Cognitive and Metacognitive Processes of Self-Regulated Learning

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ABSTRACT

In this article the authors try to form a theory of self-regulation in learning. There are three levels with respect to the (self-)regulation of tasks: a) (metacognitive) knowledge and conceptions, b) executive control or regulation processes and c) transformations or executive skills. Self-regulated learners are able to prepare their own learning, to take the necessary steps to learn, to regulate learning, to provide their own feedback and to keep themselves motivated and concentrated. From this, the authors assume that students should be "active learners". But there are impediments to active learning as well. These impediments consist of student factors and interactive factors. The research described in this article was carried out to see whether students could be trained to become active learners. This was done by integrating a learning-to-learn program in computer-assisted instruction in four small-scale training studies.

TOWARD A THEORY OF SELF-REGULATION IN LEARNING

In our conception (see also Lawson, 1984), three levels or perspectives should be discerned with respect to the (self-)regulation of tasks : *(metacognitive) knowledge and conceptions* (for instance, knowledge of strategies, knowing when to use certain strategies, or conceptions of self-regulation), *executive control or regulation processes* (for instance, deciding on a plan, attention maintenance, monitoring, or repair mechanisms) and *transformations or executive skills* (for instance, reading, sawing or selling). Metacognitive knowledge is knowledge of one's own cognitions (thinking, problem solving, learning, remembering) or of third persons' cognitions (e.g. knowing how students in general think or learn). Executive control or regulation processes refer to the steering and control of cognitions and actions. Herbert Simon (1979) defined an executive control process as: "The control structure governing the behavior of thinking man is a strategy or program that marshals cognitive resources for performance of a task" (p. 42). Transformations and executive skills refer to the actions themselves, both overt and covert ones.

What are important abilities of self-regulated learners? Self-regulated learning, in our opinion, pertains to: a) being able to prepare one's own learning, b) to take the necessary steps to learn, c) to regulate learning, d) to provide for one's own feedback and judgement and e) to keep oneself concentrated and motivated. The five tasks underlying these abilities can also be executed by teachers. That is the case in many highly structured forms of teaching. Teachers there prepare the learning of the students, let them make learning steps (through assignments or the presentation of information), regulate the learning of the students through testings, questions observations (etc.), judge the learning progress and provide feedback and try to keep students motivated and concentrated. One may also say: a self-regulated learner is able to be his own teacher.

Below follows our view on the various subskills that comprise self-regulated learning:

- *Self-regulated preparation on learning* consists of:
  - an adequate *orientation* on learning goals and learning activities
  - an adequate *planning* of learning activities tuned to the goals set
  - an adequate *choice of learning goals* tuned to your ability and knowledge
  - knowing what learning *goals* you strive for and why they are relevant.
  - *self-motivation*: intrinsic motivation for the goals or motivation to learn (cf. Brophy, 1988)
  - being able to find relevant *prior knowledge and skills* that can be used in the new learning
  - *attentional, volitional and emotional strategies* (i.e. getting started, getting attention, self-esteem, attribution (cf. Corno,1988)).

Self-regulated learning itself consists of the use of adequate learning activities and strategies (tuned to the goals set). A self-regulated learner is able to flexibly shift between different learning activities, depending on the goals and task constraints. He is able to execute learning activities that lead to knowledge, comprehension, integration and problem solving. Several authors have studied the learning activities that lead to these four kinds of goals (for instance, Biggs, 1984; Entwistle & Ramsden, 1983; Janssen & Deneve, 1987; Marton & Säljö, 1984; Ng, 1988). Vermunt (1987) integrated many previous attempts in his description of learning activities. He discerned the following: memorizing, repeating, analyzing, structurizing, relating, selecting, concretizing, personalizing and criticizing. Like previous investigators, Vermunt found individual differences in the extent in which students were able and ready to use these learning activities. Three kinds of processing of study texts showed up: *deep processing* (using the activities relating, structurizing, criticizing and selecting of relations, views, conclusions, structure and aim of the author), *surface processing* (using the activities analyzing, memorizing, repeating and selecting factual information) and *concrete processing* (using the activities concretizing, personalizing and selecting applicable content). Some students only used one kind of processing, others switched between two or three approaches, depending on conditions like exam demands, task characteristics (i.e. interestingness) and time constraints.

Self-regulation processes in learning consist of: monitoring, testing and questioning, revision and evaluation. Monitoring refers to constant observation and interpretation of the learning processes in light of the goals. Thus, whether they are still on their way to the goals; thus, whether the information is recalled understood, integrated or applied (consulting their feeling of knowing). Testing has to do with more explicit attempts to check whether one is still progressing towards the learning goals through paraphrasing, trying to think of new examples, schematizing, searching an analogy (etc.). By answering self-made or supplied questions as well, self-regulated learners can test their state of knowledge and understanding. Revision mechanisms refer to decisions one has to take when problems or blockades occur. One can then try another strategy, think of the possible causes of the comprehension failure, shift to a different goal (etc.). There is growing evidence that especially a reflective way of processing forms an important aspect of self-regulated learning (Nelissen, 1987; Vermunt, 1987; Salomon, 1988). Evaluation of the process of learning forms the last regulation mechanism leading to changes in future processing and metacognitive knowledge of learning.
Another aspect of self-regulation, *performance judgement and feedback*, is of special significance in learning situations. Teachers have very dominant roles as to performance judgment (grading) and feedback. Self-regulated students, however, have to be able to judge their performance on their

own. They will not receive feedback from the outside, either. Self-regulated learners should use opportunities to optimally obtain feedback. When there is a possibility to get feedback (for instance, because the right answers are given at the end of a book), a self-regulated learner should resist the temptation to cheat himself by looking up answers he does not immediately know.

