Cognitive abilities, motives, learning strategies and social interactions as components of long-term learning in basic electricity

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Carring out a teaching experiment in 8 grade clacces achievement tests and instruments measuring learning habits and attitudes, special interest, the development of formal operations, the social climate in the classes, and learning strategies were administered. Causal relations between these components were analized by LISREL and subgroups were characterized (continuous and sporadic learners, girls and boys).

Kognitive Fähigkeiten, Motive, Lernstratepien und soziale lnteraktionen als Komoonenten lanafristigen Lernens in der Elektrizitätslehre
Im Rahmen emes Unterrichtsexperimentes im Verlauf des 8. Schuljahres wurden Lernleistungen, Lerneinstellungen, Entwicklungsniveau formaler Operationen, spezielle Interessen, das Klassenklima sowie Lernstrategien erhoben. Mit LISREL wurden Kausalbeziehungen zwischen diesen Komponenten erfaßt und Untergruppen (kontinuierlich und sporadisch lernende Jungen und Mädchen) charakterisiert.

Introduction

Since research in learning and instruction turns back to the process of understanding, the learning of the student is seen as an active process of knowledge construction. In this context learning means “to develop understanding” or “to know something well that was unknown before”. This process can only be studied in a specific knowledge domain. In our case, students conceptions, concepts and rules in physics, and integrated knowledge of the circuit as a system belong to the specific knowledge domain.
If in thisfirst approximation the cognitive aspects of learning are emphasized, learning should not be seen as a process without emotions. It is a principle of learning psychology that cognitive and motivational processes are intermixed, when learning takes place. The handy formulation of “will and skill” (Salomon 1987) describes this evident fact.
Besides cognitive actions and motivational states the strategies used by the students are very important for the learning outcomes. The students do not reach the objectives of the teaching unit by mere participation during the lessons, but they have to get involved and apply their learning strategies extensively. Since no standardized tests for learning strategies are available, other evaluation procedures -- even indirect inferences -- have to be used.
As an additional factor which may influence the learning processes we control how he or she perceives the environment. It ranges from more distal cultural and social influences to the proximal social interactions with teachers and class-mates, which define the social climate in the classroom. Especially, in the case of long-term learning the class climate may influence the learning processes.

The Study

During the last two years a study was carried out which aimed at describing the development of the knowledge structures and the interaction between learning and its cognitive, motivational and social conditions. The study was carried out in five classes (grade 8, Realschule) for about three quarters of a year. The results depend on the teaching method. It may be described as follows: At a first stage the concepts and rules used in physics are presented with the emphasis on correct and clear information. The teacher and the students

discuss those situations systematically where conflicts arise between the everyday meaning of concepts and their meaning in physics, or between students conceptions and a correct description of the processes in the electric circuits. Teacher and students must come to a common view of the processes in an electric circuit and the used concepts.
For us, the development of a correct view of the processes in the electric circuit is very important. For that reason we check the concepts and rules as well as the integration of their components with exercise tests parallel to instruction and in addition with a special test, called intermediate test. No marks are given in these tests. In the following problem-solving sessions a supportive climate is offered in which students are given the opportunity to practice and integrate the concepts and rules that will facilitate conceptual change. At the last stage of the unit just before the final class test is presented, teacher support is reduced to improve autonomous problem-solving.
The psychological factors and the results were measured on the basis of the following tests. Data were collected on:

Study habits and attitudes (Thiel et al. 1979).
Some of the 20 variables of the test may be quoted:
In the domain of motivation we find four variables:
- success orientation,
- failure orientation,
- extrinsic vs. intrinsic motivation,
- self-esteem which may be achievement oriented or multithematic.

The proper study habits and attitudes comprise:
- assimilation of subject matter,
- phase of actualization (disturbed vs. undisturbed),
- learning style,
- achievement control.

The reactions to lack of success are described by:
tolerance of failure, resistance to stress.
The influence of the pedagogical environment is measured inter
alias by variables like:
- learning behavior,
- attitude toward school.

