Symposium:

Scientific Literacy: From theory to practice

Organizer: Wolfgang Gräber, Institute for Science Education (IPN), Kiel, Germany
Discussant: Doris Jorde, University of Oslo, Norway
Panel members: Hans-Jürgen Becker, University of Paderborn, Germany
Peter Nentwig, Institute for Science Education (IPN), Kiel, Germany
Anja Pitton, Elke Sumfleth, University of Essen, Germany
Kai Wollweber, Integrierte Gesamtschule Eckernförde

Objectives.

Gerhard Schaefer in his keynote address at the Second International IPN-Symposium on Scientific Literacy thought about educational solutions for citizens in a changing world: "Taking into account the growing complexity of our world, caused by the opening of national borders and by almost infinite electronic communication, and the increasing speed of global ecological, economic and political changes, number 1 of the educational challenges of the next century seems to be: high flexibility, both in storing and using knowledge, and in international communication." Thus he argues for "life-competence" as a goal of school education. This symposium will focus on the part the sciences have to contribute to this goal.

The Second International IPN-Symposium on Scientific Literacy, held in October of 1998, serves as the starting point for our current efforts. The goals of the conference were to apply various conceptual understandings of scientific literacy to the concrete world of science teaching and learning. A significant product of the fall symposium, a collection of video-taped segments of science lessons taught by science education experts, will be made available to all session participants. Based on the symposium's experience we have produced three new videos which will be used to illustrate the application of various aspects and definitions of scientific literacy to the teaching practice. Segments of these videos will be used to stimulate discussion about the promotion of scientific literacy.

Significance.

There is worldwide consensus that our societies, regardless of any cultural differences that there might be, need scientifically literate citizens. The National Research Council (1996) of the US in its Science Education Standards states: "All of us have a stake, as individuals and as a society, in scientific literacy. An understanding of science makes it possible for everyone to share in the richness and excitement of comprehending the natural world. Scientific literacy enables people to use scientific principles and processes in making personal decisions and to participate in discussions of scientific issues that affect society. A sound grounding in science strengthens many of the skills that people use every day, like solving problems creatively, thinking critically, working cooperatively in teams, using technology effectively, and valuing life-long learning. And the economic productivity of our society is tightly linked to the scientific and technological skills of our work force."

And the BLK (1997), a governmental commission for the coordination of research
activities and educational matters in Germany in its expertise for the preparation of a just recently installed program for the enhancement of science education, which, by the way, is being coordinated by members of IPN, claims: "Biology, chemistry, and physics provide basic scientific concepts for the interpretation of nature, humanity and a world that is formed by science and technology. The various epistemic methods of the sciences serve as basic tools for understanding oneself as part of the world." (p. 44)

Agreed that scientific literacy is a must, then what could the term mean? There are bookshelves full of definitions. The international concern about what constitutes appropriate and adequate science education for citizens has received ever greater attention in recent years (Shamos, 1996; Bybee, 1997; Gräber & Bolte, 1997).

Rodger Bybee (1997) e.g. has proposed a sequence of steps for all students to achieve higher levels of scientific literacy. He distinguishes nominal, functional, conceptual and procedural, and multidimensional scientific and technological literacy (p. 84).

Koballa, Kemp and Evans (1997) combine levels, domains and values to a three-dimensional landscape representation of the scientific literacy spectrum.

An interesting one was recently added by the Science Functional Expert Group of the OECD PISA project (1998), who propose: "By scientific literacy we mean being able to combine science knowledge with the ability to draw evidence based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity."

Again, it seems, we can reach some kind of consensus on what school science should be about. The next step then is to have a look at the outcomes of science teaching. What does school science really achieve?

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. Only 7% of the people investigated in 1995 scored high on both factors, and can thus be considered fully scientifically literate.

For Germany the findings of TIMSS/III is particularly disheartening, but there are several other countries, which cannot be happy either. Baumert et al. (1998) state in their German report that "only a small portion of the students reach a level of assured and independent application of their knowledge. Whenever the tasks leave the familiar school-context, the majority of participants in the basic courses face great difficulties." (p. 101) "There is a substantial discrepancy between the competencies which, according to the curriculum should be expected, and the really achieved goal at the end of upper secondary level. Particular deficits are in the areas of conceptual understanding and of understanding scientific inquiry and reasoning. (p. 89)

IPN's own studies on students' interest in physics and chemistry (Gräber 1998; Häußler 1987, Hoffmann & Häußler 1995) confirm worldwide research findings that the "hard" sciences physics and chemistry rank very low, particularly with girls.

