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Paper Title: **COGNITIVE ABILITIES, PSYCHOLOGICAL MOTIVES, AND SOCIAL INTERACTIONS AS COMPONENTS OF LONG-TERM LEARNING IN BASIC ELECTRICITY**

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If in this first 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 it is important for the learning of the student 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.

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COGNITIVE ABILITIES, PSYCHOLOGICAL MOTIVES, AND SOCIAL INTERACTIONS AS COMPONENTS OF LONG-TERM LEARNING IN BASIC ELECTRICITY

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1. 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 this first 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 it is important for the learning of the student 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.

2. 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 of this study 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 initiate 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 learning 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****.*

The 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 Piagets's theory of cognitive development.
- ***interest*** in electricity (Häussler 1987),
- ***invested effort*** of the student during the course and during the preparation of the final class test [see AIME (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***.

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 month after the class test. Again no marks were given.

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 class-room.

3. 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.

	exercise 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**
aggression against class-mates	-0.24*	-0.28*	-0.26*	-0.47**
order and organisation	-0.21	-0.20	-0.21	-0.34**

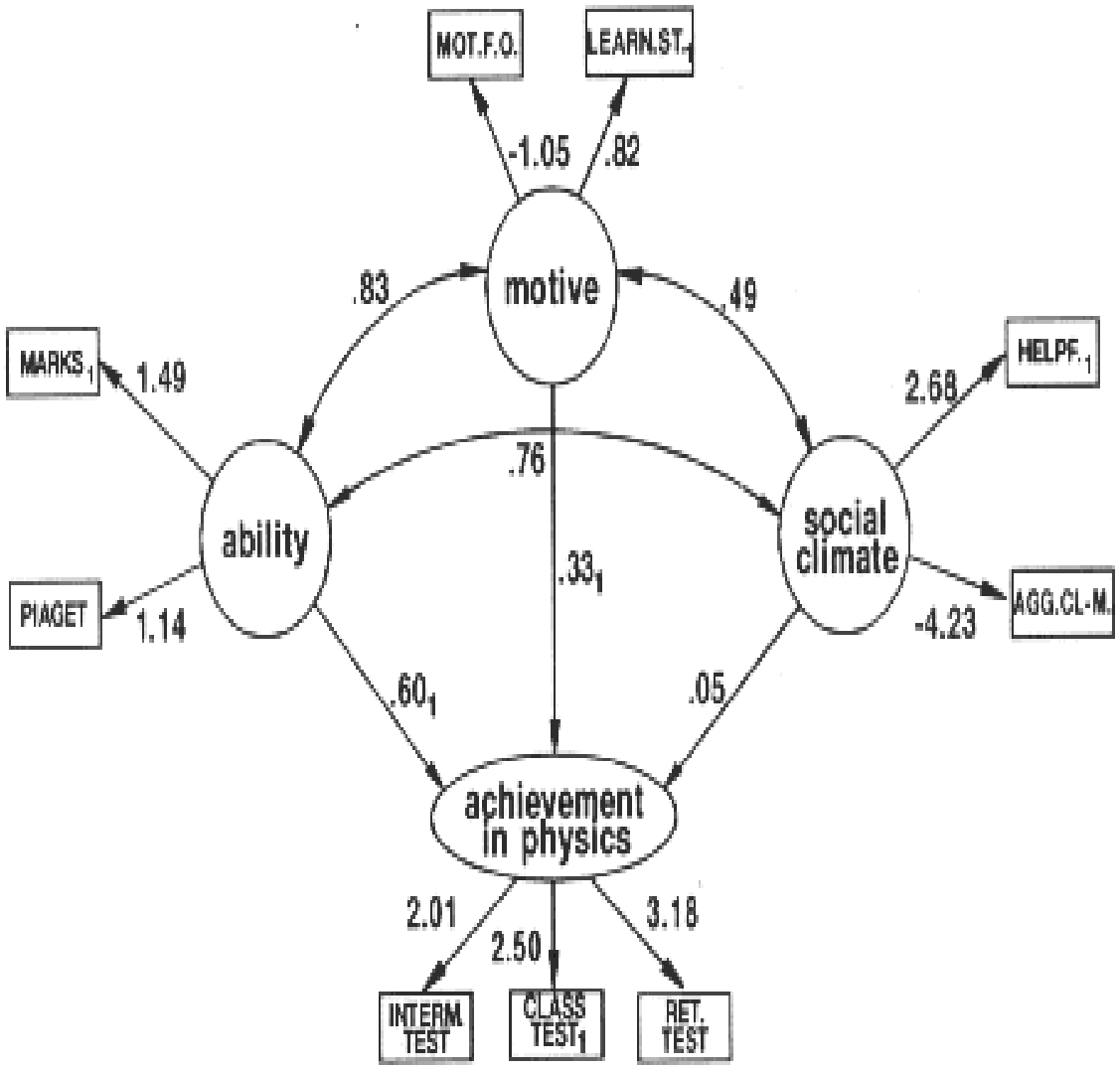
Table 1: Significant correlations between achievement in physics, ability, study habits and attitudes, and climate of the class-room (grade 8, five classes, N = 123). Significance *: 0.01, **: 0.001.