The final aspect of self-regulated learning, *self-motivation and concentration management*, concerns, for instance, keeping oneself motivated to learn by looking back at the learning goals and their relevance, or by thinking of future rewards. Concentration management concerns, for instance, decisions with reference to: when and how long one should take a break, what to do when concentration fails, how to exclude internal and external distractions (etc.).

ACTIVE LEARNING

The central assumption underlying our approach is that those learning activities are chosen in optimal learning that have the greatest chance of letting the students reach their goals. Learning activities, in other words, should be tuned to learning goals. When a student wants to understand a certain part of a domain of knowledge, he should engage in other learning activities than when he wants to be able to apply that part of that domain. Learning for recall should be different from learning for understanding or integration. This means that we do not believe that all learning should be "active". Nor do we believe that it is wrong when students try to expend less than maximum effort. Furthermore, effort expenditure probably proceeds in phases, high and low levels of activity following each other. When we use the term active learning we therefore do not refer to the amount of effort expended, but to the quality of the learning and regulation activities used (coming very close to deep and self-regulated processing as described above).

In this respect our ideas resemble those of Shuell (1988), who assumes that learning should be active, constructive, cumulative and goal-directed. "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." (pp.

277-278). Our ideas differ in this respect from those of Bereiter and Scardamalia and their group (for instance Bereiter and Tinker, 1988; Ng, 1988), who seem to assert that "constructive effort" should preferably be high all the time. Salomon (1988) in his concept of "mindfulness" also seems to assume that students should strive for activity in learning and problem solving as a value in itself. In our view, the essential thing to do is to be constructive and mindful at the right moment, depending, among other things, on one's learning goals. Another difference between our approach and the other two mentioned lies in the distinction we make between the quality and the quantity of learner activity (see below). Both in the concept of constructive effort and in the concept of mindfulness these two aspects seem to be mixed in an unclear way.
Our investigations so far suggest that many students only engage in certain learning activities, being unable or not ready to engage in the others. These concern not the amount of effort invested (many students study very hard but inefficiently, using activities like summarizing, selecting and writing, etc.), but the quality of learning activities (like personalizing, criticizing, concretizing and finding connections with other information).

There are several reasons why students should be able and ready to engage in active learning (although not always): a) some kinds of learning goals can only be reached through active learning; b) active learning, being an important part of self-regulated learning, might be considered an important goal of education; c) empirical studies suggest that active learning causes better learning performances.

STUDENT FACTORS IMPEDING ACTIVE LEARNING

In our research as well as theorizing, we found several factors impeding active learning. These factors have to do with student characteristics. These impediments will be reviewed below.

The first one concerns *learning conceptions*. As was shown, amongst others, by Vermunt (1987) students differ in the way they see the fundamentals of learning and the division of tasks between teachers and students. Five kinds of conceptions could be discerned, with two fundamental underlying ideas: On the one hand there were students who regard learning as having to copy ideas and information out of books and the heads of teachers into their own heads. This conception often concurs with a view on teaching accentuating that it is the teacher who has to structure, analyze, personalize, etc. through his presentations and assignments. On the other hand there were students who see learning in essence as the construction of knowledge, which one can only do oneself. Teachers can only help in this construction process, they cannot do it for the student. Students with the conception described first will not engage in active learning on their own, because they wait for the teacher to do this for them. Van Rossum, Deijkers & Hamer (1985) claim that there is an almost perfect correlation between learning conceptions and learning activities. Furthermore, our studies suggest that students often fail to engage in active learning when invited to do so because they interpret assignments within their "surface" framework. Many students could have great problems working on assignments that were meant to stimulate active learning.

A second set of impediments to active learning has to do with learning *goals*. Many students do not think about the goals of learning, they do not "thematize" learning, they take learning for granted (Säljö, 1979; Thomas and Harri-Augstein, 1985). Therefore, they do not make their goals explicit, nor do they pay attention to the goals formulated in books. As a consequence of this, as was shown in one of our experiments (Lodewijks, Place-van Tongerloo, & Simons, 1983), many students fail to vary their learning approach according to task demands and imposed learning goals. Finally, students easily misinterpret goals formulated by others within their own framework, missing an invitation for active learning.
A related and in our view very important problem concerns students' perceptions of tests and exam demands. Many students report that they have to choose for surface level activities because of the testing customs. Even if teachers frequently value higher level goals, their testing practices are often perceived by students as stressing lower level goals. This does not mean, of course, that testing practices are always as students expect them to be: students' perceptions may well be distorted by their learning conceptions and motivations.

