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ABSTRACT

Students' attitudes toward chemistry change throughout their educational life. While enthusiasm is observed among 10-12 year-old pupils, in the upper grades the positive attitude changes to lack of interest and the likelihood of dropping the subject or course. This study investigates international researchers' point of view on the decrease of interest in chemistry and the tendency to drop the subject. The program ParCIS: Partnership between Chemical Industry and Schools was developed to promote self-regulated learning and media competence. This partnership focuses on developing and evaluating exemplary lesson plans. (Contains 28 references.) (YDS)

ParCIS: Aiming for Scientific Literacy Through Self-Regulated Learning with the Internet

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When you ask adults what their favourite subject was in school, they almost never answer "chemistry". Most of them will only remember formulas and equations which they never really understood. The same is true for calculations and reports which ruined even that little fun they had doing the few experiments they were to do. Another thing most adults have in common is the feeling that what they learned in chemistry class was not important for later life, unless they ended up working in a chemistry–related profession.

When such statements are compared with those from students who have not had any chemistry lessons yet, a deep schism between the two becomes obvious. Ten to twelve year–old pupils generally look forward to having chemistry lessons and expect a lot from them. They hardly can await the first chemistry period. But pupils' originally positive attitude towards science subjects changes significantly in the upper grades (9th and 10th), especially in chemistry and physics. Many English–speaking authors have commented on this (Schibeci 1984). The same is true for German–speaking authors. Such a negative attitude towards a subject leads to a lack of interest and, when the subjects can be selected as in the course system of the upper secondary level of the German GYMNASIUM or the British sixth form they are likely to drop the subject or course (Schmied 1982).

The task of compulsory schools is to educate students to be mature responsible citizens. Science education contributes to fulfil this task by imparting knowledge and skills as well as fostering the development of attitudes, interests, and values. Interest, therefore, has a double function: On the one hand, interest is a pre–requisite for meaningful learning (see also Rennie & Punch 1991; Nenniger 1992; Schiefele U. et al. 1992; Voss & Schauble 1992); recent empirical findings underscore this assumption by recognizing that learning guided by interest leads to a more complex and flexible structure of knowledge than extrinsically motivated learning processes (Biggs & Collis 1982). On the other hand interest represents the goal of teaching to guarantee a life–long open–mindedness (see Schiefele, H. et al. 1979).

Because of this double function, importance should be attached to the construct of interest within research of science education. For about twenty years now, the IPN has been doing research on "interest" or "subject–related motivation" especially in physics (see Lehrke et al. 1985). Between 1984 and 1989 a comprehensive longitudinal study (Häußler 1987, Hoffmann & Häußler 1995) was carried out in connection with a cross–sectional one on this specific topic. In 1988 we began to plan a study on research interest in chemistry (Gräber 1998) similar to that in physics so that the knowledge and experiences gained from the given long–standing research could be referred to. Besides, the chemistry–related study of interest was founded on an extensive inquiry of relevant literature. We intended to find out how the decrease of interest and the tendency to drop the subject Chemistry has been explained by international researchers so far. We found that even the daily press has called attention to this topic: For example, the British newspaper "The Observer" (Noble 1993) pointed out that pupils turn their backs on chemistry because of its negative image. "It is that, compared with 30 years ago, the downside to science and technology is more fully recognized. Technological disasters such as Chernobyl and ethical problems arising from advances in genetics have weighed heavily with those who imagine that life was once relatively problem–free." The study of Heilbronner and Wyss (1984) demonstrates it in an impressive way: 11 to 15–year old students at various "Gymnasiums" and "Realschulen" were asked to portray their imagination of chemistry in a drawing. Two thirds of the drawings predominantly displayed the negative aspects such as the pollution and destruction of the environment or animal experiments.

