A Blended Learning concept for self-directed and situated learning in the science domain

How 'hands-on eLearning' can motivate pupils to deal with natural sciences

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Abstract:

Pupils in Germany as in many European countries perform weak in natural sciences (PISA 2000 and PISA 2003). To meet this challenge a Blended Learning concept was designed and implemented within a pilot project at the University of Koblenz-Landau. The concept aimed to facilitate situated and self-directed learning and a shift from teaching to learning in science lessons at schools. From October 2003 to June 2004 the concept was evaluated at 6 schools with a total number of 191 pupils. Results indicate that self-directed learning was successfully stimulated. Moreover the combination of situated and self-regulated learning is a way to enhance interest and motivation of pupils to deal with natural science topics. Both the cognitive and motivational effects of the concept are subject of further research.

1 Background

Pupils in Germany as in many European countries perform weak in natural sciences as lastly was shown by the OECD programme for international student assessment [1], [2]. Although pupils' performance in natural sciences has improved compared to PISA 2000, it remains only average on an international level. This is a multi-factorial problem, mainly consisting of too much theory and old fashioned teaching methods in schools both decreasing pupils' learning motivation towards natural science. School science lessons are so "boring" and "overloaded with facts" that they can put people off the subject for life [3]. Thus school teaching at the beginning 21st century has to address stronger motivation and interests of young people. To meet this challenge a pilot project was realized in the federal state of Rhineland-Palatinate in Germany from September 2002 to October 2004.

2 Pilot project

The pilot project "Self-directed learning by hands-on experiments and eLearning in full day school" was funded by the School Ministry (MBFJ) of Rhineland-Palatinate. The project's main intention was to develop a concept which allows facilitating situated and self-directed learning and a shift from teaching to learning in science lessons at schools at a wide range [4]. The project was realized at the University of Koblenz-Landau in Germany by experts from natural sciences, pedagogy and computer sciences.

Interest and motivation of pupils were key issues. For experimentation is the specific procedure of knowledge acquisition in natural sciences, by doing hands-on experiments explorative learning and understanding of natural science legalities should be promoted. A special Blended Learning concept was designed that combines experimental work with eLearning in a synergistic way [5]. From October 2003 to June 2004 the project was evaluated on 6 schools with a total number of 191 pupils from grade 3 to 10.

In the same field other interesting initiatives came up in the past few years, for instance school labs or experimental laboratories as “Xlab” [6] or “teutolab” [7] in Germany. They aim to improve pupils’ science competencies rather in a scientific formal way by authentic work in an authentic laboratory. They address the gap between scientific research and school teaching. In contrast the pilot project uses self-directed experimental work as a method to promote natural science learning in the lessons on a lower difficulty level on-site at schools. Science teaching can be improved at a wide scale without spending much effort on technical facilities and organization. Another important issue of using hands-on experiments was to address pupils with averagely weaker performance in natural sciences and to motivate them at least to get involved with such topics. Successfully addressing this target group can be seen as one major challenge of science teaching in the next years due to PISA 2000 [1] and 2003 [2].

3 Concept

3.1 Pedagogical assumptions

Analyses of German classroom teaching in the context of the PISA study and other studies of educational research indicated that situated and self-directed learning is a possibility to improve science teaching and learning at schools. Some aspects are of general importance for the facilitation of situated learning:

1. Learning has to take place in realistic and authentic contexts which are of relevance for the pupils [8], [9]. Thus learning has to be grounded in the daily life of pupils in order to “bridge instruction to learning” [10]. By this pupils are enabled to recognize for what kind of problems and situations their knowledge is applicable and of importance. As well interest and intrinsic motivation of pupils should be supported. Therefore doing experiments is central for the concept. Experimenting is the 'authentic' procedure of knowledge acquisition in natural sciences, even as performed as hands-on experiments. The hands-on experiments require daily use requisites and demonstrate exemplary phenomena, which show the daily life importance of natural sciences for the pupils and allow integrating newly built knowledge in prior knowledge.
2. Learning is seen as acquisition and application of knowledge. It should take place in multiple contexts to support flexible knowledge transfer [11]. Knowledge should be applicable in different situations. Therefore natural science legalities become evident in different topical contexts. Phenomena are not artificially de-contextualized as it is typical for school subjects. By this the interdisciplinary relations of natural sciences and the school subjects biology, chemistry and physics can be experienced by the pupils.
3. Self-directed learning in authentic contexts is supported. Experimenting is only motivated by the learning environment and necessary requisites are provided. Thus pupils can decide on their own what is of interest for them and how to deal with problems and tasks. In the context of the PISA study self-regulated learning becomes more relevant to deal independently with natural science problems and to train problem solving. Self-regulated learning stresses interest and motivation of the learner [12] as relevant prerequisites of elaborated learning processes.

3.2 Context

Some special challenges for the concept design came up in the context of full day schools and the scope of the pilot project. The concept had to include different school types and pupils with averagely weaker school performance (i.e. from secondary modern schools). The learning groups in German full day school at the afternoon are often assembled from several regular classes, because the pupils subscribe for special courses which work on certain subjects or topics. Therefore learner groups tend to be very heterogeneous due to their age, prior knowledge and interests. Moreover reality on full day schools sometimes means that teachers are foreign to the subject of their learner groups, which can be a problem especially concerning natural science topics.

3.3 Blended Learning Approach

In order to enhance natural science learning of pupils a blended learning concept was designed. It combines self-regulated and situated learning of pupils by hands-on experiments [13] with personalized media support. Pupils should be allowed to perform hands-on experiments on their own, motivated by their own interests, and thereby learn on natural science legalities. Self-regulated learning takes place both during online- and Face-to-Face episodes: The eLearning episodes offer several degrees of freedom for the learner to promote motivation and commitment of the pupils.

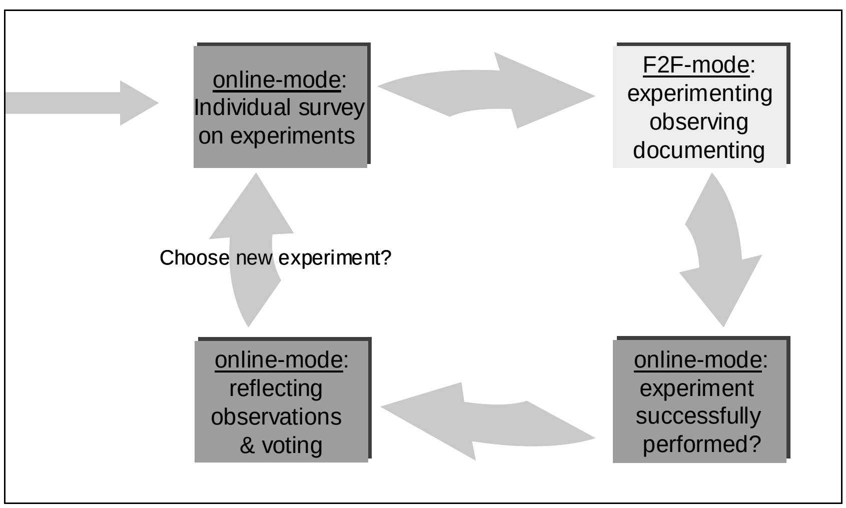

Figure 1: Blended Learning Concept: eLearning episodes support practical experimenting of the pupils

Learners can choose experiments by their own interests. Once a learner has found an experiment he is interested in, he can practically perform it in Face-to-Face mode quite safe on his own (with harmless daily use requisites). Reflection and interpretation of the pupils' observations is done again in the online environment by reflection questions. These questions check whether or not a pupil has understood what he has observed whilst experimenting. Thus the scientific context of a phenomenon should be understood by the pupils and a transfer to similar problems should be stimulated. Once pupils have fully performed an experiment, they can voluntarily rate the quality and attraction of it. At any stage the learner has got full control on his activities and the effort he wants to spend.

