14 Constructive Learning: The Role of the Learner

P. Robert-Jan Simons

University of Nijmegen, Nijmegen, The Netherlands

In long term memory there are, we think, three kinds of memory representations: semantic, episodic and action representations (see Boekaerts, 1987). Semantic representations refer to concepts and principles with their defining characteristics (like a bird is an animal with feathers). Episodic representations are based on personal, situated and affective experiences with instances of the concepts and principles (like I love my little bird). Action representations refer to the things one can do with the semantic and episodic information: solving certain kinds of problems, using the knowledge (like birds can bring over messages).

In our definition, constructive learning has to do with attempts of learners to build rich and complex memory representations showing a high degree of connectedness (see Prawat, 1989) and having strong relations between semantic, episodic and action knowledge. Ideally, the connections both within these three kinds of representations and between them are rich and strong. Furthermore connections with the three kinds of knowledge representations in other domains are also thought to be important. Constructive learning is learning striving for these kinds of connected representations.

Characteristics of Constructive Learning

Six Core Characteristics of Constructive Learning

The main characteristics of constructive learning were formulated by Shuell(1988):

> ....(constructive) 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. (p. 277-278)

Two additional characteristics of constructive learning are, in our view, that it is diagnostic and reflective. This means that learners should undertake activities like monitoring, self-testing and checking that help them diagnose and judge whether they are still pursuing the goal they had set. Moreover, it means that learners should be or become aware of their way of learning.

Though these six characteristics form the core of constructive learning, this does not mean that all constructive learning is proceeding or should proceed according to all of these lines at the same time. Sometimes constructive learning is very active indeed, but at other times the amount and quality of activity drops to lower levels. Nobody can stay active all the time: activity levels should vary. Perhaps very active learning periods and more passive ones should follow each other for learners to hold on for longer periods of time. In a similar way constructive learning cannot be cumulative all the time. Some times prior learning confuses new learning so much that it is better to build a wall between the two. Moreover if you do not have much prior knowledge in a certain domain it is impossible to learn cumulatively. Of course you may then use prior knowledge of a general nature or from other domains (analogies).

Thus, the amount of cumulativity possible and desirable should and will also vary across learning situations. Furthermore, learners cannot learn constructively (in the sense meant by Shuell) all the time. Sometimes you have to concentrate on the specific subject matter that you have to learn without elaborating and integrating too much. As shown by Pask (1976) some learners act as globe-trotters, who go everywhere without finding a place to rest or stay: they relate everything with everything else and end in total chaos and confusion because they do not focus on details and procedures. Also, learning cannot and should not be goal-directed all the time. Sometimes one should be satisfied with a global, general learning goal and let the learning environment guide discoveries. Sometimes it is even impossible to have clear learning goals: if there is no teacher to help formulate goals reachable in a certain amount of time, learners can only know what goals are possible when they have become an expert in the field. Of course learning cannot be diagnostic all the time either. If a learner spends all the time diagnosing his own learning he has no time to learn. Focusing too much on the state of your mind may even hinder learning, as Kuhl (1983) has shown. Finally, the argument also holds for our last characteristic reflectivity. In learning, reflective periods should occur, but not continuously.

The six characteristics of constructive learning thus do not form necessary conditions that have to be fulfilled in all instances of constructive learning. Instead they should be seen as prototypical in the sense that when they are all there it is clear that learning is constructive. But if one or more fail to occur, learning still can be constructive. Still in our approach they are considered to be so important that they belong to the six core characteristics.

Six Secondary Characteristics of Constructive Learning

Some other characteristics of constructive learning, though showing up in some instances of constructive learning and in its descriptions by others, do, in our view, not belong to its prototypical core. We do not believe that constructive learning in its essence should be discovery oriented, contextual, problem oriented, case-based, social, or intrinsically motivated. Thus, these six other characteristics, although they may have to do with some forms of constructive learning, are in our approach not as central as the prior mentioned six.

Although discovery learning can be very powerful and constructive, the research and debates in the educational psychology of the sixties, has clearly shown that we should not confine learning to discovery learning alone. It is too time-consuming and inefficient. Discovery learning can have an important place in a sequence of learning processes (especially in the beginning phases to motivate and in the final stages when application is the goal of learning), but it should not be the only learning model.