Besides this *poor image of science and technology*, I would like to point out some common associations with chemistry lessons:

- Many male and even more female students complain that chemistry is *too abstract, thus cannot be related to their environment*, and quote this as reason for dropping chemistry. With regard to this deficiency, Stork (1984) says: Chemistry lessons mainly focus on problems which are related to the interconnection of chemistry–specific concepts. As students see it, chemistry is limited to the proceedings only within the lesson, while the knowledge gained from it cannot be utilized for mastering off–school life situations."
- Science lessons are very often dominated by the teacher. Instead of organizing a student oriented stimulating learning environment teachers tend to transfer knowledge to passive students by lecturing. In this context the *teacher's personality* gains much importance. Mead and Métraux (1973) studied many thousands of teachers and their characterization can be summarized as follows: "Scientists tend to transfer their discipline's abstracting methods to everyday life and the classroom instead of enlivening the material with their personality."
- Another reason for the unpopularity of chemistry lessons comes with the *subjects' difficulty*. Most of the topics in chemistry are abstract in nature, meaning working with theories and models. Such work requires thinking at a formal–operational level. However, various studies show that most of the students at the age level in question

have not reached this level of thinking. We have carried out an empirical study using a Piaget test from A. Lawson on 354 students at 10th grade at German "Gymnasiums" and found that only one quarter of these 15– to 16–year olds were able to think in a formal–operational manner (Gräber & Stork 1984). Miller (1997) has been involved in measuring the scientific literacy of the American public for many years, and has extracted two factors from the data that were produced by the National Science Foundation: the vocabulary dimension, and the understanding of the nature of scientific inquiry. His findings underline the difficulty of learning science: Only 7% of the people investigated in 1995 scored high on both factors, and can thus be considered scientifically literate.

All in all, Seelig (1968) comprises his investigations of the popularity of chemistry and physics courses: "Physics and chemistry lessons give pupils the impression of being too theoretical, too dry, and too difficult." Many other studies have confirmed this negative view on science teaching and learning world wide (e. g. Simpson & Oliver 1990, Sjöberg 1997, Miller 1997, TIMSS III). Attitudes toward science and science teaching are negative, interest in the subject is declining with progressing school time and the cognitive learning outcome is very poor. Even the small amount of facts and concepts which has been learned and kept in mind can't be applied to everyday life situations by the majority of students.

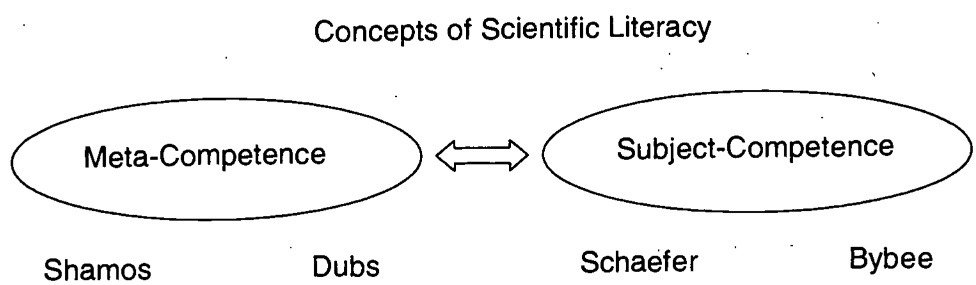
These disappointing observations raise the question of whether we even treat the right topics in school and follow adequate goals. Which criteria are important for selecting goals and content? P. Häußler listed the following five points in his presentation at the IPN–Seminar on scientific literacy: the academic disciplines, life situations, recommendations of experts, interests of students and concepts of general literacy. Each of these criteria has its own significance, while the last one, a concept of general literacy, which of course also includes parts of the others, seems us to be the most important one and leads us to scientific literacy.

Scientific Literacy: The Goal of Science Teaching and Learning at School

We organized two international symposia on scientific literacy at the IPN, which helped to structure the topic and formed the base of further research and development. While the first one (Gräber & Bolte 1996) focused on the theoretical background, the second one (Erdmann, Gräber, Nentwig 1999) intended to bridge the gap between theory and practice.

The 2nd International IPN Symposium on Scientific Literacy (Kiel, October 7–11, 1998) (http://www.ipn.uni–kiel.de/projekte/a4_5/sympos2/allgem2.htm) was part of a long–range multi–national initiative to promote the development of scientifically literate citizens. It built upon and extended the outcomes of the first symposium and involved some past participants as organizers. Specifically, the purpose was to apply our conceptual understanding of scientific literacy to the concrete world of science teaching and learning. The symposium also strived to bridge the gap between theory and practice by having academics, university professors and researchers, develop and teach lessons to pupils. Four keynote speakers (Rodger W. Bybee, Rolf Dubs, Gerhard Schaefer, Morris Shamos) described the theoretical background and tried to bridge the gap to practice, while 12 video contributors presented real science lessons. These video contributors from different countries all over the world showed tape recorded science lessons of how they try to promote the development of aspects of scientific literacy. Each video presentation was complemented by a discussant who was expected to enrich the discussion with his own view on the subject.