Development of formal operations
- Piaget test (Lawson 1978). This test presents 15 demonstration items that illustrate problems from physics. Finding solutions to the problems involves problem solving strategies, which are interpreted in the context of Piaget's theory of cognitive development.
- interest in electricity (Häussler 1 987)
- invested effort of the student during the course and during the preparation of the final class test (see Ame - Salomon 1987-)

Climate of the class-room (von Saldern 1987). This test comprises three aspects: the interaction between student and teacher, between student and student and the perception of instruction. The main variables for teacher-student-interaction are:
- thoughtfulness of the teacher, authoritarian style of leadership, aggression against the teacher.

The student-student-interaction is described by:
- cliquishness,
- helpfulness,
- aggression against class-mates,
- discrimination of class-mates, satisfaction with class-mates.

The general characteristics of instruction comprise among other variables
- order and organization;
- reduced participation in instruction.
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Also included in our evaluation were
- exercise tests, which describe students spontaneous grasp of information about scientific concepts and rules. No marks were given.
- intermediate test. This test combined test items related to several concepts and rules. No marks were given.
- class test. The test covered the content of the teaching unit.
- retention test. This test recapitulated the problems of the intermediate test with similar items two months after the class test. Again no marks were given.

The learning strategies were measured in a preliminary form with a questionnaire developed by Lompscher (1993). Finally, data in the form of school marks were collected on the students ability in mathematics, biology, German language and English language in the school year prior to the teaching sequence of this project.
In the following, we will try to put these different aspects together for a better understanding of the learning processes in the classroom.

General Results
The most important correlations between psychological and achievement variables are presented in the correlation matrix of table 1 for the pool (N = 123 students). The matrix of variables shows that increasing abilities (Piaget test, marks), better study habits and attitudes (motivation oriented to failure with negative sign, learning style oriented toward basics, positive attitude toward school), and a positive climate of the class-room lead to better achievements. The positive and negative signs in the correlation matrix are stable all over the teaching unit and correspond to the expectations.

	exersice tests	intermed. test	class test	retention test
marks	0.35**	0.31**	0.35**	0.38**
Piaget test	0.32**	0.27**	0.42**	0.44**
motivation (failure orientation)	-0.26*	-0.17	-0.23*	-0.27**
learning style (facts vs. basics)	0.12	0.16	0.25*	0.16
attitude toward school	0.05	0.21	0.26*	0.19
aggression against teacher	-0.20	-0.05	-0.25*	-0.43**
cliquishness	-0.22	-0.19	-0.24	-0.39**
helpfulness	0.12	0.20	0.23	0.34**
discrimination of class-mates	-0.23	-0.33**	-0.30*	-0.53**
satisfaction with class-mates	0.26*	0.32*	0.30*	0.48**
agression against class-mates	-0.24*	-0.28*	-0.26*	-0.47**
order and organisation	-0.21	-02.0	-0.21	-0.34**

Table 1: Significant correlations between achievement in physics, ability, study habits and attitudes, and climate of the class-room (grade 8, five classes, N = 123). Significance *:0.01, **: 0.001.

The causal relations between ability, motive, social climate and achievement in physics were analyzed with a LISREL analysis. In a first step, these constructs are assessed on the base of factor analysis, and then the causal relations between these constructs are calculated on the base of regression analysis. The results of the LISREL analysis are presented in figure 1.