The interactions 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 afterwards 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.

Cognitive ability is the most important determinant of achievement in physics. The social climate in the class-room exerts only a small direct influence on physics achievements, i. e. the class climate during the unit is rather neutral to learning. As we expect, the motives of the students have an effect on physics achievements. But since the analysis only comprises those variables which are important for all students and different subgroups 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 raise the question why some students learn and others do not. But hypotheses on connections between the constructs are on a very general level. Therefore we analyze the correlations in detail for special subgroups of students.

Causal analysis (LISREL)



CHI SQUARE WITH 23 DEGREES OF FREEDOM = 18.36 (P = 0.738)
GOODNESS OF FIT INDEX = 0.960
ADJUSTED GOODNESS OF FIT INDEX = 0.921
ROOT MEAN SQUARED RESIDUAL = 0.495

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

4. Subgroups 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 1989) 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 separated 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 the 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).

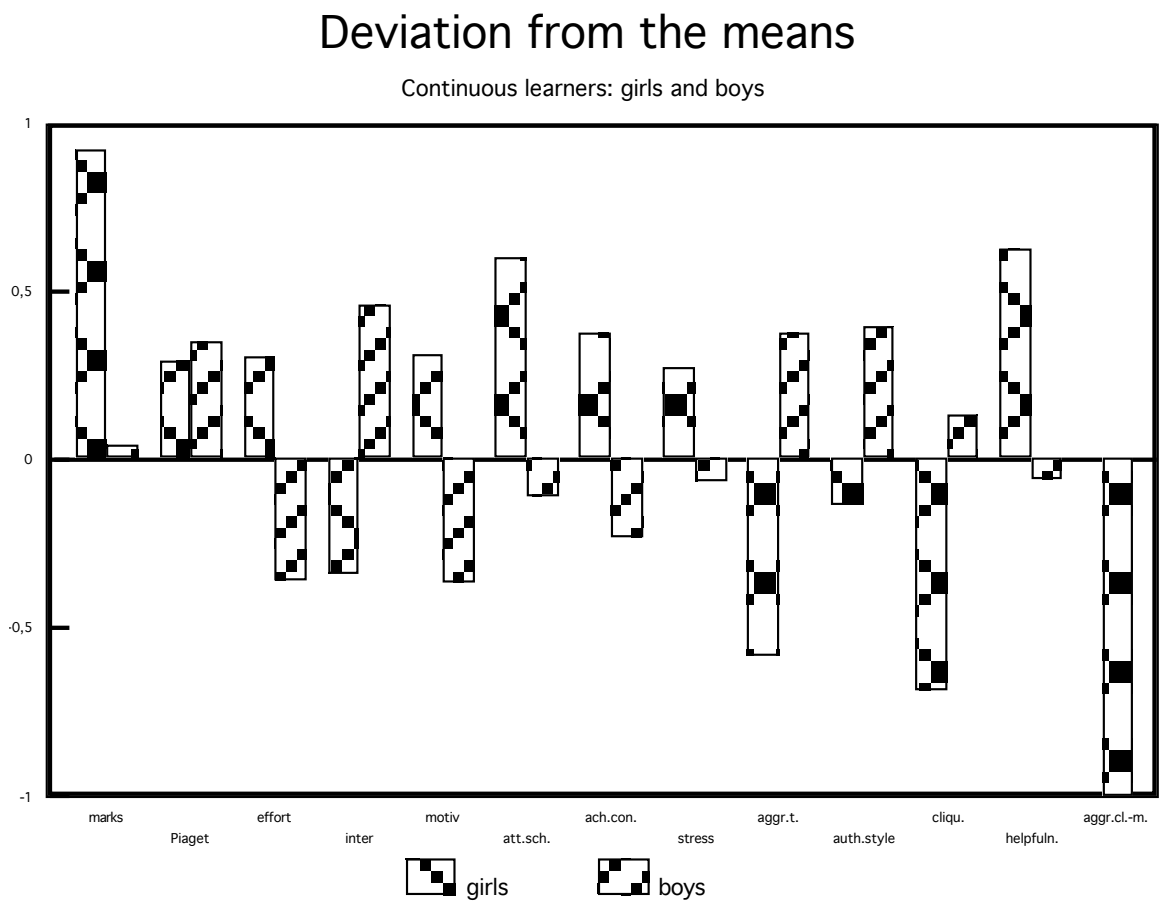


Figure 2: The deviation from the means in standard deviations for the subgroups of continuous learners: girls and boys.

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 agains 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.

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* is 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 systematic activities of the sporadic learners.