Our keynote speakers' definitions of scientific literacy could be placed (roughly taken) along a continuum with the poles of focussing more on subject competencies or on higher meta–competencies.



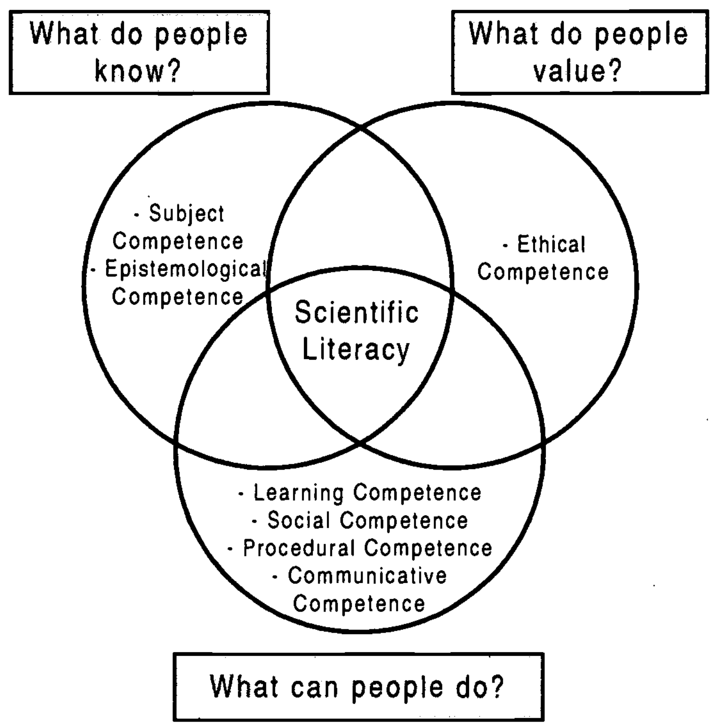
Rodger Bybee has proposed a comprehensive hierarchical model, which forms the base of the National Science Education Standards of the USA, which is still very much driven by the science's discipline (by of course considering life contexts and cross–curricular competencies).

Gerhard Schaefer tries to mediate between the two extreme positions. His literacy model is not based on a mosaic–like summary of academic defined subjects as propagated by many scientists, but there are general competences which constitute the construct general literacy or life competence. A central position is taken by subject competence through which the different subjects contribute to develop the other competences.

According to Rolf Dubs the general aim of teaching science should not be to reproduce the university disciplines at the general school level but to be oriented towards societal requirements, to learn how to deal with social issues and to make rationally founded decisions.

Morris Shamos (1995) refers to the negative outcome of science teaching and has suggested that the science education community has deceived itself into thinking that a definition of scientific literacy which includes both wide and deep content knowledge and process competence is possible. He proposes a more realistic definition which challenges science educators to help students become competent consumers of science and to trust the real issues to science experts.

Summarizing the various proposed definitions and models and taking into account the skepticism of Shamos and others, we would like to suggest a competency based model of scientific literacy, going back to Schaefer's request for "life–competence" as a goal for education in school. In this approach the question is not the causal "why" do we teach science to children but rather the final "what for", and consequently the answers are not "because our societies need a scientifically literate workforce" (or other justifications). The answer is "for the individual to cope with our complex world." Competencies are needed for that task, and some specific competencies can be acquired in the science domain better than in others. Science teaching traditionally concentrates on the knowledge aspect, adding perhaps a few of the procedural skills, but usually neglecting the other competencies. The view proposed here may help to reconsider the balance between the various competencies and to reflect, what specific contribution science education can make.



The Gap between Theory and Practice

An analysis of science–classroom videos at the 2nd International IPN–Symposium on Scientific Literacy shows that science teaching can be described in three dimensions. Each dimension can be characterized by two extremes on a scale:

teacher centred – student oriented

It is either the teacher governing the classroom activities, steering the students' learning processes, and dominating the communication process or the students taking responsibility for their own progress, initiating their learning processes in a more or less autonomous way.

teaching facts – teaching processes

The teaching/learning activities aim either at science facts, laws, and formula or at the acquisition of problem solving strategies and skills of processing information and interpreting data.

discipline oriented – daily–life oriented

The aim of the lessons can be to either delineate the structure of a scientific discipline and to reproduce research findings on a reduced level or to provide means to understand daily–life phenomena, including their social, technological and economic implications.