3.4 Online learning environment

A web-based learning environment was designed which offers instructions for different hands-on experiments both for pupils and teachers in a personalized way. Within the Blended Learning approach the learning environment was used as a didactical tool [14] to individually support learners exploring hands-on experiments, depending on their age and prior knowledge. Especially the possibilities of self-guidance while learning with experiments was enhanced by the deployment of computer based media. As self-directed learning is not possible without pre-requisites [15], [16], computer based tools can help to deal with the complexity which is caused when inexperienced learners have to manage and monitor their practical experimenting. Moreover information to be processed can be reduced specific to a learner’s individual profile, which helps to prevent cognitive overload.

Pupils are motivated to fully perform a growing number of experiments in the learning environment. Therefore they can rise in a ‘scientific career’ by fully performing and assessing a growing number of experiments. Their actual title is shown together with their name in the main screen of the online environment. Furthermore the learning environment gives them the possibility to monitor and assess the outcomes of their exploration by themselves, and an individual and scientifically appropriate feedback to their experimenting activities is given. Most important the feedback and questions delivered by the learning environment should initiate and structure reflection on their practical experiences in order to achieve maximum insights.

The online environment offers several possibilities to support and motivate self-directed learning of the pupils. They could do surveys by themselves according to their interests in a specially designed database [13], which contains at present 132 different experiments. In contrast to rather passive and receptive school teaching any learning activity starts from pupils' own interests. The experiment database existing from the pilot project covers four topical areas which deal in an interdisciplinary way with phenomena located in biology, physics and chemistry: Water, Forest, Energy & Heat and Air & Atmosphere.

A ***Search Tool*** was designed which allows pupils to perform surveys on the experiment database in more or less pre-structured ways. All pupils can do free text queries or choose to list all available experiments in the database by using empty search strings. Additionally they can choose to list all experiments of a topical area by clicking on the corresponding title or icon. Apart from primary school pupils it is possible to do surveys by using key words as all experiments have been annotated.

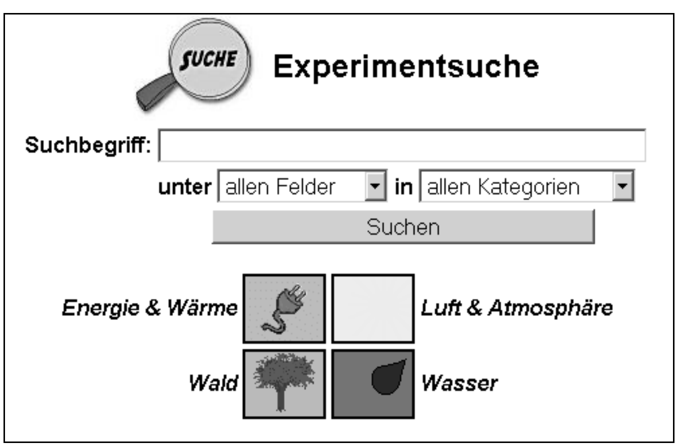

Figure 2: Screenshot from Search Tool

Every learner owns his ***Personal Work Space*** called “My experiments”. There one can get an individual overview on the own experimenting activities. According to that pupils administrate four different categories to look up what experiments they have already seen, which ones they are currently performing, what experiments they have fully performed and in which cases they still need to vote on an experiment. By their personal workspace they have immediate access to the listed experiments without doing a new survey.

Figure 3: Screenshot from Personal Work Space

The learning environment provides a grade specific ***Top Ten list*** of the most famous experiments, which is generated on the pupils’ votes. By this they can see the most attractive experiments of their peers for motivational reasons. They can access the listed experiments directly, given that they the have fully performed all the preconditioned experiments, which are otherwise shown to them.