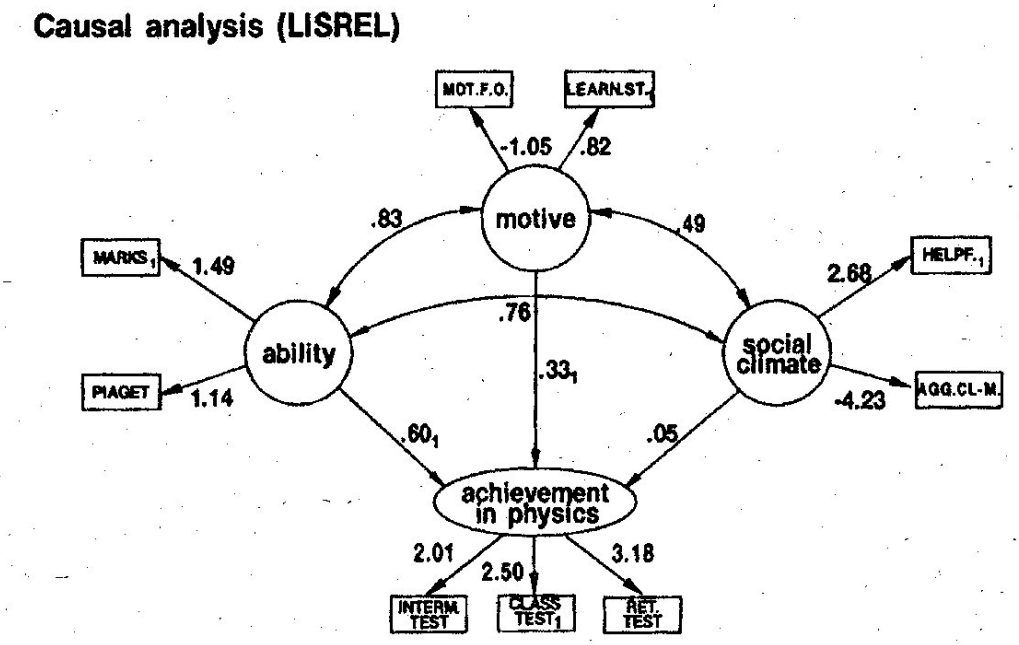

Figure 1: The causal relations between cognitive ability, psychological motive, and climate of the class-room estimated by LISREL (LISREL 1991).

Cognitive ability is the most important determinant of achievement in physics. The social climate in the classroom exerts only a small direct influence on physics achievement, i.e. the class climate during the unit is rather neutral to learning. As we expected, the motives of the students have an effect on physics achievements. But since the analysis only conpromises those variables which are important for all students and different supgroups show other motives, the effects on physics achievements are limited.

The correlations of table 1 and the more detailed analysis of the connections between the constructs in figure 1 answer the question why some students learn and others do not. But results on connections between the constructs are on a very general level. Therefore we analyze the correlations in detail for special subgroups of students.

Subarouns and Subgroup Results

The categories for the definition of subgroups may be chosen freely. Of course, the categories should be oriented toward approved classifications. Gender differences (Kotte 1992), differences between students in rural and urban classes (von Rhöneck and Grob 1991), and achievers vs. nonachievers are such categories. From experience in an earlier study we learned (von Rhöneck and Grob 989) that in the first stage of instruction the students conceptions of electricity may bifurcate in two directions: some students develop a correct understanding, whereas the rest tends to an alternative view of the processes in an electric circuit. That gave us the idea to analyze the learning processes very carefully during the first half of the teaching unit. Here exercise tests and intermediate test document the learning processes. As an instrument for the analysis we used a cluster analysis. By means of this analysis we isolated two well separateci groups, which we call continuous and sporadic learners. Continuous learners show a steady learning behavior, sporadic learners concentrate their learning activities on the preparations for the class test.

The groups of continuous and sporadic learners may be divided in subgroups for girls and boys. This partition is confirmed by the specific profiles and the characteristic correlations for these subgroups. As an example, we interprete the differences of the means in special variables for two subgroups: the continuously learning girls and boys (see figure 2).

The group of girls is characterized by good marks, a certain amount of effort (Aime) and no interest in basic electricity. The motivation is more intrinsic and the attitude toward school is good. Better achievement control and resistance to stress are typical of them. There is no aggression against the teacher, and an authoritarian style of leadership is not mentioned. Cliquishness and aggression against class-mates do not seem to be a problem, and helpfulness seems to be important.