Sjöberg (1997) concludes: "We have to admit that science and technology, at least in Western democracies, are met with distrust and suspicion, and that there seems to
be a falling interest in science in schools. Norwegian data show declining enrollment in schools, especially in physics, and we are facing a recruitment crisis in the whole sector of science and technology. Similar trends are visible in many OECD countries." (p. 14)

Morris Shamos (1995) has taken all this in account 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.

Recent educational discussions, however, come back to the questions of the 1970’s stimulated by hot political debates about "what should the world's children know?" and about the concept of "general education" (Schaefer, 1998), questions which had been discussed during the First and Second International IPN-Symposium on Scientific Literacy in detail.

As these and other scholars take us closer to a global, cross-cultural concordance on science literacy, it becomes increasingly important that we move on from mere definitions of what it means to be literate to discovering how such a construct should affect our classroom teaching.

**Background.**

International science education professionals from ten different countries with a particular interest in scientific literacy issues were invited to participate in the Second International IPN-Symposium on Scientific Literacy during October of 1998. Before the meeting, each taught a lesson to a secondary science class with the goal of illustrating how one aspect of scientific literacy could be brought to students via a typical lesson. There was a wide range of literacy aspects addressed in these classes such as subject competence as well as epistemological, learning, reasoning, methodological, communicative competence, and ethical competence

20-30 minute videotapes of each illustrative lesson were transcribed, subtitled and presented for discussion at the fall symposium. From discussions and analyses of each, a selected group of teaching segments and the associated analytical discussions, were accumulated in a video/paper format. Based on this experience we have produced three new videos, which illustrate how to promote aspects of scientific literacy by focussing on a) teacher – student communication processes and acquisition of thinking skills, b) cooperative learning and c) daily-life experience. These videos will be presented as a basis for discussion about ways of promoting scientific literacy.

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Bybee, R. 1997. *Achieving Scientific Literacy: From Purposes to Practices.*
The "daily-life" approach to scientific literacy
Hans-Jürgen Becker
Universität Paderborn

Abstract.
It is not a new insight that science teaching, in order to be meaningful for students and to contribute to their scientific literacy, should best be related to their "daily-life" experience. This can be done in different ways, e.g.

- by teaching about matter in everyday life;
- by teaching about everyday activities (processes) with matter;
- by teaching about chemistry communication situations in everyday life.

The knowledge of science related issues in daily life, of common scientific processes and procedures, and of typical ways of communicating science related issues in society as well as the ability to act in an enlightened and responsible way are ingredients of what is described as Scientific Literacy in current literature. The presentation will attempt to show how role-playing is used to help students understand typical communication situations, as they may be experienced in their
daily life as open-eyed citizens.

Synopsis.

What do a judge, a musician, a businessman remember when they think about their chemistry classes? Redox processes, delocalized electrons, inductive effects? Hardly! If they have any memory at all, it will probably not be without negative aftertaste. They might remember that water can be hard or soft, how glass can be made, and how steel is tempered. We would hope so, but we cannot be certain. Such topics, and similar ones, have played only a marginal role in the discipline oriented chemistry teaching of the past twenty years. The "real thing", was the elaboration of the scientific discipline. Applications, technological contexts, societal relevance, environmental problems related to the chemical content matter were, if at all, mentioned as a byline. These, in reality, are the issues that will concern our students in their life after school. For such issues it is Science Education's responsibility to provide necessary orientation and decision-making aids. Freise, for instance, describes a daily-life teaching concept as a chance to “relate science and technology with the understanding and the lives of the students in our society” and thus as a possibility for “understanding life in a world made scientific”.

Only few students benefit from the current theory-oriented chemistry teaching. The competency to act appropriately in daily life is only acquired if facts, theories and phenomena are taught in daily life contexts. In life after school, knowledge of chemistry is necessary to understand and evaluate technical aspects (including the effects on society), environmental problems and questions about health (see the video sequence), the energy discussion, law making procedures, substances at home and in everyday life. Knowledge about materials, machines, production processes, or social conditions at the workplace will be important in the students' future crafts and businesses. Students need to be prepared for independent and critical behavior in such contexts. Science teaching has to have in mind the students' activities in their future adult life. Chemistry and daily-life phenomena are then not viewed as opposites but as a unit.