In the third place, *motivational, volitional and affective factors* may also impede active learning. For instance, we found students to be afraid of changing their learning approach. Students were also very active during learning in an unproductive way *just to be sure*. Especially in secondary education we found many instances of students overlearning facts and details many times, or underlining almost every word in a text, or copying translations ten or more times. Furthermore, students may fail to believe that active learning really "works" (i.e. that you can remember information just by thinking about it). Some students also believe that active learning requires too much effort or energy. Students who do not believe that they are able to learn in a active way and reach acceptable or even better results (lack of self-confidence), may not even try to engage in it. Students who are too much mind-oriented in the sense described by Kuhl (1983) will not be able to be an active learner. Mind orientation refers to fixations on certain parts of the regulation process: on previous failures, on previous successes, on goals or on planning. Because of these fixations, students are not able to regulate the whole process, consisting of evenly distributed attention to the beginning state, the end state, the difference between the end and the beginning state and possible ways to get from the beginning to the end state. Simons (1989) collected thinking-aloud protocols of students from special secondary education. Although the number of mind-oriented statements on the level of individual statements was rather small, in a more molar analysis of protocol fragments of a whole, many mind-oriented patterns showed up in this sample. This mind orientation correlated with learning performance and traits like impulsivity and field dependence.

The fourth impediment concerns *the skill of active learning itself*. Students who do not use certain activities will lack the necessary learning skills (elaboration, analyzing etc.). Research on learning styles (Vermunt, 1987) suggests that many students use surface processing strategies. A group of students explicitly stated to have many troubles in active learning (Schmeck, 1983; Vermunt, 1987). The question remains to be studied, however, whether students actually have trouble in performing active learning, since relevant observational and experimental studies have not yet been done. Furthermore, there are some indications that many students lack the necessary metacognitive knowledge: they do not know what kinds of learning activities exist and when to use which ones.

The final impediment to active learning concerning student tasks are *regulation skills*. As shown by De Jong (1987), De Jong & Simons (1988) and Simons & Lodewijks (1987), students in secondary education often fail to adequately plan and orientate beforehand. Only when they encounter problems, they start to think. Few students monitor, test and check their learning activities in a way that is tuned to the learning goals. Revision mechanisms (like re-orientation, new planning etc.) showed up only very rarely. The number of negative self-statements correlated negatively with learning performance. The most important result from studies done in our laboratory is that the amount of regulatory activity and especially the extent in which students tune the nature of their self-testings to the learning goals is a powerful predictor of performance (Simons & Lodewijks, 1987; De Jong, 1987). Furthermore, patterns of regulatory processes were very task-dependent. Vermunt (1987) studied adult students' self-regulation abilities by means of questionnaires. He also found relations between individual differences in regulation styles (internal and external regulation and lack of regulation) and learning performance. Thus, active learning also seems to depend on regulation styles and skills.

INTERACTIVE FACTORS IMPEDING ACTIVE LEARNING

The most extreme form of self-regulation in learning occurs when students have ample opportunity to perform all five of the task aspects themselves: making their own preparations, executing the actions independently, regulating themselves, making their own performance judgments, giving feedback to themselves and keeping themselves motivated and concentrated. Most of the time, however, third persons (parents, teachers or their substitutes, for instance books or computers) take care of at least part of these tasks. In essence, there always seems to be a division of tasks and responsibilities. Hardly anyone learns completely independently of others. On the other hand, there is some opportunity for self-regulation in almost every situation, albeit only decisions as to speed of working or effort expenditure. Extension of the responsibility of students for their own learning may in some cases improve performance. Lodewijks (1981) for instance showed that students learning science concepts in a self-chosen sequence performed better than students learning these concepts in a predetermined sequence. Likewise, Van der Sanden (1986) showed that some students (especially the better performing ones) performed better on a practical construction task without instructions than with detailed and explicit advice.

According to these and other studies, improvement of performance might be reached by giving students more opportunities to regulate their own activities and to bear responsibility. This, however, is often problematical in practice, naming only a few problems: apart from the students who might profit from these opportunities, there are also those who will perform (even) worse when left free (Lodewijks, 1981; Van der Sanden, 1986). Students who are not used to freedom and responsibility may not (yet) have the capabilities needed for independence. Students may not believe that they are capable of self-regulation. Students may dislike responsibility. Teachers may hesitate to hand over responsibility to their students. Larsson (1983) discussed these kinds of conceptions, circularities and paradoxes in the context of the division of tasks between teachers and students: some teachers would like to give students more freedom to learn, but do not believe that students are able to handle this freedom. Some students believe that only the teachers should make decisions on learning and seem to hand over all responsibility to the teachers.

What seems to happen 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 on their own. For instance, teachers expecting their students to make their own notes using their schematizing and structurizing abilities, soon 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.

An important lesson to be learned from all of this, is that much more is needed than just giving opportunities for independent work: there is (metacognitive) knowledge to be acquired, there are conceptions to be changed and there are activities and regulation processes to be learned. In our opinion there is only one way out of the paradoxes and circularities discussed and that is by training students in self-regulation. One main goal of training programs should therefore be to convince students that they have their own responsibility and that they can become able to regulate their working, problem solving or learning.