Probably the most controversial part of our view of constructive learning is that we do not believe that contextualization belongs in the key characteristics. Of course, many instances of school learning are too decontextualized and many improvements can and should be made as to the contextualization of school learning. Contextualizing knowledge representations with episodic and action representations are, however, only two of many instances of constructive learning. Building strong connections within semantic, episodic or action representations form equally important instances of constructive learning. Furthermore, forming connections between different domains of (semantic) knowledge also are important examples of constructive learning. Experience with learning environments that have hagh context (e.g. job training, discovery learning, simulation) has shown that decontextualization, rather than contextualization, is the main problem. Under these circumstances learning is often not constructive because there is no decontextualization. Learning remains bound to the context of the simulation, or some job contexts. The consequence is that the resulting memory representations are inflexibly related to one or a few contexts only. The key problem is that there should be a balance between contextualization and decontextualization. Not the question whether there is contextualization and decontextualization, but their interrelations and their timing are the important issues in learning. Finally, we have serious doubts whether the sequence of contextualizing first and decontextualizing afterwards is the optimal sequence for all kinds of subject matter (see higher mathematics) and is the optimal one for all kinds of students (see also Prawat, 1989).

We also question the position taken by some others that constructive learning should be problem-oriented and case-based. Problem orientation and organizing learning around cases clearly is good for contextualization and motivation. Problem orientation strengthens the connections between semantic and action representations. Cases connect episodic and semantic representations. As stated before, these are important indeed, but not the only ones to be considered in constructive learning (see above).

The position that constructive learning is social or even that only social constructions of reality are possible, is strongly defended. Most of the time in this connection, in one way or another, Vygotsky shows up. In the Netherlands, already in the seventies, when we had our "Russian revolution" in educational psychology, many of the debates concentrated on this social issue. Learning together with other learners can be a very powerful form of learning, in which learners help each other's construction processes. Many studies show how powerful social learning environments can be (see Palincsar and Brown, 1984). In our view, however, and according to our experience, social learning can also be very ineffective and inefficient (see also Salomon, 1988b). Some teams do not function the way they ought to. Some learners (for instance the author of this paper) prefer to learn without social support. Some contents and domains do not lend themselves to social learning (see for instance Biemans and Simons, 1991). Besides, people can also discuss and interact with themselves and be social in this way. Finally, social aspects of learning can also be built into teaching materials and computers.

The last characteristic to be considered is intrinsic motivation. Constructive learning can have some connections with intrinsic motivation, but many times it will not. Convincing arguments were put forward by Brophy (1988). It is not the kind of motivation that comes out of the materials and the environment that is the most important, but the motivation to learn. This means being motivated to find out certain things, to have a desire for knowledge, to like learning and to keep on learning even if its relevance is not immediately clear or when it gets boring.

Constructive Learning is Self-Regulated Learning

The points discussed before can be summarized as follows. Constructive learning is learning striving for rich and varied memory representations within the three kinds of memory representations discerned, as well as between them and between different domains. Six characteristics are believed to be of primary importance without them being present necessarily all the time: that constructive learning is active, cumulative, constructive, goal-directed, diagnostic and reflective. Six other characteristics, being stressed in other theories are considered to be of secondary importance only: that constructive learning is discovery oriented, contextual, problem oriented, case based, social and intrinsically motivated.

Because constructive learning relates so closely to the building up of certain kinds of memory representations by learners themselves, a very important role for the learner himself cannot be missed or denied. Only learners themselves can be the active participants in the learning process. Only they know the prior knowledge that should be used cumulatively. Only the learner himself can be constructive (in the narrow sense meant by Shuell). Only the learners can be the diagnostics of their own learning. An outsider (like a teacher) can never have access to the inside of the learner that the learner himself can have. Only a goal that a learner himself strives for counts. One can never force people to have goals they don't want to have. Finally, reflectivity also demands an active role of the learner. Constructive learning presupposes, it is our conviction, self-regulated learning. In part three of this paper therefore we elaborate on the subject of self-regulated learning. First, however, some of our experiences with constructive learning are discussed in part two.

Students View Learning Differently: Some Experiences With Constructive Learning

We have experience with constructive and self-regulated learning in several research projects in our laboratory. One study, for instance, was about learning conceptions and learning styles of Open University students who are learning out of self-instructional packages (Vermunt & Van Rijswijk, 1988). Another studied self-regulated learning of students from secondary education (De Jong & Simons, 1988; 1991; Simons & De Jong, 1991). A third research project was on self-regulated learning of a word-processing package, WordPerfect, (see Biemans & Simons, 1991; Teurlings & Simons, 1991). A fourth research project was on the activation of prior knowledge (De Klerk, Ali & Simons, 1991). Innovative projects concerned on the one hand introducing open learning in an industrial context, implementing so called Leittexts and problem oriented learning environments in industrial and school contexts (see below) and on the other hand trying to implement learning to learn approaches in schools. Currently we are involved in a large scale innovative project in the city of Rotterdam. Here, schools are stimulated to introduce integrated learning to learn approaches in all of their lessons and to stress constructive learning by students themselves. One very powerful strategy introduced here is that teachers should divide instructional and learning time equally over knowledge, integration and application. This means that if there is, for instance, one hour time, maximally 20 minutes are devoted to knowledge transfer by the teacher. The other 40 minutes are to be used for integration activities by the students (for instance finding relations with episodic knowledge, increasing connectedness) and for applications. It proved very difficult for teachers to hand over control to the students. Those who succeeded, however, improved the learning of the students considerably.