We do not deny the problems caused by this orientation. Daily-life situations are most complex and of diverse structure. They are perceived differently by different individuals (see video sequence). The question is still open, how the structure of a discipline can be communicated with this approach. Apparently incompatible aspects have to be brought together in the discussion about daily-life approaches. Its high motivational power is an asset, its complexity is a problem. Both arguments are relevant from a psychological point of view. Seldom are themes like washing powder, soda, steel, glass, polyvinylchloride, or glues obligatory parts of a syllabus. Usually it is left to the methodological and experimental skill of the teacher to liven up the discipline oriented course with daily-life phenomena. Science education has offered help for that task, however.

In simulation games the development and the solution of complex problems is acted out in a reality related way. Among simulations role-playing is probably the best way to methodologically liven up science lessons. Role playing can easily and quickly be incorporated into the lesson, whereby the students’ interests can be taken into consideration. It is also a chance to train students’ competence of judgment, even though role playing is more a way of re-thinking an issue, a game set down by role cards. Teaching experience shows that role playing in chemistry lessons promotes
motivation, activates participation, and can effectively be built into lessons. Students as actors (role players) can experience in which daily-life situations scientific (chemistry) knowledge can be important. Systematic fundamental knowledge, which can be imparted in various methodological ways, can be applied, practiced and expanded ... (cf. video sequence). For younger children the teacher prepares the various roles for the play. Older students can be involved in this as well. Points of view and arguments are written on role cards for each role (cf. video sequence).

We do not have much feedback yet about role playing in daily teaching practice. We, therefore, feel that it is a most important task for teacher training to provide adequate methodological foundations in connection with the “change in legitimation”.

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Influence of instructional discourses on the acquiring of definitional knowledge and thinking skills
Anja Pitton, Elke Sumfleth
Chemistry Department, Essen University, Schützenbahn 70, D-45127 Essen

Introduction.
Summarising the results of research in science education there is a general agreement that it is important to improve the quality not the quantity of reproducible elements of knowledge. With respect to learning Duit (1991, p. 68) summarises major trends: „Learning is not seen as a process of simply storing pieces of knowledge provided, for instance, by the teacher. On the contrary, it is seen as a process of active construction of knowledge on the part of the learners themselves on the basis of their already existing conceptions.“ And Brody (1994, p. 423) formulates additionally: „Children have existing conceptions which influence their understanding of the world and their acquisition of new knowledge. Learning cannot be considered as simply the acquisition of a set of correct responses. Alternatively, meaningful learning is considered as process of conceptual change. Learning is a process of active knowledge construction based on learner’s previous knowledge. Problem solving requires that the learner picks up his previous knowledge to integrate new elements of knowledge in existing individual cognitive structures.

Often learning is related to verbal interactions between two or more individuals, as for example learning at school. But does a student at school get this chance to construct his knowledge actively? In many cases the students remain passive, listening. They comply with the request of the teacher to answer and adopt teacher’s words. Roth (1994, p. 437) says very pessimistically: „In contrast, it is a common practice in today’s schools that students sit, listen and respond to teacher-investigated question-answer-evaluation sequences.“ Teachers believe to support the students in problem solving, but actually, they focus on imparting and examining definitional knowledge without realising this discrepancy. But teaching should mean to help the students to construct knowledge actively, to activate previous knowledge and to relate new struc-
tures to known ones (f.i. Kluwe and Spada 1981, Sumfleth 1988, Stachelscheid 1990). Teachers must influence students’ processes of problem understanding by structuring the objective task environment as clearly as possible. They have to try to recognise the individual thinking and acting of the students and to judge them with regard to a meaningful use of prior knowledge (Fleer 1992).

**Problem.**

Communication mainly is verbal. In classes verbal acting is adapted to the institutional framework ‘school’. In order to identify students’ difficulties, teachers have to take students’ statements seriously. An instruction based on students’ preconceptions is possible only when teacher and students exchange their individual arguments and compare them concerning their meaning in explaining the facts discussed (Gramm 1992). During lessons the teacher cannot care about each student individually. Communication between teacher and some students as well as among students has to give impulses to the individual learning processes. The teacher must refer to audible and visible signs of the students and he must make sure that he has interpreted the signs in the way they had been meant (Dierks and Weninger 1988).

Geißner (1994) names communication in lessons apparent. The teacher is the leader. The students are leader-oriented. Thus, the course of discussion is asymmetrical. In contrast, during a symmetrical explaining discussion the „leader“ is participating in the discussion. The group determines the velocity of learning and searches for a solution commonly. The students are partner-oriented and contents-oriented. These patterns of communication are determined by the type of teacher questions and the aims pursued by the teacher. Therefore students’ problem solving ability depends on the kind of teachers’ instruction. An explaining communication pattern, a ‘student question-dialogue’ is important to enable students to speak about their ideas, a fundamental prerequisite even to consider students’ preconceptions.

