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The Impact of the PARSEL Way to Teach Science in Germany on Interest, Scientific Literacy, and German National Standards

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ABSTRACT: This paper shows how PARSEL modules help to realize the German standards in practice. After analyzing the disappointing results of the TIMSS- and PISA-studies, which caused a kind of "PISA-shock" in Germany, and looking at school systems of winning nations, several changes have been initiated in the German educational system. The most radical change to the German school system may be the introduction of national education standards in 2004. These standards do not only focus on the content as did the former curricula, but also stress the development of competences, which should be attained by the ninth- and tenth-grade students who reach the middle level (Secondary I) examination. Pre-tests (questionnaire and group interviews) indicated that the students like to do experiments, like to work on topics from their everyday life, and they consider science (chemistry) to be an important school subject. Furthermore, the pre-tests showed that students like to self-regulate their work, to choose their own content and goals, and to invent their own ways to solve problems. But, this was only partly true; deeper interviews revealed that at least low-achieving students aim to be prepared for the next test, and they prefer well-structured lessons, which are usually dominated by a well explaining teacher. More surprisingly, we identified that student opinions changed after studying PARSEL modules. For example, after completing the module "Which soap is best?" students reported that they really enjoyed the feeling of autonomy and the inclusion of everyday life topics during their self-regulated learning process.

KEYWORDS: Interest, intrinsic motivation, self-regulated learning, socio-scientific decision making

Introduction

PARSEL is a coordinated action of partners from eight European nations, funded by the European Union, through which innovative science teaching modules were collected and tested in different countries. Best practice examples were also identified and disseminated throughout Europe. Innovative to us means that the selected modules deal with topics relevant to students' lives, can help to raise students' interest in science, and promote their scientific literacy. This exactly fits the current German science education landscape. Research indicated that German science teaching did not usually reach its expected goals. The main complaint referred to deficient transferable or applicable knowledge. German students were not able to apply their gained factual and procedural knowledge to everyday or vocational situations. This complaint was not only formulated by the science education research community, but also by the public media, industry, future employers and by politicians.

Two aspects need to be taken into consideration. We intend to help students to be intrinsically motivated to be engaged in the learning process and in the process of developing themselves, but we also intend to provide students with the content and goals to prepare them for critical life-long learning. While the first aspect refers to theories of motivation and interest, the second discusses scientific literacy. Deci (2002) presented the main aspects of the self-determination theory (Deci & Ryan, 1985) and explained the importance of competence, autonomy, and social context for the development of interest and intrinsic motivation, while research related to interest indicated that the relevance of the topic for the students was of significant importance for raising their interest:

> *Both intrinsic pro-activity and organismic integration operate most effectively within contexts that support satisfaction of the intrinsic needs for competence, autonomy and relatedness, which are theorized to be innate to all individuals (p. 157)*

To seek comments on scientific literacy, we asked international experts, during two symposia on scientific literacy in 1996 and 1998, whether German schools used the right teaching methods and the right content, and aimed for adequate goals. We defined scientific literacy as the goal of school science education and discussed (1) the definition of scientific literacy, and (2) the way to teach for scientific literacy (Graeber & Bolte, 1997; Gräber, Nentwig, Koballa, & Evans, 2002). The symposia participants affirmed the importance of learning discipline-specific and cross-curricular competences, instead of a mosaic-like summary of academically defined facts, and suggested a competence-based model of scientific literacy. Of course, the participants stated that facts and concepts were required, and that the ability to develop this knowledge (Nature of science does not mean facts and concepts) was needed. But, at least, it was realized that the same degree of importance had to be attached to competences, like learning, communication, and evaluation. It was pointed out that when acting on context-based and everyday life issues, you could not solve conflicts, or answer questions, merely by reasoning logically; it usually required value-oriented decisions.

After analyzing the disappointing results of the TIMSS- and PISA-studies, which caused a kind of "PISA-shock" in Germany, and looking at school systems of winning nations, several changes were initiated in the German educational system. The most radical change was the introduction of national education standards in 2004. International comparative studies seemed to show that students from countries with a systematic quality management structure and output monitoring achieved better results. The publication edited by Klieme (2004) showed how and why an input-oriented steering mechanism could (must) be changed to an output oriented controlling system. Particularly in a federal system, a nationwide change in this direction would help not only to improve schools, but also to standardize the requirements, and facilitate comparison and change between different school types, or states.

Along with national standards for the major subjects (Mathematics, German, and English/French), standards in the science subjects (Biology, Chemistry, and Physics) were released in December 2004. These standards did not focus on the content, like former curricula, but stressed the development of competences, which should be attained by the ninth- and tenth-grade students who reach the middle level (Secondary I) examination. Even where the standards for the single science subjects were not the same, they were structured in the same way, covering four areas of competences: (1) content knowledge, (2) epistemological competence (NOS), (3) communication competence, (4) evaluation competence (decision-making). These areas were subdivided into 5 – 10, more detailed descriptions of competences, expected to cover three levels with increasing complexity (reproduction, construction of connections, reflection/evaluation).