A general conclusion from our research and innovations is that both in students from secondary education and in adult learners there are different views about learning. Some see learning as the reproduction of facts and ideas, whereas others see the essence of learning as construction of knowledge representations. Some of these constructive learners emphasized semantic and episodic kinds of knowledge. Others stressed action knowledge and were oriented to the possible use and application of the information they encounter. Thus there were three kinds of views: reproduction, construction and use-oriented. These different views on learning correlated closely with different learning styles and strategies: surface learning, deep learning and concrete learning. Against our expectations, we failed to find evidence for some expected correlations between the different learning styles and learning outcomes. We had expected that reproductive surface learners would reach better results on recall questions, constructive, deep learners on insight questions and concrete use-oriented learners on application and problem solving kinds of questions. Instead, constructive learners performed the best on all three kinds of outcomes and reproductive learners the worst.

One important thing we learned is that constructive learning is, for reproduction-oriented learners, not an easy approach to learn. There are many obstacles in real life impeding the development of constructive learning abilities and tendencies (see Simons, 1989). Reproductive learners do not believe in the possibility to learn without their secure "learning by heart procedure". They have fears of constructive learning activities. They tend to distort assignments in a reproductive direction (for instance by learning the answers to questions that were meant to stimulate constructive learning by heart instead of thinking about it). They avoid learning situations that call upon constructive learning abilities. They interpret exam demands as calling for extreme reproductive abilities (even though they may be directed at higher level skills). They lack the skills to use their prior knowledge and to monitor and check their own construction processes.

Learning is an ability that is deeply rooted in personality, that develops over years and years and that cannot be changed easily. Furthermore, there are all kinds of interactive patterns between learners and teachers that impede the development of constructive learning abilities and tendencies in learners. Teachers tend to believe in active, constructive learning by students themselves. Eighty percent of teachers agreed with the statement that independent learning is very important. If and when they try to call upon independent learning abilities, however, they discover that many students are not able or willing to reach an adequate level of independent learning on their own. Therefore, they decide to take back control over the learning processes by providing structure and informing students intensively. In this way, however, students do not learn how to control their own learning processes. Many even come to believe that it is the teacher who should organize learning. It is our belief that this interactive pattern of teachers and learners, showing up in all kinds of learning situations and with learners of all kinds of ages and ability levels (see Larsson, 1983), forms the main obstacle for constructive learning. Because of its circularity and because it reinforces all kinds of needs of both teachers and learners it is very difficult to break the circle. If we want to have constructive learners, however, we should find a way out. Below we will come back on this interactive pattern and illustrate it.

Toward a Theory of Self-Regulation in Learning

Self-Regulated Learning

In this section we discuss our theory of self-regulated learning. What are important abilities of self-regulated learners? Self-regulated learning, in our opinion pertains to: being able to prepare one's own learning, taking the necessary steps to learn, regulating learning, providing for one's own feedback and judgement and keeping one's concentration and motivation high. 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 learning of the students through testings, questions observations (etc.), judge the learning progress and provide feedback and try to keep students motivated and students' concentration levels high. One may also say a self-regulated learner is able to be his own teacher. Following Shuell (1988), the underlying psychological functions to be fulfilled either by learners themselves or by teachers will be called learning functions.

Below follows our view of the various skills that comprise self-regulated learning or, in other words, of the various learning functions to be fulfilled:

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 (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 (Corno,1988).

Self-regulated learning itself consist of the use of adequate learning activities and strategies (tuned to the goals set). A self-regulated learner is able to shift flexibly between different learning activities, depending on the goals and task constraints. He is able to execute learning activities that lead to knowledge, to comprehension, to integration and to problem solving. Several authors studied the learning activities that lead to these four kinds of goals (for instance Biggs, 1984; Entwistle & Ramsden, 1983; Janssen & Deneve, 1987; Marton & SÑljî, 1984; Ng, 1988). Vermunt (1987) integrated many previous attempts in his description of learning activities used by Dutch Open University students. He discerned the following: memorizing, repeating, analyzing, structurizing, relating, selecting, concretizing, personalizing and criticizing. Like previous investigators, Vermunt found individual differences in the extent to 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, learners should observe and interpret their own behavior and thinking and control whether they are still on their way to the goals and 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.). Also by answering self-made or supplied questions self-regulated learners can test their state of knowledge and understanding. One important result from studies done in our laboratory is that especially the extent to which students tune their self-testings to the learning goals is a powerful predictor of performance (Simons & Lodewijks, 1987; de Jong, 1988). Revision mechanisms refer to decisions one has to take when problems or blocks occur. One then can 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, 1988a). Evaluation of the process of learning forms the last regulation mechanism leading to changes in future processing and metacognitive knowledge of learning.

