session) thinking-aloud protocols were collected, and posttests, transfer tests, and questionnaires were filled in a second time.

In the first series of four studies, in which human tutors trained the students, significant differences in both processing and performance were shown in three of the four studies (De Jong & Simons, 1988; 1992; Simons, 1989). Encouraged by the success of these training studies, De Jong (1992) did some more training studies, but now employing computer-aided instruction (CAI). A learning heuristic was built into two CAI programs and was labelled 'Learning Aid'. The learning heuristic consisted of three layers. The first layer consisted of a flow chart (see Fig. 1) with several processes to execute when regulating one's own learning and reading. One of these is, for instance, the process "Check whether you understand what you read". The processes were presented in an almost serial way and an imperative mood. In the second layer, the parts of the diagram were translated into questions that have the function of triggering adequate executive control processes. For instance, the process just described became "What exactly do I not understand in what I have been reading?". In the third layer, information was provided about WHAT is meant by each question, HOW one can answer or realise it (concrete activities), and WHY one should do it at all.

All these training studies used the same approach, materials, and design. The subject population, however, differed with respect to intelligence, school achievement, and the learning difficulties of the students.

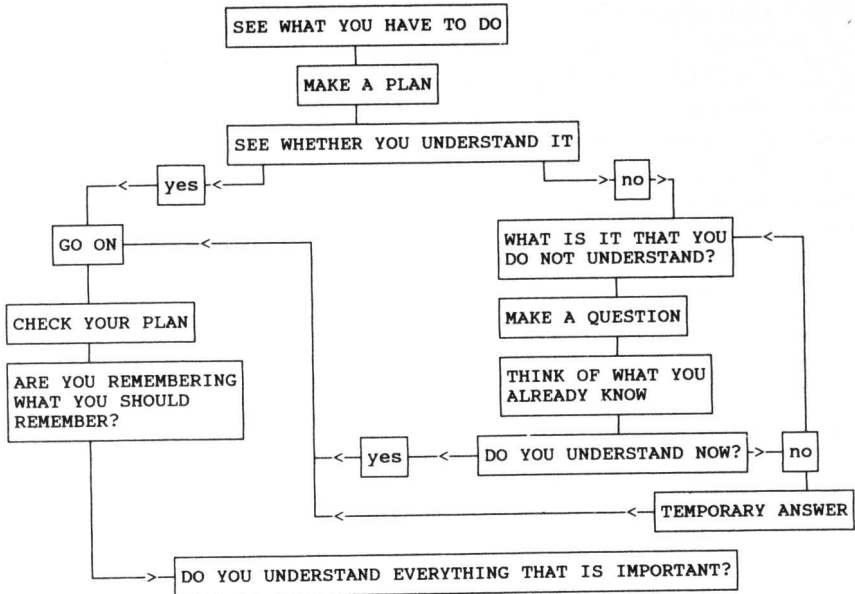


FIG. 1. Heuristic of active learning and regulation processes.

In three of the four studies the learning aid was presented through computer-aided instruction integrated in biology and history lessons. In one study the aid was integrated into a text comprehension curriculum, also as computer-assisted instruction. The flow chart was presented whenever study text was presented during the first four lessons. The two deeper layers could be consulted any time the students wanted to do so by a special key on the computer keyboard. At regular times the deeper layers also intervened as a learning aid without the student asking for it. It checked whether the student was using the heuristic, and it posed bugging (in the students' eyes) questions to the students when they did not. Then the student involuntarily came to the third level of the learning aid. These interventions were 'scaffolded' during the last four sessions, in that their frequency of occurrence was lowered, they were replaced by screen-filling prompts in order to remember and stimulate the execution of important regulation processes, and finally they stopped completely.

The research question for the four studies was: Is there an effect of the learning aid on learning and regulation processes, and learning performance? An experimental group studied the learning material with the help of the learning aid, and a control group did so without the learning aid. Before and after the training, students learned two texts as transfer tasks, and were required to think aloud. The thinking aloud processes taking

place while studying the texts (as transfer tasks) were analysed with a categorising scheme described in De Jong and Simons (1988). The use of regulation categories like monitoring and testing constituted the process-measures. Learning performance was measured through a multiple choice test. The texts were presented in counterbalanced order, one featured 'hair', the other 'burns'. The sequences of sessions started with a training session in which students were trained to think aloud. The design in all four studies was a pretest-posttest control group design (with exception of Study 4 in which no control group could be formed).

The expected results were found in only one of the four studies. It was only in the last training study that changes both in processing and in performance showed up. In one study neither processing nor performance effects were found. In one study only performance effects, but no processing differences showed up, and in one study only some small processing differences appeared, but no performance differences. Changes in meta-cognitive knowledge, however, were significant in all cases. The main conclusion drawn from these results is that it is more difficult than we had thought to change self-regulation processes through computer-assisted learning to learn courses. Moreover, training of self-regulation processing was less effective with computer tutors than with human tutors. Computer-aided training programs, using the same training material as in human tutor experiments (De Jong, 1992), failed in three out of four cases. This conclusion, however, is too general. The last training study with computer tutoring did succeed. Furthermore, Biemans, Van Deursen, and De Jong (1989) achieved impressive effects of computer-aided training on performance and processing in a study on learning how to regulate translations of English texts into Dutch. Both of these studies, however, employed older students of higher intelligence.