TRAINING STUDENTS TO BECOME ACTIVE LEARNERS

Though there are many obstacles and impediments for active learning, recent studies by, for instance, Palincsar and Brown (1984) show that there are more possibilities and promises for training than we thought some years ago. In our department we previously had done some successful training studies. Typically and uniquely in our attempts, thinking-aloud protocols were used as the dependent measure in addition to the normally employed learning performance measure. Furthermore, the training programs were based on previous studies showing relations between certain active learning and regulation processes and learning performance. Processes having a relation with learning success were trained with students not using these active processes of learning and regulation. Simons and Lodewijks (1987) reported a relatively short training study (3 sessions only) with eighth-graders (N=14) of relatively high intelligence. The subjects came from so-called HAVO-VWO schools that accept only the top 30 per cent of the student population, using performance on primary school and intelligence as admission criteria. The trained students increased both their number of text-comprehension testing-processes and their text-learning performance, whereas control subjects remained at the same level as before. Simons (1989) reported two training studies with children from special secondary education, learning to solve word problems. Here, we dealed with students with learning difficulties (especially concentration problems). The first training study (N=10), having a training duration of four hours, failed to have any effects: there were neither changes in the thinking-aloud protocols nor changes in learning preformance. The second training study (N=6) had a much longer and more intensive training. Now there were increases in both word-problem-solving and in regulation processes. The number of mind-oriented patterns decreased significantly as well as the number of negative self-statements. From these three studies we concluded that it seems possible to make students more active learners, but that it takes a lot more time and energy to do so with learning-disabled students.

INTEGRATING LEARNING-TO-LEARN INTO COMPUTER-ASSISTED INSTRUCTION

In the rest of this paper four small-scale training studies are briefly reviewed. They all used the same training approach and design. The subject population, however, differed with reference to the intelligence, school achievement and learning difficulties. In the training an heuristic of active learning and regulation processes was used (see appendix 1). It consisted of three levels. The first level consisted of a flow chart with several rules to be followed when regulating your own learning and reading. One of these is, for instance, the rule "Check whether you understand what you read". At the second level the rules were transformed into questions. For instance, the rule mentioned above became "Why don't you understand what you have been reading?". At the third level, there was, for everyone of the questions, a section on *what* was meant by the question, *how* one can get an answer to the question through concrete regulating activities and *why* it makes sense to do so (the functionality of the question and answering sequence). In three of the four studies the learning aid was presented through computer-aided instruction integrated in biology and history lessons. The heuristic was available all the time during the first four lessons. The two deeper levels could be consulted any time the students wanted to do so. At regular times the deeper levels also intervened without the student asking for it. It checked whether the student was using the heuristic and posed bugging (in the students eyes) questions to the students when they did not. The student would unvoluntarily come 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 and finally stopped completely.
In the first study to be reported, however, the learning aid was presented through a booklet, not on the computer. A human "learning aid" helped the students to use the booklet, which had the same three levels as the computerized learning aid.

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 (in counterbalanced order, about "hair" and "burns"), thinking aloud. 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. The thinking-aloud protocols were audiotaped, transcribed and analyzed through a scheme used in previous studies (e.g. De Jong and Simons, 1988; see appendix 2).

Study 1
In the first study 26 pupils of the first class of HAVO/VWO (see above) participated. All of them had difficulties with mathematics. Metacognitive knowledge of regulation was registered by a situational questionnaire before and after the training. Furthermore, there were 12 sessions: a thinking-aloud training session, the pre- and posttest sessions, three 'awareness of their state of regulation' sessions, one reciprocal/modelling session and five 'on the job training' sessions. The pre- and posttest consisted of two texts (counterbalanced over the sessions) concerning an introduction on the theory of chances and related problems to solve. Performance tests consisted of one multiple choice question and nine chance problems to solve.
Several ANOVAs with Condition as between factor and Time as within factor were carried out on the data. A significant Condition x Time interaction ($F(1,24)=15.3; P \leq 0.001$) turned up concerning the metacognitive knowledge. Subjects in the experimental group stated on the average 13.1 (SD=2.4) adequate self-regulation activities in there answers to the eleven posed learning problem situations in contrast to 8.5 (SD=2.4) statements on the pretest. For the control group holds a M(pre)=8.1 (SD=2.8) and M(post)=7.5 (SD=3.7). The training also affected the actual self-regulation. A Condition x Time interaction effect ($F(1,24)=4.8; P \leq 0.01$) was determined concerning the category Testing. The averaged testing activities on the pretest was 29.7 (SD=20.9) and on the posttest 43.5 (SD=16.3) for the experimental group. For the control group the M(pre) was 29.9 (SD=19) and M(post) was 27.8 (SD=10). On the level of the subcategories the expected Condition x Time was significant for the subcategory 'Correct paraphrasing' ($F(1,24)=5.59; P \leq 0.03$). The experimental group had a M(pre)=1.6 (SD=2) and M(post)=5.5 (SD=4.7) and the control group had a M(pre)=4.2 (SD=6.7) and M(post)=2.3 (SD=3). There was also a significant interaction concerning the subcategory 'Checking the answers' ($F(1,24)=7.8; P \leq 0.01$). M(pre) for the experimental group amounted to 5.0 (SD=4.7) and the M(post) to 8.7 (SD=4.4). For the control group the M(pre) amounted to 5.2 (SD=5.4) and M(post) to 5.5 (SD=3.8).
The performances of the experimental group increased from 4.1 (SD=1.6) on the pretest to 5.4 (SD=1.7) on the posttest in contrast to the performances of the control group M(pre)=4.5 (SD=1.5) and M(post)=4.5 (SD=1.8). This result was not statistically significant. Performances of the experimental group during the training on the job were in three out of five sessions significant better than those of the control group.