The fourth aspect of self-regulation, **performance judgement and feedback**, is of special significance in learning situations. Teachers have very dominating roles as to performance judgment (grading) and feedback. Self-regulated students, however, have to be able to judge their performance on their own. In addition, they will not receive feedback from the outside. Self-regulated learners should use opportunities for obtaining feedback optimally. When there is a possibility to get feedback (for instance because the correct 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 know immediately.

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 refers to questions like: when and how long should one take a break, what should one do when concentration fails, how can one exclude internal and external distractions, etc.

Self-Regulation Versus Regulation by Others

The most extreme form of self-regulation in learning occurs when people 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, feeding back to themselves and maintaining high motivation and concentration. Most of the time, however, third persons (teachers, or their substitutes, 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 independent of others. On the other hand in almost every situation there is some opportunity for self-regulation, be it only decisions as to speed of working or effort expenditure.

Extension of the responsibility of people 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 people (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 people more opportunities to regulate their own activities and to bear responsibility. This, however, is often problematic in practice. Apart from the people who might profit from these opportunities, there are also who will perform (even) worse when left free (Lodewijks,1981; Van der Sanden, 1986). People who are not used to freedom and responsibility may not (yet) have the capabilities needed for independence. People may not believe that they are capable of self-regulation. People may dislike responsibility. Responsible persons may hesitate to hand over power to their subordinates. Larsson (1983) discussed these kinds of conceptions, circularities and paradoxes: 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. An important lesson to be learned from all of this, is that there is needed much more 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.

On Becoming a Self-Regulated Learner

In our opinion there is only one way out of the paradoxes and circularities discussed and this is by training people in self-regulation. We propose a kind of paradoxical solution. We can only expect teachers to hand over control to students when they believe that they can bear the responsibility. Therefore we need to convince students that it is important to become a self-regulated learners. Moreover we need to teach them certain basic self-regulatory skills and habits. Following that, the teacher should withdraw gradually and hand over control to the students more and more. One main goal of training programs should thus be to convince students that they have their own responsibility and that they can become able to regulate their learning.

Instructional systems differ in the extent to which they provide for explicit help, structure or advise for the various learning functions. Some systems take care of almost all of the functions, leaving only few possibilities for the student. Other systems let students fulfill many of the functions themselves. We think that there are three ways instructional systems can have an influence on the learning functions of students: taking over, activation or stimulation (cf. Wittrock, 1979). Taking over a learning function 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. 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 advise to execute certain learning activities and leave out some other, or training students in the learning functions. Stimulation occurs for instance when a teacher advises students to learn in a meaningful way, or when he teaches them to use certain learning strategies or self-regulation skills.

There are advantages and disadvantages connected to the three ways to cope with learning functions. **Taking over learning activities** that students could perform themselves decreases the active participation by students (sometimes even interference effects may occur, see Simons, 1980; 1984). A consequence may be that students 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 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 use which 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 pre-conceptions and advance knowledge with new knowledge and skills. Perhaps self-chosen activities and regulation processes might lead to better results than the activated ones.

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. On the short term, however, this may result in lower performance, frustration and resistance.

Thus, when teachers present a summarizing scheme students cannot and will not create their own structure. When teachers activate structurizing activities by giving them the assignment to create a scheme of relations, students cannot and perhaps will not use their other structurizing abilities. Finally, when teachers stimulate students to structurize text information in a way that is too general, students who are unable to do so may acheive lower results than they would have given other methods.

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 make their own notes using their schematizing and structurizing 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, one is usually forced to take over important learning activities as a first step. Gradually then the learning activities and regulation processes, once they have been learned, can be activated. Thus 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 practiced and activated, gradually the teacher should replace his 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 until now have failed to succeed. Overall there was a complete lack of transfer to regular learning situations. Domain-specific approaches, however, seem to be more promising (see below). Perhaps a combined general and domain specific approach might form an acceptable compromise.

In the next section three new instructional systems will be discussed in light of the concepts introduced in the present section.

Analyzing Three Learning Environments that Aim to Induce Constructive Learning

The Leittext Method

In the West-German industrial sector, as a reply to new demands on flexibility and independence of workers, a new method was developed to teach practical working skills, like constructing a machine. Later this method was broadened and became applied to other kinds of skills and subject matter, for instance machine repair, selling strategies and text processing. In this method one structures the learning by the workers in six phases: informing, planning, deciding, executing, controlling and evaluating. Thus workers are informed (or inform themselves) about the kind of product they have to make, how it looks, what principles to use, what is important, etc. (informing). Then they plan for the way they want to proceed. This plan is discussed with the teacher or counsellor (deciding). Then the plan is executed. Next, the product is controlled by the workers themselves (controlling). Finally, together with the teacher, the whole process of learning is evaluated.