The conclusion to be drawn is that computer-aided training only worked for older students, and not for younger and learning-disabled students. What could cause the relative ineffectiveness of computer-aided training programs for younger and learning-disabled children? One possible explanation is that this has to do with motivation and affective processes. Changing one's regulation processes and becoming an active learner is a difficult and stressful process, demanding a lot of endurance, belief, and self-confidence. Based on informal observations, we believe that our human tutors provided a lot of affective help that our computer programs did not give. Presumably, they encouraged students to go on, they gave them somewhat more self-confidence, and made clear that it was a worthwhile thing to do and to learn. Would it be possible to extend our computer learning aid with affective and motivational help? We think it to be possible, at least more than in our programs.

Learning to Learn a Vocabulary through Computer-aided Instruction

In another series of studies in our department the theory presented was applied to the domain of vocabulary learning. The keyword method developed by Atkinson in the Sixties (see Atkinson, 1975) was used as an instruction strategy. In this strategy students were asked to learn foreign words with the help of a keyword. This is a word in the native language sounding somewhat like the foreign word to be learned. Thus the Spanish word *pato* sounds like the possible English keyword 'pot'. The second element of the strategy is that a verbal or imagery association should be formed between the translation and the keyword. Thus, in our example, one should make a sentence with the translation (being 'duck') and the keyword, for instance "The duck is in the pot", or one should think of an imagery relation between 'pot' and 'duck', for instance imagining a duck with a pot on its head. Several variants of the keyword strategy are possible: presenting the keywords and asking students to make the associations, either through sentences or through imagery; presenting both keywords and pictures or sentences; asking students to make their own keywords and associations. Prior research (see Pressley, Levin, & Delaney, 1982) showed that for younger children it was better to present both the keyword and the association, whereas adults performed better when they invented their own associations, but used ready-made keywords.

In a first study with college students, replicating an experiment in which two keyword conditions were compared with a control condition in which students used their own strategies, some interesting observations were made. Some of our students in the experimental condition did not use the keyword method but stuck to their own method. Some did not use the keyword presented, but invented their own. Some found a shorter meaning connection than the keyword connection, for instance in order to remember the connection *frio* ('cold'), they used their own keyword 'freeze' and did not need an association at all. Some did not use the imagery association presented, but used their own. Some students were not able to find a suitable keyword or association in time. On the other hand, some students in the control group did use a variant of the keyword method spontaneously. Finally, many words could not be used in the experiment because they did not fit the criteria for good keywords. Overall there were no differences between the two versions of the keyword methods (with and without associations and keywords presented). Both groups remembered about 18 out of 30 of the word combinations. Their results were, however, much better than those of the control group, who remembered only 12 out of 30.

These results inspired us to devise a system that would make it possible for students to regulate their own learning strategy on the word-level in a more flexible way. For each word combination students should quickly decide whether they want to make use of the keyword strategy, whether they need a keyword, and whether they can invent a verbal or imagery association on their own. The underlying assumption was that the learning, through this system, could be as active, constructive, cumulative, and goal-directed as possible. One's own strategy, one's own keyword and one's own association was expected to function the best, because of its effects on activity, cumulativeness, constructiveness, and goal-directedness. This, however, was expected to work only if one has a better strategy available, when one is able to hear a keyword, and when one can think of an association. If these conditions are not fulfilled then one can better make use of help offered by a teacher or a computer program.

The students were advised to use the keyword method only when they had no better method. The designed system offered students the choice of employing their own strategy for each word combination, getting a keyword, or getting an association. At first, this system was tried out in a non-computerised system. The experimenter presented help when (college) students asked for it. A control group ($N = 14$) learned through a fixed keyword method. The subjects in the control group again remembered 18 of the 30 translations of the (Portuguese) words. The subjects in the experimental group ($N = 30$) remembered 22 of the words. The difference between the two groups, however was not statistically significant. In a second experiment, the system was computerised. Now there were no differences between groups at all. Both groups reached an average of 18 correct translations. Observations showed that students in the experimental group were very confused by the many choices they could make.

In the final experiment, therefore, students were trained before they could learn with the help of the program. The training, taking one hour, had three components: (1) students were made aware of the possible strategies for learning with and without the keyword method; (2) they practiced with all the possible strategies discerned, receiving feedback and; (3) they learned when to use which of the strategies, according to the advice already described. The students in the control group only learned how to use the fixed keyword method. The results were quite clear this time. The experimental group had an average of 25 (SD 3) correct translations, whereas the control group reached an average of 17 (SD 5). This difference was highly significant ($F = 23.9$, $P < 0.001$).

Thus, even grown-up, highly intelligent, college students do not spontaneously use the possibility of regulating their vocabulary learning in an active way. Offering choices and giving advice is not enough. But a short training session, taking only one hour, that teaches them how to be more

active, cumulative, constructive, and goal-directed raises the students' performance dramatically.

CONCLUSIONS

We started this paper with the presentation of a theory about self-regulation in learning. Learning functions and the three ways through which instruction can have its influence formed the core of it.

The experiments about computer-aided learning to learn showed that it is possible to improve the regulation processes of learning through an embedded training, but that this is by no means an easy thing to do. Younger children of lower intelligence and with learning disabilities failed to profit from an intensive embedded training through CAI, whereas a comparable training with human tutors had succeeded earlier. We hypothesised that the affective learning functions of our theory were not stressed enough in the computer version of the training program, whereas human tutors tend to take over these functions spontaneously.

The experiments in the last part showed that stimulation of learning and regulation processes does not lead to better results than activation when students are not ready and able to fulfil the necessary learning functions themselves. After simple training, in which students were taught how to choose, the stimulation approach was more successful than the activation approach. This supports our hypothesis that stimulation of learning functions is to be preferred when students are ready and able to fulfil learning functions themselves.

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