Study 2
In this study 40 students from the first grade of lower vocational school (secondary school) participated as subjects. There were 11 sessions: a thinking-aloud training session, the pretest and posttest sessions and 8

learning sessions. The materials consisted of 4 biology lessons and 4 history lessons respectively.

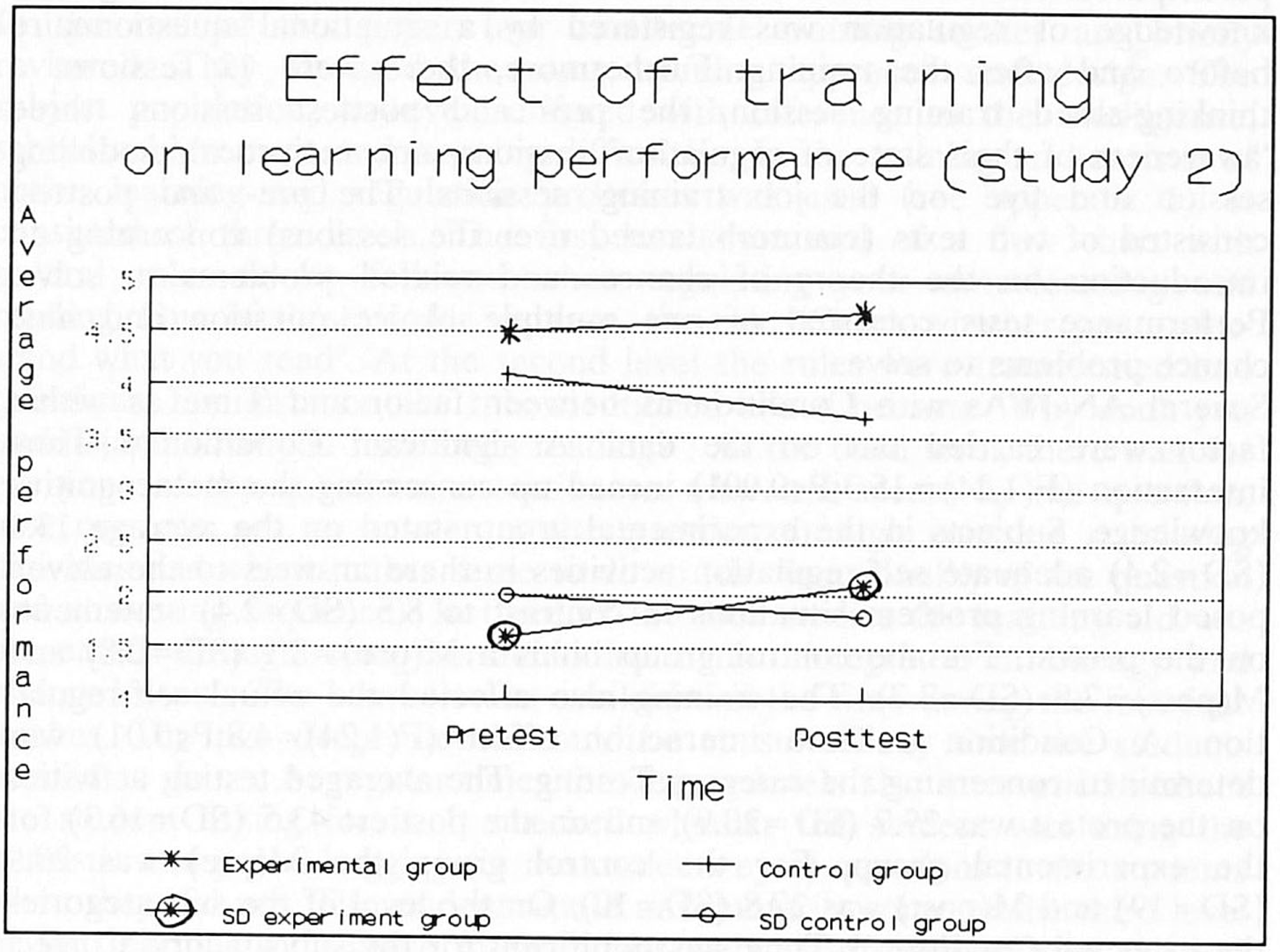

Figure 1: Average performances in study two.