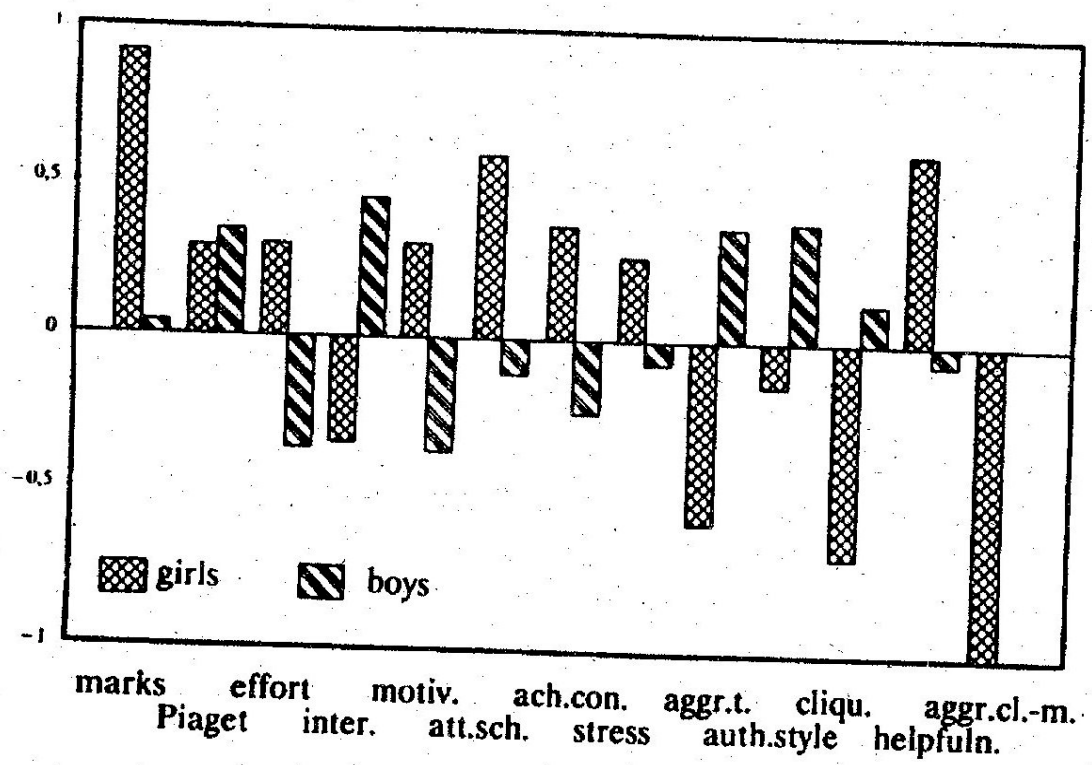

Figure 2: The deviation from the means in standard deviations for the subgroups of continuous learners: girls and boys.

The boys use a totally different approach for learning basic electricity. They learn without effort (Aime), but their interest is high. The motivation is more extrinsic. Achievement control and stress resistance are not prominent. They indicate aggression against the teacher and they impute to the teacher an authoritarian style of leadership. They notice the formation of cliques. Helpfulness is less important and aggression against class-mates ist much stronger than in the equivalent girl group.

A second argument for the partition into subgroups results from the means for different tests in physics (see figure 3). The rather small differences in the exercise tests accumulate to large differences in the intermediate test. These differences are only partly reduced in the class test, which reflects the activities of continous vs. sporadic learners.