Traditionally, science teaching is lopsided towards the left side of each of these scales. Teachers tend to dominate the teaching/learning process with fact oriented lesson contents and the aim to reproduce (at least part of) the structure of their scientific discipline in the heads of their students. The results of these efforts have been disillusioning world wide.

A look at the list of competencies which, each with their own weight, constitute "scientific literacy", makes it evident that such science teaching must fall short of reaching the goal. We are not suggesting that all engines should be turned on reverse and that the opposite approach – student autonomy, acquisition of process skills, daily–life orientation – is the recipe for successful science teaching. Obviously often enough students do not take responsibility for their own learning processes, facts are necessary for applying skills, and daily–life phenomena are often too complex to understand with regular students' limited knowledge.

However, to reach some extent of scientific literacy for all students, more of these ingredients must be introduced to science classrooms, and in order to do that, teachers must be able to act expertly on both sides of the scale in all three dimensions.

Self–regulated learning

If we take scientific literacy serious as a goal of science education, and if we want science classes to contribute to the general education of emancipated citizens, we must re–balance the orientation of our teaching. Careful guidance of children towards self–regulated learning must have priority. This can be explained with terms such as self–determination, self–responsibility and self–activity.

Self–determination as a basis of all emancipative efforts makes the learner independent of a teaching person. Self–responsibility for one's own learning process is the prerequisite for life–long learning, which depends on self–activity, if it is meant to be fruitful and lasting.

ParCIS: Partnership between Chemical Industry and Schools

The new electronic media are ideal vehicles to support self–regulated learning. We try to use this chance by starting a new project ParCIS (Partnership between Chemical Industry and Schools) in cooperation with schools and industry aiming for developing competences for self–regulated learning and media–competence.

The most important goal of ParCIS is to promote self–regulated learning and media–competence. In addition to ordinary classes, the students will work autonomously in small groups on open questions. They will gather information from various sources (e.g. textbooks, encyclopaedias, newspapers), but in particular from the internet, where information is supplied by several educational services, textbook publishers, schools, universities as well as industry. All these possibilities are to be used, but the focus of this project will be on those websites created by chemical enterprises in the neighbourhood of the schools

Most of the information nowadays found in the internet is – although it might be relevant in terms of the curriculum – either incomprehensible or not meaningful to the students, and cannot be used in the classroom. The chemical enterprises participating in this project will help to close this gap. They will present general chemical content as well as specific information from their field in a way that is meaningful to students. These websites will be designed and developed by a research group consisting of industry representatives, researchers and teachers.

We are going to develop and evaluate different exemplary lesson guides. Because of our first industrial partner, the international chemical concern Bayer, we will focus on plastics and dyes; these are the main fields of expertise of Bayer in Schleswig–Holstein (Germany). The traditional way of teaching dyes in German schools is to start with theoretical foundations on the structure of dye molecules, chromophoric π-electrons system, and coloured light and electromagnetic waves. With this background the different classes of dyes will be treated one after the other, e.g. polymethines, triphenylmethanes, azodyes, phthalocyanines a.s.o. This course will be finished by the discussion of applications of dyes in chemistry and everyday life situations. The whole sequence is structured and dominated by the teacher, enlivened by some groupwork labs.

Our intention, in promoting self-regulated learning competences, is to teach in a more student oriented way adapted to the cognitive apprenticeship model (Collins, Brown & Newman 1989) with the following steps: Modelling, coaching, scaffolding, fading, articulation, reflection, exploration.

The whole sequence is taught in a way that is application led similar to the central way of STS teaching. The first step (modelling) is the introduction of theory and practice of dyes through a teacher structured example from everyday life (e.g. hair dying).

The teacher shows as an expert how to work on such a topic, which questions to ask, how to plan the project, how to find, handle and evaluate adequate information (particularly from the internet) and how to present and discuss the results. Although the teacher controls the procedure the students are not passive consumers but join him/ her actively asking questions, planning, experimenting or thinking.

Following this introduction the students work in groups on own mini–projects of dyes' application. The teacher's main task is to coach and scaffold the self–regulated processes, with a gradually fading of support. Articulation and reflection of the processes and their results will be completed by presentations of the groupwork through posters, portfolios, html–documents, PowerPoint–presentations or the like.

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