Figure 4: Screenshot from Top Ten list

A ***Glossary*** provides suitable explanation on technical or otherwise complicated terms in the experiment descriptions according to the individual grade of a learner.

The hands-on experiments have didactically been edited in different variants appropriate to the grades 3 to 10 of primary schools, secondary schools and secondary modern schools. Thus the content is described by metadata, which allows to deliver content dynamically out of the database and to adapt it to the individual user profile. Both tools and content are delivered in personalized form. Generally what content is available and which privileges users have in common is depending on the individual profile, including data on status (pupil/ teacher), grade and experiments already performed. Teachers get comprehensive information on the scientific background of every experiment in the database. This allows especially non-specialist teachers to support practical experimenting and to explain certain phenomena to pupils in an appropriate way.

4 Evaluation of the pilot project

From October 2003 to June 2004 the usage of both hands-on experiments and eLearning components was formatively evaluated at 6 schools with a total number of 191 pupils. The evaluation focussed the quality and suitability of the resources offered to the pupils instead of pupils' performance on given materials. The evaluation in July 2004 involved questionnaires for both pupils and teachers, written reports of the teachers and analysis of logging data which reported the usage of the eLearning functionalities and offered hands-on experiments in the database for the entire evaluation period. Due to the objective and design of the pilot project it wasn't possible to conduct a large-scaled testing and evaluation of the motivational effects of the concept as well as of the effects on natural science learning outcomes. The evaluation did not deliver empirical proved data, but indicators which allow formulating hypothesis for further research.

4.1 Usage during evaluation period

Pupils have fully performed hands-on experiments from doing the survey up to reflecting their observations for 1187 times. The following data highlight the usage during the entire evaluation period.

Involved pupils over the evaluation period: 191 pupils
Number of experiments embedded in the learning environment: 132 experiments
Number of times experiments have been accessed: 3892 times
Number of times an experiment was fully performed: 1187 times

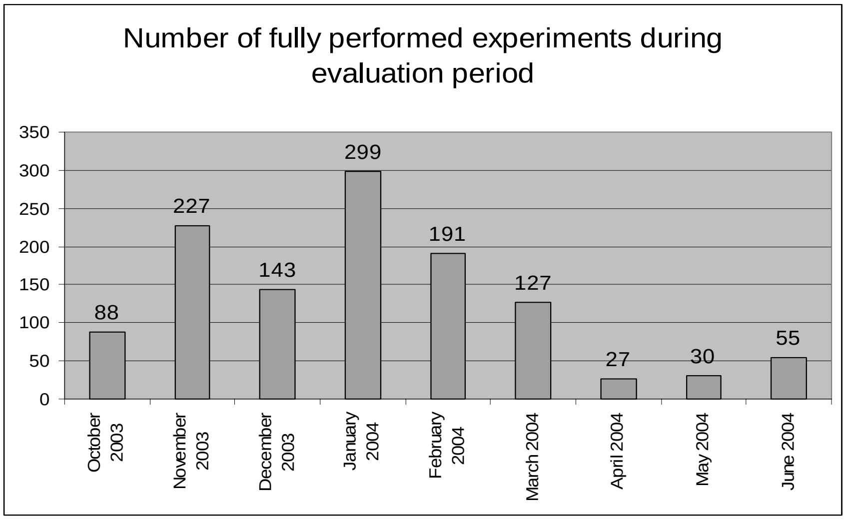

Figure 5: Experimenting performance of pupils due to work in the online learning environment

4.2 Promotion of natural science learning

Both the learning environment as well as the practical experimenting emphasized the self-guidance of the learner. The self-guidance realized during selection, performance and reflection of experiments often stimulated further interest on natural science phenomena. Pupils could successfully use their own interests for experimenting beyond instructional situations as typical for school teaching. The deployment of hands-on experiments supported this effect, for they could be easily performed by the pupils on their own with harmless daily use requisites.