When the method is used for the first time the steps are structured in a detailed way. Later the role of the teacher can be reduced and workers take over more and more, using the same six steps on their own. This method was developed out of dissatisfaction with independent learning projects that were used often in German industrial training. The projects often failed. In seeking ways to give more structure to the approach, the Leittext method arose.

Four specific kinds of learning aids were developed: steering questions, information questions, planning aids and control lists. Steering and information questions are used in the first phase (informing), directing students towards an analysis of the end product, both with reference to skills and knowledge to be used and to regulation processes. Different kinds of planning aids are used: a) planning cards on which the different steps to be taken were ordered randomly (to be put in the right sequence by the workers); b) planning cards where certain steps were filled in already, while others had to added by the workers themselves and c) empty planning cards. Control lists consisting of the criteria to be used in judging the product when ready. These can be ready made, or filled in by the workers themselves.

The Leittext method explicitly aims at allowing one to work independently and to solve problems on one's own. It does so by creating a structure in which workers can work independently without encountering too many problems or straying too far away from the intentions of the teachers. The preparatory phase of the work planning and problem solving are especially highly structured. At first, the method takes over the orientation on goals and activities, the choice of goals and their relevance (through steering questions and informative questions), the planning of activities and their sequence (planning and deciding) and the evaluation afterwards. The recall of prior learning is activated through questions. The control of the work, when it is finished, is activated through control-lists and the evaluation, judgment and feedback is taken over in the evaluation phase. When workers get used to the method, taking over of the orientation and planning is replaced by activation or perhaps even stimulation and the activation of control is replaced by stimulation of control.

It remains unclear, however, how and when the gradual shift toward activation or stimulation takes place. Also, it remains unclear whether the other aspects of self-regulation play any systematic role at all, for instance: Is self-confidence stimulated? Are students helped with other noncognitive aspects of self-regulation (getting started, getting attention, staying motivated, concentration management). Is there any systematic help during the execution phase (monitoring, testing, revision, reflection)?

One remarkable tendency we noted, is that most of the published applications of the Leittext method apply it in rather distal situations. For instance students develop a hobby machine in a school-like setting having hardly anything to do with the kinds of machine they have to construct or use later on. Few applications use real life simulations or even on-the-job settings.

The Leittext method does not explicitly aim at learning to work independently and learning to learn since its main purpose is to guarantee that independent work leads to satisfactory results. Perhaps, however, the system as a whole has some influence on the way students tackle other problems and on how they proceed when learning independently.

Typically in the Leittext method one tries to create conditions that permit students to work independently without doing too much harm. This is accomplished by placing heavy emphasis on the orientation and planning phase: "Think before you do. Collect all the information you might need; think of criteria your product should meet; make an explicit work plan; start only when your teacher says your planning and list of criteria is complete (etc.)". For some products (like constructing a machine) this seems to be the only way to do it. In other cases (for instance in learning to work with a text processing program) there might be solutions that place less emphasis on the orientation and planning phase. In our experience, as is the finding of Carroll (1987), many people hate to think before they start doing. Carroll's subjects for instance "jumped the gun" and wanted to start working as soon as possible. Also, in many Dutch training studies applying Galpe´rin's theory on the stepwise building of mental activities, similar problems occurred (Van Parreren, 1983). Students did not like to become oriented completely beforehand, they wanted to start as soon as possible. Furthermore, in many situations (according to Van Parreren) it is impossible to plan everything before you get started: only during the working or learning event itself can complete control develop.

Therefore, in our opinion, adaptations of the Leittext method should be developed which incorporate possibilities for orientation and planning during or even after the completion of construction activities. Moreover, perhaps "on-the-job" applications or real life simulations like "lernburos (office simulations)" of the Leittext method should be preferred in the future. Finally, there is, in our view, need for a more systematic approach in the Leittext method toward the gradual withdrawal of the external regulation of the orientation, planning and control phases, incorporating notions about learning to work independently and learning to learn. The theory described might offer some help in this respect.

The main experiences we had with the Leittext method show that in general learners are very enthusiastic about it. However, they sometimes think it is cumbersome to find out everything on their own. They prefer to have simple information told to them instead of having to discover it themselves. Moreover, it became clear that the method takes a lot of time. This time-investment may perhaps have long-term effects. Since we are not able to measures these kinds of effects adequately, it is difficult to prove that they are real and not only existing in the minds of teachers and learners. Finally, it also became clear that it takes some time to convince teachers and learners that the method really works and to teach them the relevant teaching and learning skills.