The data were again analyzed through several ANOVAs. There were several significant Time effects on the main categories of the category system as well as on the subcategories. Thus, during the posttest session students in both groups used less regulating activities than during the pretest session. The expected condition x time interactions failed to show up, for all of the main categories and all but one of the subcategories tested. The only interaction effect approaching statistical significance was in the subcategory "Rereading a word" ($F(1,37)=3.98; P=0.053$). The subjects in the experimental group reread on the average 7.0 words ($SD=6.4$) as compared to the 5.2 words at the pretest time ($SD=4.1$). For the control group, the figures were $M(post)=4.4$ ($SD=4.6$) and $M(pre)=5.6$ ($SD=6.1$). The expected condition x time interaction turned up to be statistically significant in an ANCOVA with verbal intelligence and comprehensive reading ability as covariates for the performance measure ($F(1,32)=3.9$;

$P<0.05$). The average performance of the experimental group increased from 4.5 (SD=1.6) to 4.8 (SD=2.2), whereas that of the control group decreased from 4.1 (SD=2.0) to 3.6 (SD=1.6) (see figure 1). At the end of every learning session some questions were posed. The experimental group performed better than the control group in the sessions 6 and 7.

Study 3

In this study 20 students from the first grade from a special school for agricultural lower vocational education participated. It formed a complete replication of study 2 with reference to design, materials, procedure, data analysis, etc.

Again, there were no condition x time interactions when the main categories formed the dependent variables. One of the interaction effects for the analyses with subcategories was statistically significant: "Noticing positive results" ($F(1,17)=5.2; P<0.04$). The control subjects increased their average number of these statements (M(pre)=0.1, SD=0.3; M(post)=1.3, SD=1.7), whereas for the experimental subjects a decrease occurred (M(pre)=1.0, SD=1.2; M(post)=0.4, SD=0.9). The expected condition x time interaction also failed to show up in the learning performance. The means and standard deviations are shown in figure 2.

Study 4

Because of the meager results of studies two and three a fourth study was set up in which the regulation training was embedded in a curriculum of learning how to identify the main ideas in a text (Aarnoutse, 1985). Regulation training took place during the time the students made their homework for this curriculum on the computer. The control group made their homework at home, as usual. A reading test to diagnose students' ability to identify main ideas in text was added to the pre- and posttest sessions. As posttest a modified version of the situational questionnaire of the first study was also added.

Forty reading disabled students from the first grade from a special school for agricultural lower (individual) education took part in the experiment.

Protocol data were analyzed by ANOVA and two Condition x Time interactions appeared to be significant for the subcategory 'Noting negative results' ($F(1,35)=5.72; P<0.05$) and the subcategory 'Noting task features' ($F(1,35)=5.04; P<0.05$). The first subcategory mentioned holds a M(pre)= 3.0 (SD=3.9) and a M(post)=2.0 (SD=3.2) for the experimental group and a M(pre)=0.7 (SD=1) and a M(post)=1.4 (SD=1.9) for the control group. For the second subcategory M(pre)=2.5 (SD=4) and M(post)=1.5 (SD=1.4) for the experimental group and for the control group the M(pre) amounted to 0.6 (SD=0.8) and the M(post) to 1.8 (SD=2.4).

None of the expected Condition x Time interactions regarding the performances were significant. The same holds for the test scores related to the curriculum. However a t-test on the data of the situational questionnaire reveals a significant Condition effect (t(38)=3,03;P<0.05). The experimental group posed on the average 4.6 (SD=2.0) statements related to self-regulation which was trained in order to solve the hypothesized situation in contrast to the average of 2.8 (SD=1.7) statements by the control group.