The user experiences both expressed from teachers and pupils confirmed this positive effect of the concept on the pupils' motivation in comparison to regular school teaching. Most pupils answered that they appreciated it to perform experiments by themselves. They stated that for them natural science teaching without experiments would be boring and that they wished a larger number of experiments for certain topical areas.

Due to pupils' direct votes the experiments have prevailingly been rated to be useful for learning from pupils' point of view (on a scale from 0 (weakest) to 10 (best) the median was 10 of 1161 votes in total). Logging data points in this direction as in 77% (1840 of 2403 cases in total) the pupils gave a correct answer towards the observed results of performed experiments. Explanation of what happened whilst experimenting was said to be important. That was widely confirmed by the teachers and indicated interest and motivation of pupils. Moreover teachers widely stated that their pupils have gained better understanding of certain things in natural science teaching by performing hands-on experiments. Some teachers reported that pupils who performed experiments have been more committed to natural science teaching afterwards. Teachers from primary school uttered the expectation that a basic knowledge und interest for later natural science teaching was successfully built.

The pupils very positively considered the possibility to do self-regulated queries on the experiment database and thus to choose experiments by own interests. Teachers confirmed the positive motivational effect. Moreover they reported that their pupils have been motivated by the title award within the learning environment, depending on their individual experimenting performance. Teachers stated that experiments from the Top Ten list have been particularly interesting for their pupils.

There is evidence that the concept had got a positive effect on natural science learning at all. Firstly answers of the pupils in the questionnaires point to this direction. Secondly interest and motivation are both important pre-requisite of elaborated and sustainable learning processes [35] and have been successfully fostered by the concept.

4.3 Self-directed learning and mixed ability work

Evaluation data showed that the web-based learning environment widely supported pupils of all grades and all school types to operate in a self-directed way.

Pupils stated that they experienced no noteworthy problems to log in and use the computer in general and the learning environment in special. This was widely confirmed by their teachers. In the beginning primary school pupils needed more support from their teacher to get familiar with the computer and its usage. Pupils stated that they liked to work with the learning environment and would have preferred it against books to access the experiments. A prevailing majority considered it easier to find interesting experiments and to work on them in the learning environment as with the help of books. Logging data showed that 64% (394 of 607 cases in total) of all free text search queries had been successful in spite of the fact that many pupils had got problems with correct spelling and many “off-topic” queries had been sent. Primary school pupils made only limited use of the free text search feature.

By this the eLearning components helped to deal with disparity in learner groups in a pedagogical appropriate way. Due to the PISA 2003 study [2] this issue should be paid attention to by future pedagogical innovations. Especially a longer preservation of heterogeneous learner groups combined with a stronger individualization of teaching and learning processes offer promising possibilities to improve not only natural science competencies of pupils [2]. The web-based learning environment supports this claim by allowing an individualized self-directed learning of pupils. Also learner groups with mixed abilities can be supported by teachers to a large extent, and even individual support is possible, while the remaining pupils keep on learning self-directed. Teachers said to like the possibility to work with heterogeneous groups of pupils. The personalization made possible by media support offers especially for less skilled pupils a way to deal with natural science topics which is appropriate to their abilities, without separating them from more skilled learners. Moreover the usage of media and the design of the online environment motivated pupils to explore natural science phenomena which otherwise would not have been addressed. Also less skilled learners are motivated within the learning environment to improve the quantity and quality of their experimenting by the structure of experiments and the “scientific career”. Very talented pupils have got the possibility to “upgrade” and to perform experiments meant for higher grades. This option was intensively used by certain pupils during the evaluation period.

4.4 From teaching to learning

The focus on self-directed learning had got an effect on the role of the teachers in the project. It changed from teachers to mediators of learning processes. The presentation of content and instruction appropriate to the learner was mainly realized by the learning environment. This not only allowed the pupils to learn in a more self-regulated way, but gave teachers necessary freedom to care in particular for pupils with problems.
Thus teachers can deal more effectively with heterogeneous groups, for instance in terms of performance or age, in a pedagogically differentiated manner.