Problem-Oriented Learning

In the Netherlands another new system of instruction was developed. Originally it was used in professional medical education. Later on, applications in other domains like law, social science industrial training and teacher education were used successfully. This method consists of fixed phases: problem discussion, analysis, hypothesis generation, finding knowledge gaps, deciding on individual learning goals, individual study and synthesis. At first the students get a written problem description (for instance about a patient coming to his doctor with certain symptoms like coughing, breathing problems, blood spitting,etc). This description is as realistic as possible. The students' task (as a group) is not to solve the problem, but to analyze it and to generate as many hypotheses as possible about explanations of the symptoms. Moreover, they have to find out what they already know about these explanations and what their knowledge gaps are.

Following this they decide on group or individual learning goals: what do we (or do I) want to learn relating to this problem and its possible explanations. Then follows individual study in the library or at home, using lists of books and articles supplied by the department. A tutor is available for any help the group or individuals might find useful. Finally, individual learning results are brought together in the group. The students inform each other about what they found and learned. They look one more time at the problem description that started the whole learning process and try to formulate conclusions. At regular times there are exams where the subject matter knowledge and skills to be learned are tested. Every year of study the students should be better able to answer the exam questions. At the end they should be able to know the answer to 80 % of the questions.

In the Problem Oriented method, like in the Leittext method, an emphasis lies on the preparatory phase. Through the problem description that is provided, students are activated to orient themselves on possible learning goals. The problems are written in such a way that there is a close link to the later professional practice. In this way the motivating to learn function is taken over by the system. Either as a group, or individually, students are activated to choose certain learning goals which automatically have relevance for them (through the connection with their later professional practice). Also, the recall of prior learning is taken care of explicitly: students are activated to think of everything they know in relation to the problem and its explanations.

The actual learning steps and their regulation are unguided however. Students are expected to be able to take the necessary steps to learn in order to reach their agreed upon learning goals. The way they should monitor and test their learning, or revise their strategy when confronted with problems, is unguided. They have, however, ample opportunities to "practice" independent learning. Furthermore, the tutors may provide help to those students asking for it. Some structuring of the judgment, feedback and evaluation occurs in the synthesis phase where students integrate and discuss their individual learning. Finally, there is no help in staying motivated and concentrated.

The Problem Oriented method does not aim at the improvement of problem solving or thinking skills in a direct way. Students do not learn how to solve the problems presented, nor do they learn a problem solving strategy. Because of the direct connection of the learning goals to the problem descriptions, however, some effects on problem solving skill may perhaps be expected. In most of the Problem Oriented systems of education separate skills courses supplement the theoretical study.

Finally, the Problem Oriented method can teach students how to learn to a certain extent. They learn how to prepare themselves for learning (orientation on possible learning goals;

choice of goals, recall of prior learning, motivating oneself to learn). It depends on coincidence however whether the actual skill of learning and regulation of it will develop or not.

What one could and, in our view, should learn from the experiences with Problem Oriented learning is that it is very important to focus on real professional problems (for instance through problem descriptions) and help students connect their learning to professional practice in a direct and clear way (promoting the relevance of learning goals). Furthermore, the great success of the Problem Oriented method, from our experience, lies mainly in the possibility for students to pursue their own learning goals. However, these are restricted to the domain of professional practice through the connection with the problem descriptions. This not only motivates students to learn, it also takes care of an optimal connection between existing knowledge and gaps in it and the knowledge and skills to be learned (stressing the cumulative nature of learning as discussed by Shuell). A final important aspect of the Problem Oriented method is its emphasis on integration at the end. Students have to inform their fellows students, discover what they learned, and address how it relates to the central problem.

Experience with the Problem-oriented learning approach in different Dutch Universities shows two kinds of results. On the one hand, about one-third of the students do not like the problem-oriented method. They prefer to learn in traditional ways where less activity is demanded of them. Furthermore, some students tended to get back to more traditional forms of learning (going over the problem descriptions very quickly and learning a text book by heart). On the other hand, the results of experiments show that the learning performance of students learning through a problem-oriented method was as good as or better than that of students learning through traditional university teaching on traditional tests. However, there were effects on less traditional tests measuring general skills of problem diagnosis and problem solving that are not reached by the traditional system.

From Apprenticeship to Cognitive Apprenticeship

In earlier days, apprenticeship formed one of the most frequently used systems of education. According to this system, one became a tailor, for instance, by starting to cooperate with a master tailor, most of the time together with one or more fellow youngsters. In the United States and in the Netherlands this out of school system disappeared (recently, Achtenhagen showed that the German history on this point differs greatly from the American and Dutch; we will not go into this discussion here). According to Resnick (1987), this system of "on-the-job training", in contrast to the school system, typically employed: (1) group learning instead of individual learning (2) learning with tools instead of tool-less learning, (3) domain-specific learning instead of widely usable knowledge and skills and, (4) object-manipulation instead of symbol-manipulation. Learning took place in a real-life context. The master-tailor appointed certain tasks to the pupils. At first the tasks were rather simple, but they gradually became more difficult and complex. In the beginning the pupils had only a few responsibilities, but later on they became more and more responsible for their own work. They learned by doing, by observing and by imitating the expert and by getting feedback from him as well as from their fellow-pupils.