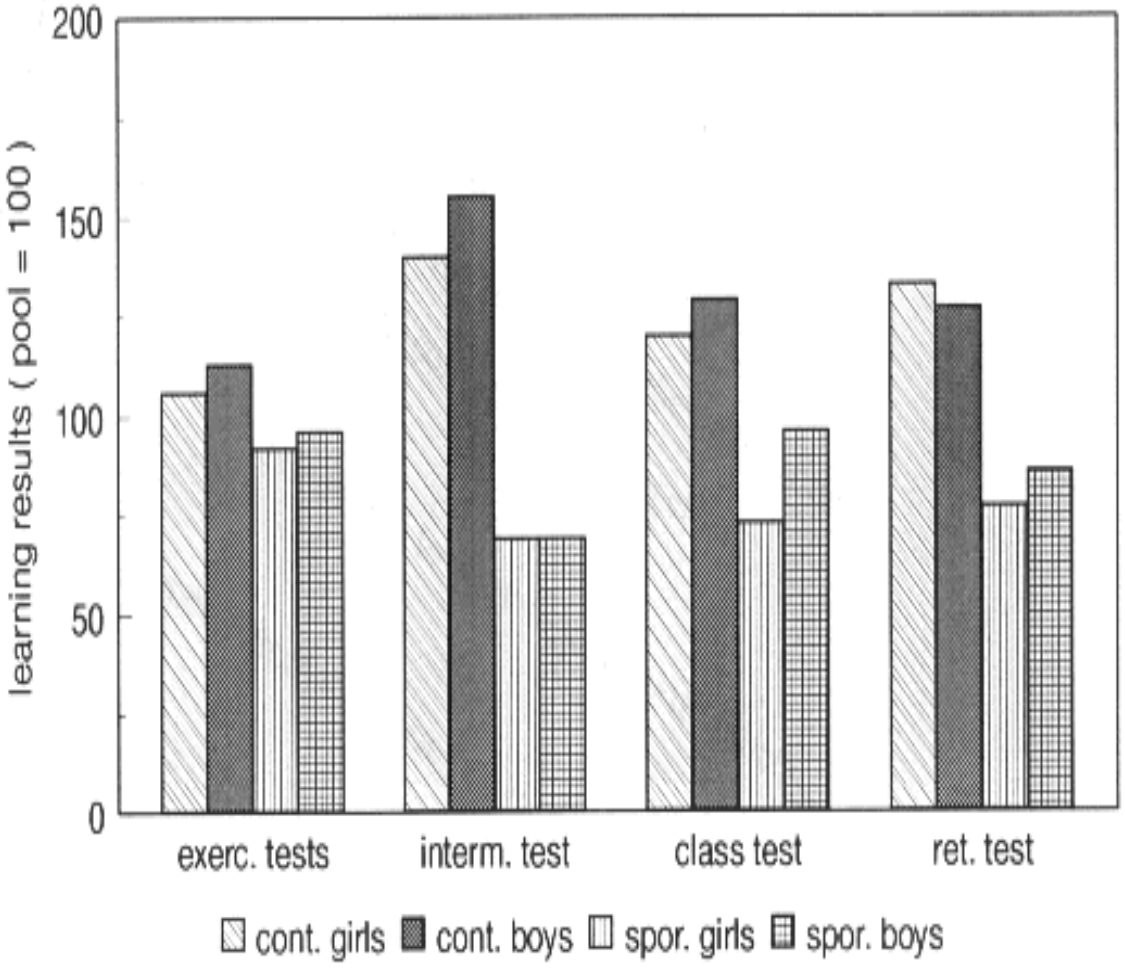


Figure 3: The means of different tests in physics for four subgroups in relation to the results in the pool.

A third argument is to analyze which learning strategies are favored in the different subgroups. For that purpose, a questionnaire developed by Lompscher (Lompscher 1993) was used. Some of the prefered statements in the subgroups are presented in table 2.

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

Table 2: Some typical statements from the strategy questionnaiere for the subgroups. (Lompscher 1993)

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 look 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.

	exercise tests	**intermed. test**	**class test**	**retention test**
continuous learners (girls)				
motivation (extrinsiv vs. intrinsic)	0.53*	0.55*	0.45.	0.48
motivation (failure orientation)	-0.53*	-0.23	-0.36	-0.41
tolerance of failure	0.63*	0.43	0.31	0.56*
resistance to stress	0.34	0.22	0.29	0.55*
sporadic learners (girls)				
phase of actualization (disturbed vs. undisturbed)	-0.10	0.00	0.38*	0.09
achievement control (capable vs.incapable)	0.09	-0.23	0.28	0.42*
continuous learners (boys)				
self-esteem (achievement oriented vs. multithematic)	0.30	0.25	0.33	0.46*
learning behavior (interest dependent vs.interest independent)	-0.10	-0.06	-0.46*	-0.40
sporadic learners (boys)				
assimilation of subject matter (slow vs. quick)	-0.18	-0.43*	0.12	0.23

Table 3: The most important correlations between achievement in physics, and study habits and attitudes for all four subgroups of continuous and sporadic learners (girls and boys).

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* [negative sign]) 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 interest. 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 they 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.

5. Discussion

The study habits of the different subgroups are very different. The female group of continuous learners is adjusted to learning in school. These students learn carefully and willingly during the course. But a lack of interest demonstrates the reservation toward basic electricity. Nevertheless they show good results in this teaching unit. The same reservation is found in the female group of sporadic learners, too. In this subgroup the girls rely on automatic learning up to the *class test*. That means they do not actively take part during the first half of the teaching unit. When the *class test* is impending, they try to reproduce learning details.

The boys find an emotional access to basic electricity via interest. The continous learners achieve successfully and show persistent learning, if they are open to the new approach and if they combine their learning with interest. The sporadic learners do not participate enough in the course. They are careless learners and forget quickly (see figure 3).

For the continuous learners constant participation in the learning processes in the class-room should be reinforced. In addition, the girls should improve their success orientation and should learn to reduce the effects of a lack of success. For the male group it is important to realize that interest in physics is not enough to learn physics and mental effort should be invested.

For the sporadic learners the situation is much more difficult, because they should be more active in the teaching unit. These students often have transmissive views of learning and teaching, and passive views of their role in these processes (Gunstone 1992). Therefore the teacher should emphasize the importance of continuous participation in the class discussions from the very beginning. The students should learn to overcome their difficulties in understanding at once.

The continuous learners are the allies of the teacher when the study habits and attitudes are brought up for discussion. This discussion can be the starting point for a better understanding what they do and what they could do for learning basic electricity. Provided the interaction between the teacher and the students of different subgroups is more intense

and is based on reflection, the construction of knowledge will improve . However, the question of how to achieve better results in learning basic electricity is significant to the students, if they are able to answer positively the question, why they should learn physics.

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