In addition to the more content-based competences, three process-oriented competences were explicitly mentioned in the standards, which triggered discussions among science teachers in Germany. Of course, all these competences were also taught in former science classes, but they were not seen in such an explicit way as it was now required. Based on the standards, some attempts to develop more competence-oriented teaching were made in recent years, through projects, like "Chemistry in Context," "Biology in Context," "Physics in Context," and the SINUS-Programme. However, these attempts, up to now, have not been completely introduced into German schools and, furthermore, were at an experimental stage until 2005. However, they have been put forward as models to introduce the standard-based way of classroom-teaching.

On the back of the 2004 released National Standards in Biology, Chemistry, and Physics, the ideas of PARSEL gained importance in putting the standards into practice. The PARSEL model focussed on the development of different competences, and one of the main goals was to help students improve their socio-scientific decision-making abilities. Related to this, the National Standards, in the area of evaluation competence, specified that the students are required to:

- differentiate between descriptive (scientific) and normative (ethic) conclusions;
- assess diverse measures to stay healthy and act in a socially responsible manner;
- assess the influence on global circuits and streams of matter referring to sustainable development;
- discuss options for actions related to resources and environment friendly participation concerning sustainability;
- use discipline-oriented and interdisciplinary knowledge and skills to explore everyday situations;
- develop current questions from their personal life, which could be answered by using science knowledge;
- discuss and assess relevant conclusions from different perspectives;

- introduce chemical facts and concepts into problem situations, develop problem- solving strategies, and transfer these strategies to new contexts;
- demonstrate through simple examples the possibilities and the limitations of scientific views (or models) in curricular and extra-curricular contexts.

Evaluation of PARSEL Modules in Schools in Schleswig-Holstein (Germany)

Teachers, Students, and Modules

In Schleswig-Holstein, the most northern state of Germany, nine teachers from five schools participated in the testing of PARSEL modules. These teachers came from schools cooperating in other projects in which the authors were involved (SINUS, ChiK, and ParIS). The teachers were informed briefly about the PARSEL project through discussions and email communications, and, were asked to explore the German PARSEL website and get informed about the pool of modules. The interested teachers were invited to join a one-day workshop in January 2008, where they received more detailed information about the PARSEL philosophy and the way an evaluation of the trials was planned. Prior to the workshop, the teachers had already made their choice concerning the modules that they would like to test, and thus discussions on specific questions were also possible during this workshop. The first modules from the 14 modules that were chosen, (i.e., 'Fire,' 'Salt,' and 'Soap') were tested in March 2008, the modules 'Lara' and 'Nuclear bomb' were tested in June 2008, and it is planned that the other nine modules will be tested from September 2008 onwards. The modules 'soap,' 'salt ,'and 'fuzzy bubbles' were tested in one grade-5 and two grade-9 classes. The fifth-grade students were volunteers in a special science course, whereas the ninth-grade students were in two elective courses choosing science instead of a third foreign language course. In Table 1, a complete list of the 14 selected modules is presented, where the modules that have already been tried out are underlined, the modules in italics were being tested, while the rest will be tested from September 2008 onwards.

Table 1
List of Modules, Teachers, and School Type and Town

Module	Teacher's Name		Type of School, Town
Fire	Ronald		Gymnasium, Schleswig
	Christa	Plastic	Gymnasium, Ahrensburg
Lara	Stefan		Waldorf-School, Kiel
	Gerrit	Chitosan	Realschule, Itzehoe
Fuzzy Bubbles	Christiane		Gymnasium, Ahrensburg
	Maren	*Nuclear Bomb*	Gymnasium, Ahrensburg
Salt	Andreas		Gymnasium, Ahrensburg
	Marcus	iPod	Gymnasium, Ahrensburg
Soap	Ulrike		Gymnasium, Rendsburg

Data Collection

Student data were collected from group interviews before and after the trials of the modules, while the participating teachers were administered the Weizmann questionnaire. Thus pre-interviews were conducted with 10 classes with an average number of 21 students per class. One class consisted of fifth-grade students, two of eighth-, six of ninth-, and one of tenth-grade students. Two classes were interviewed by both authors, six by Martin Lindner, and two by Wolfgang Gräber alone. These interviews actually followed a questionnaire, which was used for a survey on students' interest in chemistry, and all the answers were coded. Our intention was to enrich the information gained from the questionnaire using additional information from group interviews. The questionnaire was adapted from Gräber (1990), and the version used in December 2007/January 2008 with 1300 students of eighth- to tenth-grade students in five schools in Schleswig-Holstein. Analysis of the data is ongoing and published results would be made available at a later date, but first results have shown some very interesting differences. Based on self-determination theory (Deci & Ryan, 1985), we identified the importance of experienced competence, autonomy, and social relatedness. Research on interest has additionally directed our attention to the relevance of lessons. Thus, in the interviews, we asked students primarily about characteristics of science and science lessons, about topics, about relevance to their personal lives, and about their vocational preferences.