Nowadays, the apprenticeship-system has been replaced by the school-system, which stresses symbol-manipulation and knowledge. Even in skill-training and industrial and military training, we prefer to use the school-system. Typically we send our trainees (for instance in management, medical, professional and military training) to school-like settings to learn and understand the concepts and theories to be applied later on in practice. Then we let them practice in real settings, without adequate structuring of the level of difficulty of the tasks, the feedback, or the cooperation opportunities. Resnick refers to American studies showing that the results of these kinds of training are rather disappointing in general. People fail to apply in practice what they learn in theory. According to Resnick, therefore, it may be fruitful to go back to the apprenticeship system. Especially when we want to teach our students how to learn, how to think and how to solve problems, the principles of the old apprenticeship systems should be rehabilitated: this is cognitive apprenticeship. The cognitive apprenticeship approach may also be used in computer-aided instruction, and more in particular in interactive videodisc systems (see below). First we shall discuss the cognitive apprenticeship system in more detail.

In American instructional psychology there is a revived pedagogical optimism: many researchers now believe that it is possible to improve abilities of the self-regulation of learning, thinking, intelligence and problem solving. This optimism stems mainly from the remarkable results of training studies by Palincsar and Brown (1984) on reading comprehension, by Schoenfeld (1985) on mathematical reasoning and by Scardamalia, Bereiter & Steinbeck (1984) on writing processes. In these three studies and their later replications, durable, generalizable and transferable results of training were realized.

Palincsar and Brown (1984) devised a teaching procedure, which they named "reciprocal teaching". Learning disabled children learned how to comprehend texts by discussing text interpretations and text processing strategies in groups. The teacher and the students read text passages together and tried to make sense of them cooperatively. The students had to verbalize their interpretations and their way of thinking and understanding as explicitly as possible. Teaching and student roles were executed both by the students and the teacher (that is why the procedure was called reciprocal). In that way the teacher could demonstrate her own explicit thinking processes (acting as an expert model), at the same time forcing students to make their processes explicit. An important principle used in Palincsar's training was "scaffolding". Gradually, the students were made more responsible for their own reading comprehension.

According to Paris (1988) the following characteristics are fundamental in reciprocal teaching: 1) model strategies explicitly; 2) model strategies in their usual context; 3) inform students of the need to use strategies and their utility; 4) make students realize that the strategies work for them; 5) transfer responsibility gradually; 6) gradually challenge internalization of strategies; 7) tailor feedback and encouragement.

Schoenfeld (1985) taught mathematical reasoning processes. He also used forms of cooperative learning. Students solved mathematical problems in small groups. Through all kinds of questions posed by the teacher, their thinking processes were made explicit and communicated to the teacher and fellow pupils. In cognitive coaching, the following is emphasized (see Paris, 1988): 1) shared goals and affect; 2) linked assessment and instruction; 3) demonstration and explanation provided; 4) responsibility shifted to students; 5) progress is personal and continuous.

Scardamalia and Bereiter (1984) used a direct explanation method to teach children how to write texts. Through a series of questions they posed themselves during writing they were forced to plan and regulate their writings explicitly and publicly. The most important ingredients of the approach were: 1) direct modelling of strategies and regulations; 2) explanation of strategies and their utility; 3) emphasis on student's beliefs.

Resnick (1987) in her analysis of the apprenticeship system, found the following to be characteristic of programs proving successful for acquiring school learning skills:

> 1. They involve socially shared intellectual work. 2. They are organized around mutual accomplishment of tasks so that elements of the skill take on meaning in the context of the whole. Second many of the programs also shared elements of apprenticeship: 1. They make usually hidden processes overt, subject to observation and commentary. 2. They allow skill to build up bit by bit, yet permit participation even for the relatively unskilled. This is often enabled by the social sharing of tasks. Finally, the most successful programs were organized around particular bodies of knowledge and interpretation (subject matters if you will) rather than "general" abilities. They thereby engaged students in processes of meaning construction and interpretation which seem to have the effect of blocking the kind of symbol-detached-from-sense thinking that I have noted as a major problem in school but not in out-of-school-activity. It is just this kind of self-conscious meaning construction and interpretation that is likely to be needed in conditions of breakdown and transition out of school when it is necessary (probably) to use ones powers of reflection and analysis to craft sensible responses to new and as yet ill-understood-situations. (p. 20-21)

The cognitive apprenticeship systems, though they form by no means a uniform system, all focus on the learning functions and stages that the other two systems discussed neglect: these are taking the necessary steps to learn and regulating learning. They teach students how to remember, comprehend, integrate and apply and how to monitor and test whether they do so. Also, revision mechanisms (what to do when you fail to understand, how to proceed in case of trouble) get attention, as do reflection and evaluation. Furthermore, (external) feedback by the teacher and by the fellow pupils plays an important role. In these systems there is an explicit transition from taking over (modelling and explanation by the teacher) to activation and stimulation.