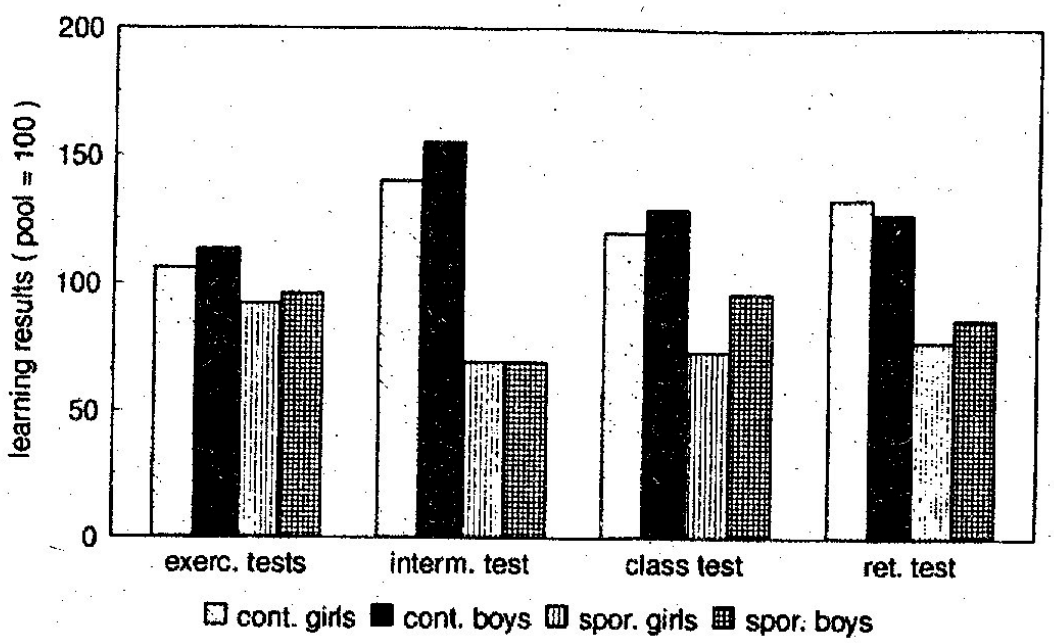

Figure 3: The means of different tests in physics for four subgroups in relation to the results in the pool.

A third argument is to analyze which learning strategies are favored in the different subgroups. For that purpose, a questionnaire developed by Lompscher (1993) was used and led to interesting results. Some of the prefered statements for the subgroups are presented in table 2. (Only those statements are listed which differentiate the examined subgroup from two or three other subgroups significantly.)

Sporadic learners, girls: I take some notes. I seek help from others.	Continuous learners, girls: I try to find my own answer to every question. I don't like to do my homework alone.
Sporadic learners, boys: Sometimes, it happens that I prepare my homework late in the evening or not at all. I don't seek help from others.	Continuous learners, boys: We do not think about the possibilities how to solve problems together. I don't like to work together with others.

Tabelle 2: Some typical statements from the strategy questionnaire (Lompscher 1993) which define significant differendes between the subgroups (significance 0.05).

The list of strategies in table 2 leads to a better differentiation of the subgroups. The girls are more cooperative than the boys. The sporadic learners in the girl group try simple reading strategies if they learn at all. The girl group of continuous learners seem to be more persistent in their efforts. The sporadic learners in the boy group are careless, whereas the continuous learners tend to isolate themselves.
Even more instructive than means are the correlations between the variables, which provide information about successful and unsuccessful students in the subgroups. We only took at the most important correlations between achievement in physics, and motives (study habits and attitudes, interest etc.). In this domain the subgroups show differences. In table 3 the correlations for all four subgroups are placed together.

All the girls preserve a certain distance to physics, because their interest is low. That does not mean, girls do not learn physics. Hints of the motives of the girls are found in table 2. In the female group of continous learners we find motivation (intrinsic motivation, failure oriented motivation Inegative signi and mastering of difficulties (tolerance of failure, resistance to stress) which allow us to differentiate between successful and unsuccessful learners.
The second subgroup -- the female group of the sporadic learners -- becomes active in learning before the class test. The correlations increase in the class test and the retention test. The successful learners in this subgroup, who are able to reproduce learning details without difficulties and show achievement control, achieve rather good results in the last tests.
The boys find an emotional access to physics via nterest. In the subgroup of continuous learners we find the following mixture of variables. Multithematic self-esteem and a type of learning behavior that depends on interest are the variables that are typical of the successful learners in this group. They are good learners if tney are not concentrated on school achievement and if their effort depends on interest.
The correlations for the male group of sporadic learners contain only the variable assimilation of subject matter. A quick assimilation of subject matter leads to poor results in the intermediate test, since these boys are rather careless and unsystematic learners.
The subgroups differ in achievements in physics, in motives and in learning strategies. Unfortunately, the number of students in the subgroups is too small for a LISREL analysis. But the qualitative results lead to rather consistent descriptions of the relations between these constructs.

Discussion

The first objective of this study was to close the gap between the analysis of pool data and students portraits by building of subgroups. The devision in subgroups led to continous and sporadic learners. Girls and boys in these subgroups use a different access to learning basic electricity.
The different subgroups differ in motives and strategies which complement one another. To change students motives -- including attitudes and dispositions -- seems to be very difficult. It is easier to analyze and influence the learning strategies.

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