The questions were grouped around the following topics:

- What are the characteristics of science subjects?
- Which topics did you like most?
- What are characteristics of science lessons?
- What do you miss in science lessons – what would you recommend to make science lessons more attractive to students?
- Do you see any relevance of science as it is taught at school to your personal life?
- Who is planning to select a science-oriented profession?

Teacher data were collected using a PARSEL questionnaire asking teachers about their experience with the taught module. The questionnaire was translated into German and sent to the participating teachers, who were asked to record all changes they had made to the content, and sequence or the material of the module, and provide reasons justifying these changes. So far, feedback has been received only from three trials. As an example, the results of the module "Which soap is best?" are presented.

Which Soap Is Best?

The module "Which soap is best?" was tested in two classes of a Gymnasium (grammar school), where students were taking part in a special course called "Applied (natural) science." These students chose the course as an alternative to the third foreign language course in grade 9. The two classes consisted of 12 girls and 31 boys. The groups were heterogeneous concerning students' interests, abilities, and motivation. At the beginning of the course, they had limited experience in conducting experiments. As the course did not have any relevance to their final examination, the students did not seriously prepare for the course, nor do their homework. The school was located in a small town and had a rural background. As the town grew fast in size during recent years, so did the school, but the available chemistry equipment was comparably poor. The teacher, Ulrike, was an experienced teacher for biology and chemistry, and participated in several projects relating to developments in chemical education.

Description of the Module "Which Soap Is Best?" The module raised the questions given in the script, together with suggestions on how to answer them taking into consideration the price, the smell, the size, and efficiency of the soap. In the first phase, the students were required to compare information on soap labels, measure the weight, and calculate the price per gram to make the costs comparable. In the second phase, students were asked to investigate the characteristics of different soaps (like comparing the water content and the colour), and the students were asked to design a set of procedures for comparing the effectiveness of different kinds of soap for cleaning. The students were expected to decide what to clean, the factors that needed to be compared, and the variables that they needed to control or keep constant. Finally, during the third phase, each student was required to individually make a decision as to which soap was the best, while these ideas were then discussed in a whole class session.

Results

Pre-interviews

In the pre-interviews, the two classes of ninth-grade students characterized chemistry as an important subject. In their justifications, they stated that chemistry was important as it can help to decide whether a substance is poisonous or not, or it could be useful to solve problematic situations at home, or during travels. Nevertheless, only a few students indicated that they would like to select a future profession connected to chemistry. Some students stated that they liked chemistry, because the class work was more practical than in other subjects, and this made it easier to learn. Besides, the common students' complaints against some teachers, the amount of work, such as preparing the tests, and about the uncomfortable rooms, the students gave an overview on aspects of relevance and popularity, as indicated in the comments attaced in the following sections.

What are the characteristics of science subjects? Some of the reasons that students focussed on were related to: interesting experiments (all classes), the connection to real life (e.g., abuse of alcohol, optic of colours, abortion), and the connection between the different chemistry topics that was considered 'higher,' in comparison with other school subjects, like history or languages.

Which topics did you like most? Some special topics relating to semiconductors, batteries, sexuality, gene-engineering, and health-oriented ones were among the topics that students liked more, while the majority of the girls reported that health was the most attractive topic. The younger students felt strongly about topics, like, animals, pets, and the human body. The tenth-grade students also liked more complex units, like atoms, electrical phenomena, or energy.

What were characteristics of science lessons? Students' answers focussed on the experiments that they considered to be well-structured and well- prepared; to be, helping them to be engaged, to fulfil the curriculum, and to undertake tests. They also emphasized the experimental work undertaken in groups, while they stated that group work was more common than in other subjects.

What did you miss in science lessons and what would you recommend to make science more interesting to students? The students expressed the idea that in physics they had to calculate in most lessons and that they would prefer more up-to-date topics, like, climatic changes or more combinations of science lessons in the schedule, so that the units were not so separated - at least in 90 minutes lessons.

Did you see any relevance of science taught at school? Students explained that chemistry was important, because they could use some of the facts they were taught. For example, they could explain the fuction of a refrigerator, why an eye turns the picture uside down, and they could also understand a few things about several diseases.

How many of you were planning a science orientated profession? The fraction of the students having a science career in mind varied from 1/5 to 2/3. Some students had precise plans, especially boys, indicating a career in science, or computer related subjects, like graphic-design. One girl explained her wish to become a hairdresser as a science-related job, mentioning a lot of chemistry that she considered necessary for the job. One student wanted to become a teacher in biology and chemistry.