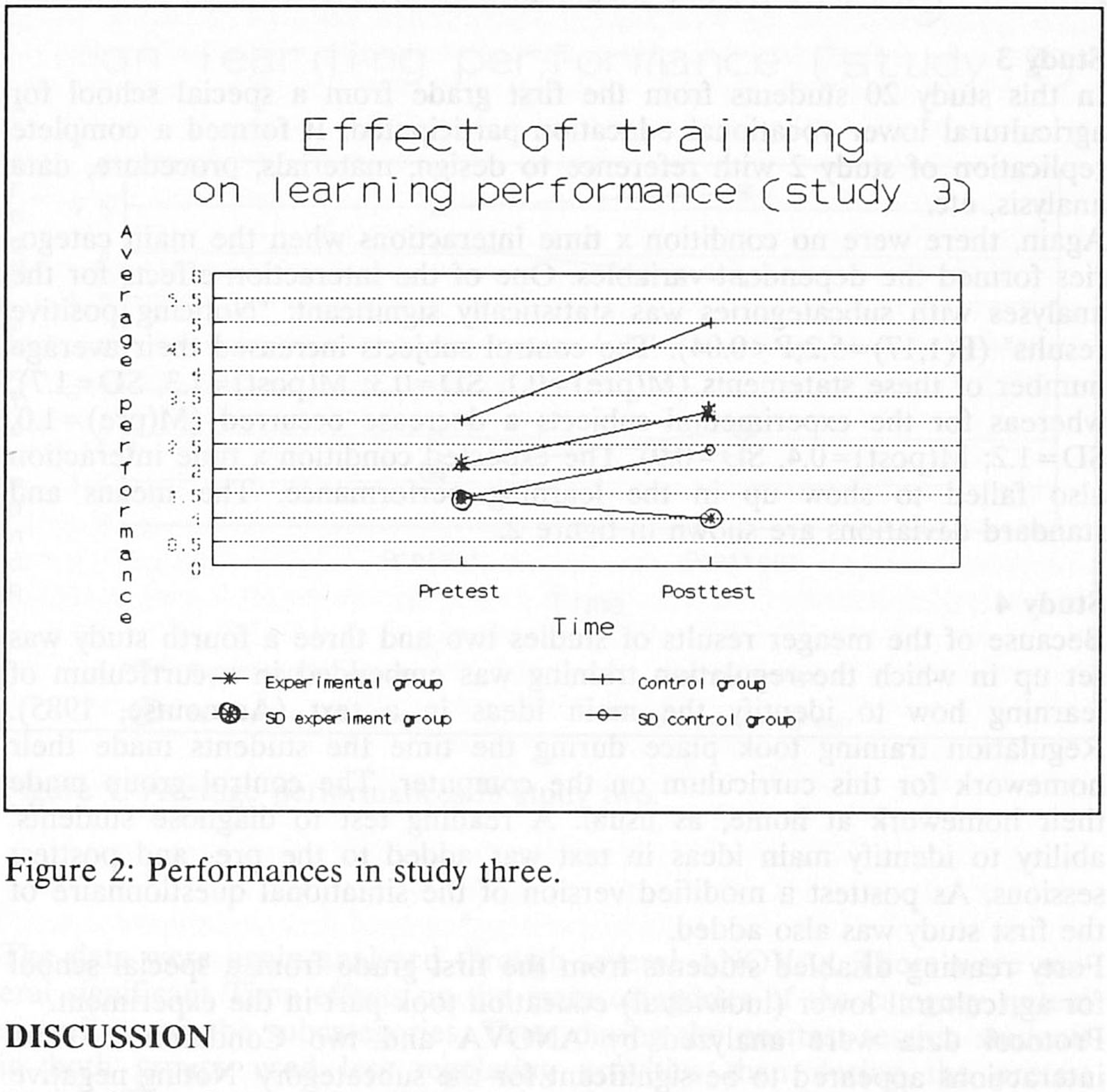

Figure 2: Performances in study three.

DISCUSSION

Two of the four studies show a positive effect of the training on the student's metacognitive knowledge. However, the results are meager as far as this knowledge is transferred in actual regulation activities during learning. Although there were tendencies towards better performances in two of the four studies they fade away when students are more disabled learners. Thus, in spite of rather intensive and lengthy training efforts, we failed to reach the expected results. Several causes might be due to these results.

In the first place, it seems to be the case that when a human tutor plays a part in the training the effects are the most positive (see study 1 and previous studies). It looks as if, when students have less intelligence or learning disabilities, the training rather has a negative in stead of a positive effect on the regulation of learning. Probably a certain ability of abstract reasoning or reading ability is necessary in order to transfer the information given by the learning aid and its interventions into adequate regulation activities. The fact that the computer assistance in learning to learn only can take place on the basis of a-priori expected failures and an almost randomly putting diagnostic questions interventions never are as tailor-made as those from a human tutor. Especially for learning disabled children this might be crucial because of students' low ability of abstract reasoning. The effect of the asynchronic intervention course of the computer tutor might even be worse by learning disabled students because of the tutor's lack of affectiveness. The same goes for its incompetence to go along with these factors in order to motivate and stimulate students concept that learning is an active manipulation of learning strategies and skills to internalize knowledge or to the reach stated learning goals. It is also possible that a more playing environment is necessary in which more demonstrations are available and students are more in the opportunity to imitate and participate in the role of a self-regulated learner and identify the sense of self-control and loss off external overcontrol and dependence. The fact that in some studies performances during the training tended to be better for the experimental group which is not reflected in the results of the posttest might be an indication that our measuring was not sensible enough. The pre- and posttest were only related but not based on the training material so the transfer from one to an other situation might reduce the effects. Secondly the pre- and posttests actually were developed for secondary comprehensive students. So the task difficulty also might overshadow the effects. Furthermore, it seems contradictory to give students with a low reading ability information about how to learn in a textual format. So probably computer assisted learning to learn for learning disabled students has to make more use of visual user interface and interactive video to demonstrate and explicate how regulation of learning takes place.

In the introduction, we discussed and reviewed several factors impeding active learning. In our training studies we tried to overcome some of these (regulation skills, metacognitive knowledge). For learning disabled students, however, this seems not to be enough. Perhaps that in other attempts we should focus more on the other impediments, in addition to the ones tried here. One possibility might be to focus still more on the affective, volitional and motivational factors impeding active learning (see for instance Paris, 1988). A second possibility might be to give more attention to the modification of learning conceptions through awareness training and discussion. Finally, perhaps the actual skills of learning, like finding the main idea of reading comprehension, should also get more attention.