4.5 Support for non-specialist teachers

The evaluation of the pilot project showed that the concept allows as well non-specialist teachers to supervise and support pupils performing hands-on experiments in natural sciences. A particular reason for that was that the teachers have been able to go back to comprehensive information on the scientific background of every experiment in the database. By this they could both support practical experimenting and explain certain phenomena to pupils in an appropriate way. Considering the actual reality at schools the concept is suitable to the management of “assembled” working groups at schools, even if specialist teachers are missing.

4.6 Overall findings

Overall the evaluation showed that boys experimented absolutely and relatively more than girls, but girls performed more precise (by means of search success and correct answers towards the observed results of performed experiments). 7% (625 of 8852 cases in total) of all accesses on the experiments voluntarily took place from outside school. In most cases this was done by girls (79% of all cases). Elder kids profited more from the degrees of freedom offered by the learning environment than younger. For instance primary school pupils did not make appreciable usage of free text queries. In primary schools more pre-structured search features have been used and the teacher had to help more intensively. Teachers of all grades stated that their pupils lack imagination of “possible” phenomena and suitable vocabulary to express their interests in a query, which limited their possibilities of self-regulated learning.

On the whole the experiences of this pilot project and the results of its evaluation have shown the possibility to design natural science education more interesting and motivating for the pupils. The combination of situated and self-regulated learning by hands-on experiments and personalized eLearning episodes seems to be a way to enhance interest and motivation of pupils to deal with natural science topics.

5 Further research

With respect to the objectives and the design of the pilot project it was not possible to conduct an empirical study to test certain hypothesis on the effects of the blended learning concept. Especially whether or not and to what extent pupils' natural science learning on a cognitive and a motivational level is positively influenced would have been of particular interest. Therefore an empirical study at the University of Koblenz-Landau has recently started with a total number of 158 pupils at three secondary modern schools to find answers to this question. In the design of the study the findings of the evaluation of the pilot project are considered. For instance the pilot project revealed greater difficulties of especially latter pupils to express themselves adequately in writing, so 9th graders (14 and 15 years old pupils) are chosen for the study to minimize the impact of lacking linguistic competence.

The study is planned in a two group design and it lasts over a period of 7 weeks from September to October 2005. It includes three tests: a pre-test at beginning of September, a post-test at October and a follow-up at January 2006. The pupils are split in a treatment group and a control group and are assigned due to their prior knowledge concerning the relevant topics for the study. This is measured in the pre-test. The groups are in charge of the same teacher and work in two different methodical ways with the natural science experiments. In the treatment group the pupils perform hands-on experiments in a self-regulated way within the Blended Learning Concept of the pilot project, whereas in the control group the experiments are demonstrated by the teacher in lessons. These lessons follow a uniform sequence to grant comparable conditions between the different schools and teachers involved in the study. So the teacher has at the one hand the classical role of a knowledge provider in the lessons of the control group. At the other hand teachers act as mediators of the self-directed learning of pupils in the treatment group. All pupils deal with the same experiments, independent from the group they participate.