Several of these answers were parallel to answers concerning the interest questionnaire. For example, students liked to do experiments or to work on topics from their everyday life. They also concidered science (chemistry) as important and relevant for their lives, because they could use learned concepts out of school, or because they liked to self-regulate their work, to choose their own content and goals, and to invent their own ways to solve problems. In the interviews, when we started to challenge their answers and tried to reach more deeply into their thoughts, we found quite different opinions, while only a few of them maintained their initial position. Mainly, the weaker students did not like self-regulated and context-oriented learning. They rather demanded for clearly structured lessons and tasks by the teacher, and they expressed the opinion that "context-orientation makes lessons complex and difficult to understand." The main goal for them was not to develop themselves, but to be prepared for the next test. Working on experiments, such as cookery recipes, was concidered as a desired must.

Teacher's Feedback after the "Which Soap Is Best" Module

The first and second phase, the *introduction of the module* and the *learning science*, were conducted as they were described in the module. The self-regulated work of the teams was highly motivated and the students worked to the tasks. In this way, they got interesting results, e.g., the weight of the soap bars was sometimes less than indicated on the boxes. They studied the product labels carefully and found other additional criteria to consider in determining the soaps' quality – such as, its cleaning power, flavour, but also the brand's images. The students' assessment was undertaken by the teacher through commenting and assessing the protocols.

Students Studying the Soap Labels

The Third Phase – Socio-scientific Decision Making

The students liked the practical work and its relevance for their everyday life. They also mentioned positively the variety in their own ways of self-determined work. Both classes liked the student-orientation of the work. Most of them realized the necessity to check declarations and advertisements by doing their own experiments and calculating their own results. They very eagerly compared and discussed their results with those of their classmates. One important, and for the students surprising, outcome was that they came to differing buying decisions depending on which criteria were given most weight.

Overall the teacher felt that the module achieved its goals regarding her students. She got some very good outcomes showing the motivation and the interest of the students, indicating the relevance of the topic. These outcomes also indicated that the scientific approach was well accepted to solve such questions. The teacher did not change the module, although in a third trial, she declared that she might shorten it a bit. She especially mentioned the assessment tools as an inspiring offer of varieties to check the outcome of the work of the students. Thus, she would recommend the module to other teachers due to its various offers for different grades, for different methods (working alone or in teams of students), and as a model for other topics.

More interestingly, in the next lesson the students, who did not belong in the most scientifically interested group, performed an astonishing change in their behaviour. The teacher asked them, after finishing the soap project, what they would like to examine next. The students were very engaged, they suggested several items, and then started planning a module on ice tea.

Discussion

In a traditional chemistry course in Germany, the topic "soap" would have been treated in upper secondary (grades 11 or 12) as part of the organic chemistry curriculum. Soap would have been introduced as the sodium- or potassium salt of fatty acids, its chemical synthesis would have been taught, and an experiment would have been demonstrated by the teacher or performed in students' group work. Nearly no connections to everyday life would have been made. Soap would just have been taught as a "chemical substance." The focus would have been on "chemical knowledge" and "nature of science" competences.

The new approach, using the PARSEL philosophy, did not neglect these competences, but additionally focussed on communication and evaluation competences. The module started from students' everyday life experience, exploring the topic's relevance to students as critical consumers, and provided students with knowledge and science-based strategies to be used in their everyday life. The self-regulated work in groups, where students needed to plan, carry out, reflect, discuss, and demonstrate their own ideas, not only helped to develop an adequate capacity for teamwork, but also supported the learning of communication skills. A remarkable change occurred in the students' opinions. Thus, they stated that they had experienced and greatly enjoyed to work in a self-regulated manner and in groups on context-oriented topics. But, they had not been left alone so that they got lost trying to undertake difficult tasks. They were embedded in a social environment, where they felt autonomy and having competence, and thus developed intrinsic motivation to work further in this field. During the discussions in the third phase, which were normally missing in traditional lessons, many questions were raised, which expanded the topic to a much more society relevant dimension. Could too much soap harm our skin? Would it be better to use liquid soap? What about the necessity of washing ourselves with soap, or cleaning clothes with soap or washing powder? Is it necessary to have shirts white, as whiter they cannot be? What about the environmental pollution from the industrial production process?

Many questions came out of the group and many went far beyond the traditional canon of chemistry lessons, which helped to develop students' evaluation competence, and contributed to educate students as responsible citizens. Many questions were discussed even after the lessons in school breaks, or with parents at home. Obviously, we should undertake more interviews with the students relating to the other modules as well, in order to get a more complete picture of the impact of the PARSEL way on teaching science in a more relevant and effective approach.

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