From the descriptions in the literature, however, it is unclear whether the preparatory phases of learning also are stressed. Some cognitive apprenticeship systems pay more attention to affective aspects of learning than others (Paris, 1988).

The cognitive apprenticeship approach focuses both on learning to think and solve problems independently and on learning to learn, depending on the particular program chosen. What one can learn from the experiences with cognitive apprenticeship systems is that learning to learn and learning to solve problems is possible, but it should be guided more closely and explicitly than was done before and a direct connection and integration of attempts to teach students how to learn and solve problems with domain specific normal instruction seems to be of vital importance.

The Three Systems Compared

The Leittext method was described as a method that accentuates the preparatory phase of independent work. The system does not provide for explicit means to teach learning to work independently or learning to learn. Furthermore there is hardly any attention paid to the executive stages of working and problem solving, nor to affective components of self-regulation. The Problem-Oriented method also focuses on the preparatory phase of independent learning. It is more a method that motivates students to learn independently and provides a way to proceed in choosing learning goals than it is a method to teach problem solving skills or other learning to learn skills. In this method, there is also no attention to the executive phases, nor to affective aspects. When students learn to learn through these two systems it is more or less coincidental and dependent on the ingenuity of individual counsellors and tutors instead of built-in approaches. The cognitive apprenticeship system on the other hand neglects the preparatory phase of learning and problem solving, but accentuates the executive phase and (more or less) affective aspects, stressing learning to think and learning to learn.

The three systems, though having much in common, differ greatly when analyzed in terms of our theory. Perhaps an integration is possible and useful. The Leittext method can then be used to structure the orientation and planning phases, using steering and informative questions, planning aids and control criteria. The Problem-Oriented method can be used for guiding the process of goal selection, recall of prior knowledge and promoting awareness of goal relevance, using problem descriptions to be analyzed by the students. The principles of the Cognitive

Apprenticeship system can especially be used in the executive phase of learning and problem solving, incorporating an explicit learning to think and learning to learn approach.

However, such an ideally integrated learning to think and learning to learn approach is difficult for human teachers. Perhaps we will be able to realize it through computer aided instruction. The possibilities of computer tools can be used to shape human thinking and learning (see Salomon, 1988a).

Conclusions

The main argument we would like to put forward in this paper is that constructive learning can not be expected to result from constructive learning environments automatically. Learners, in their long history of experiences with learning, develop persistent beliefs, habits and styles related to learning activities that will make it difficult for some of them to work and learn in constructive learning environments. Learners, from our research experience, interpret learning environments in their own way, depending among other things on their learning conceptions. Thus, we need to teach learners how to behave in constructive learning environments. If we do not, effective systems will be distorted and used in ways we would not want or expect. The tendency is very strong for learners to learn by heart, to stick to the surface, to refrain from thinking and to hand over responsibility for learning to others (such as teachers). We need learning to learn approaches embedded or immersed (see Prawat, 1991) in constructive learning environments.

A second point is that we must educate teachers. As we discovered in studying and implementing Leittext methods, it is not easy for teachers to change a traditional approach into one that stresses learner activities that they cannot control or influence. Strong tendencies which are developed through years of experience make it hard to believe that learners can learn constructively if you give them adequate opportunities combined with a learning to learn approach. Thus, we have to convince teachers, show them how to do it, and teach them the necessary skills.

Finally, we believe it is very important to plan constructive learning thoroughly and to embed it into the total instructional design. We cannot expect learners and teachers to learn constructively during a part of their school days and to return to their habitual way of learning during the rest of the time. This means that we have to offer the following principles for instructional design of constructive learning environments:

- Embed constructive learning environments in the total instructional system.
- Teach learners how they can learn in a constructive way, embedding or immersing this learning to learn into the environment.

- Teach self-regulatory skills. Learning to learn constructively presupposes and encompasses self-regulated learning. Therefore, in instructional design the teaching of self-regulatory skills should be planned.
- Teach teachers how to use constructive learning environments.
- Find a balance between contextualization and decontextualization.
- Develop learning environments that explicitly organize the five aspects of self-regulated learning: preparation, learning skills, self-regulation, judgement and feedback and motivation and concentration.

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