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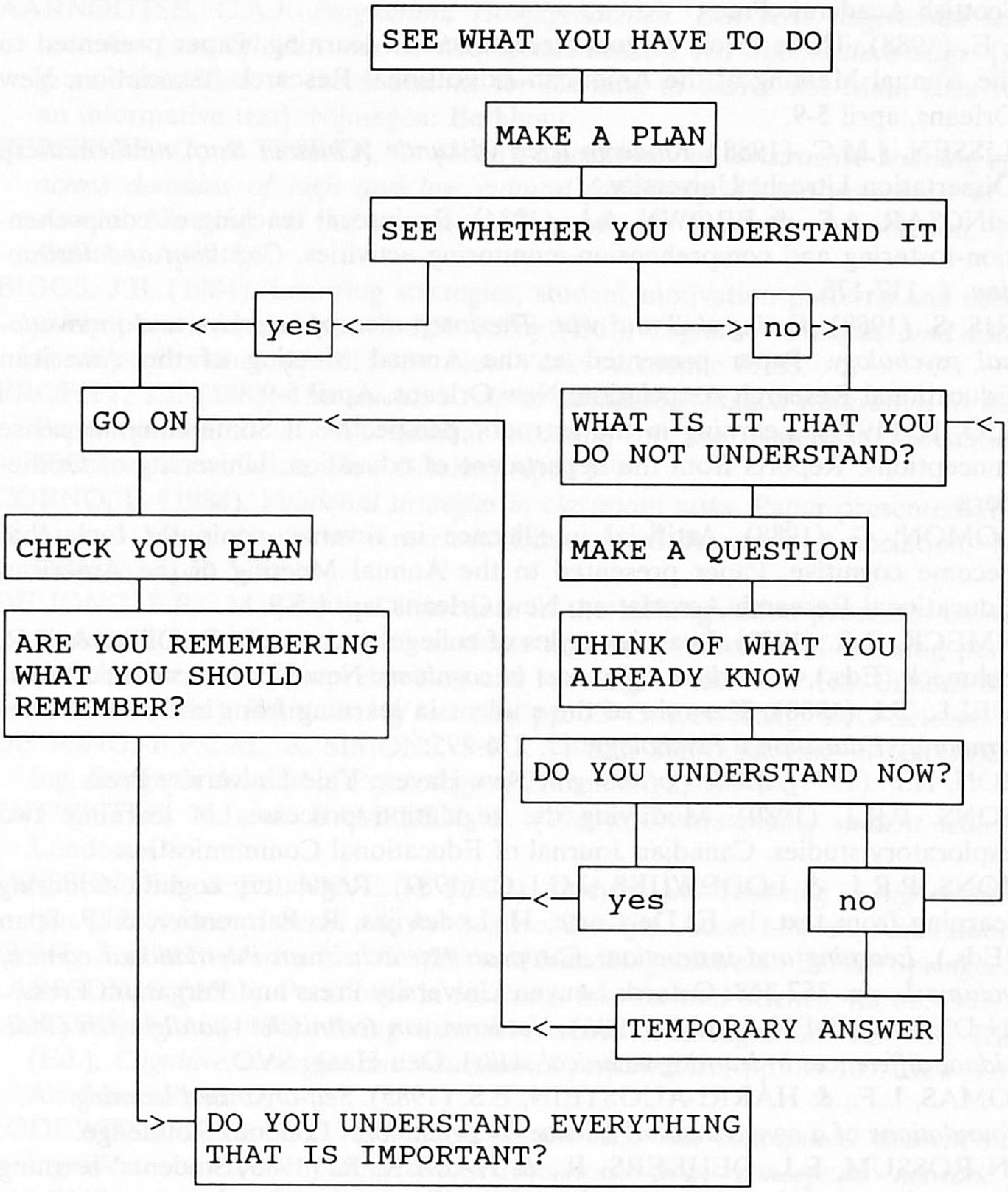
APPENDIX 1: Heuristic of active learning and regulation processes



APPENDIX 2: Process analyzing scheme

<u>Transforming</u>	
L	Reading
IP	Drilling
IA	Adding information, drawing on previous school learning
IAe	Adding information, drawing on one's own experience
LO	Copying
<u>Orientation</u>	
D	Glancing through the task
DL	Going through a subject list
AS	Mentioning his or her normal study strategy
RE	Reflecting on positive student characteristics
RE-	Reflecting on negative student characteristics
RV	Reflecting on foreknowledge
RV-	Reflecting on gaps in the foreknowledge
<u>Monitoring</u>	
CP	Noting positive interresults
CN	Noting negative interresults
CT	Noting task characteristics
CH	Noting one's own activities
TE	Interevaluation
COW	Noting uncomprehended words
COT	Noting uncomprehended text fragments
COS	Noting remainder study time
<u>Directing</u>	
PL	Planning
KA	Process selection
SA	Selecting information as object of attention
AP	Problem identification
KD	Dividing a problem into subproblems for solving
N	Ignoring an uncomprehended word by reading on
W	After noting an uncomprehended word, reading further in the expectation that classification will follow
IV	Asking information
HW	Rereading a word
HL	Rereading a text fragment
AT	Anticipation on the test
HT	Adapting one's learning to the remaining study time

<u>Testing</u>

P+	Paraphrasing in consensus with the text
P-	Paraphrasing not in consensus with the text
C+	Drawing a conclusion in consensus with the text
C-	Drawing a conclusion not in consensus with the text
VT	Comparing two or more text fragments
VC	Comparing one's conclusion with the text
R	Recalling
RS	Recalling and writing
V	Comparing the recall with the text
VRV	Comparing the recall with the text and correcting
SI	Making summaries
SG	Making global summaries

<u>Stimulations</u>

OP	General remarks of the experimentor
ROP	General remarks of the subject
SP	Stimulations to verbalize
IVP	Procedural questions of the subject
AO	Reaction of the subject to the remarks of the experimentor