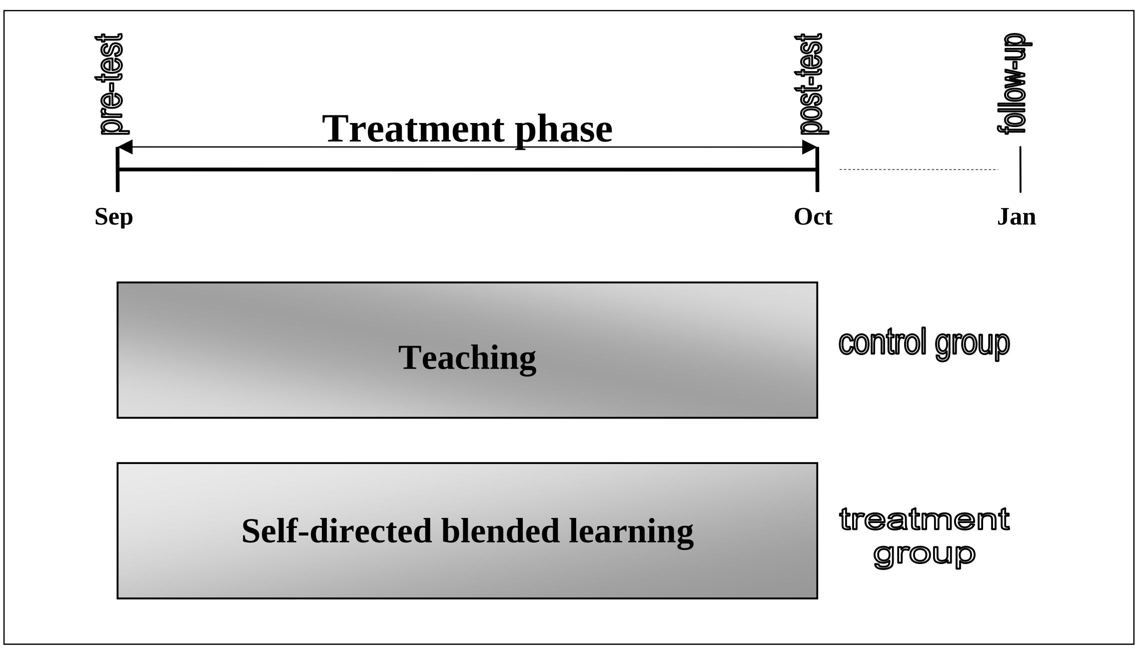

Figure 6: Overview of schedule and design of the study in 2005

For the study a cognitivistic-constructivistic view of self-directed learning [15], [16] and actual interest theory [17], [18], [19], [20], [21], [22], [23], [24] serve as a major theoretical framework. The study compares possible effects in the groups. Hypotheses are formulated at two main investigation levels: The level of cognitive learning outcomes and the level of interests. For the cognitive learning outcome it is expected that pupils working in self-directed way within the blended learning concept perform better than their peers in the control group, especially towards deeper levels of knowledge processing [25], [26]. Therefore it is also expected that the pupils in the treatment group gain more sustainable learning results.

The second level of investigation focuses the interests of the learners. Interest is an important pre-requisite for pupils' attitude to deal with natural science topics at schools and its differentiation can be seen as an outstanding educational goal [27], [18]. With respect to the duration of the study it can not be expected that significant changes in the individual interest occur, as this is a rather stable construct of a person. Therefore the study measures changes of the actual interest [28] as an indicator of the concept's capability to increase pupils' interests on natural sciences [29]. It is expected that the pupils' interest is fostered by the blended learning approach of the self-directed setting in the treatment group.

For in the discussion of self-directed learning especially intrinsic motivation plays an important role [16], [15], [30], the study focus also on possible interrelations between interest, intrinsic motivation and cognitive learning outcomes. With regard to modern interest theory intrinsic motivation can be explained by interests [28], [19]. Due to the self-determination theory [31], [32] and the person object theory of interest [28], [19] intrinsic motivation can be regarded as positive emotional and value-related valences. By this the relevance of interests for the cognitive learning outcomes of self-directed learning can be deduced.
Besides this theoretical perspective interests are said to play an important role for learning outcomes [17], [28], [33], [34]. Therefore the study examines whether or not the actual interest relates to the cognitive learning success and actual interest can be seen as a mediating variable for the postulated positive learning outcomes of self-directed learning.

The study uses questionnaires for the measurement of both cognitive learning outcomes and interests. Furthermore the activities of treatment group members in the online learning environment are logged, and the results of the pupils' reflections on the experiments are saved electronically (treatment group) or on paper (control group). All data is fetched and evaluated anonymously.

The results of the entire study will be available latest at March 2006.

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