**Findings.**

The results of the observation of lessons show that only the minority of students train active problem solving. Instructional discourses are found more often where the students are accumulating reproducible pieces of knowledge. Plenty of less structured information inhibits students problem solving. The students do not learn to use self-confident their previous knowledge in class but they depend on reproduction of definitional knowledge which is sufficient to reply correctly to a teacher question or to pass a written examination. Especially the instruction which focuses on definitional knowledge aims at a correct use of plenty of scientific terms without practising their use during chemistry lessons. So students store reproducible words without any meaning which can seldom be integrated into a context. This system hardly allows to construct knowledge structures. Misunderstanding remains unidentified because teacher and student believe to speak the same professional language. But teachers and students are not aware of the fact that this is not true and they try to persuade each other by ‘different languages’ instead of transforming the problem into a language which can be understood by both (Sumfleth and Pitton 1997).

**Aims.**

By means of video recording we want to show some characteristic teaching sequences demonstrating the relationship between communication patterns and teachers’ aims of instruction. We hope to show the superiority of acquiring thinking skills by
instructional discourses taking into account students’ preconceptions and their interpretation of scientific terms compared with the learning of facts, concepts and definitional knowledge.

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Learning Scientific Contents in Cooperative Groups

Kai Wollweber
Integrierte Gesamtschule Eckernförde
Wolfgang Gräber, Peter Nentwig
Institut für die Pädagogik der Naturwissenschaften (IPN)
at the University of Kiel

Abstract.
This contribution gives an example of how to use "cooperative learning" to promote aspects of scientific literacy. In order to foster cooperation and meaningful learning we have to do more than to just have students work in small groups. This approach like any other has to be exercised in a systematic way. To be productive, cooperative learning groups must be structured in such a way as to include positive
interdependence, face-to-face promotive interaction, individual accountability, interpersonal and small group skills and group processing. If this is taken into account, this approach can help to promote aspects of scientific literacy such as subject competency, communication competency and reasoning competency. After a brief introduction to the teaching unit, we have developed as an example, we will present excerpts of the videotaped lessons to stimulate further discussion.

Introduction.
It is well known that science is predominantly taught in a teacher centered way, focussed on learning science facts according to structured disciplines. This has led to students' decreasing interest, development of negative attitudes toward the sciences and particularly low learning outcome. These are reasons which have convinced us to not only focus on selecting and structuring suitable contents but also to consider forms of organization and social aspects of learning. One appropriate method seems to be the cooperative learning model which not only promotes the acquisition of social skills but also helps to enhance subject learning processes and thinking skills. Cooperative learning causes students to communicate their thinking in an understandable way, to debate, to take different perspectives and to handle discrepant opinions and judgements. This should help to promote students' scientific literacy through facilitating mainly subject competency, communication competency and reasoning competency.

Cooperative learning.
"Cooperation is working together to accomplish shared goals and cooperative learning is the instructional use of small groups so that students work together to maximise their own and each other's learning. ...Thus, a student seeks an outcome that is beneficial to himself or herself and beneficial to all other group members.

...In order to be productive, cooperative learning groups must be structured to include the essential elements of positive interdependence, in which each member can succeed only if all members succeed, face-to-face promotive interaction, during which students assist and support each other's efforts to achieve, individual accountability to ensure that all members do their fair share of the work, the interpersonal and small group skills required to work cooperatively with each others, and group processing (in which groups reflect on how well they are working together and how their effectiveness as a group may be improved)." (Johnson & Johnson 1992)

The aim of the presented lessons is to show how students can learn the chemical content of "aminoacids and proteins" in cooperative groups. The chosen method of teaching is the project oriented approach according to Gudjons. The content of the lessons, the arrangement of the working groups and a set of rules is given by the teacher. Students are free to choose particular topics and methods. They work autonomously over several lessons, they are responsible for the organisation of the learning process, and they have to prepare a product (e.g. a poster, demonstration experiment, report, video, etc.), which is qualified to show the results of their efforts. The unit will be completed with a test of basic knowledge and understanding of the theme.

Target group.
The observed group is a basic course in chemistry, grade 12 of an integrative
comprehensive school, consisting of 3 male and 15 female students. From grade 5 to 10 the students have been taught integrative science, from grade 11 upwards they had to choose two of the basic science disciplines biology, physics or chemistry. All students of this chemistry course had decided to take biology as their second science discipline.

**Content and context.**

As they had all taken biology at grade 11, the content of aminoacids and proteins can be taught in cooperation with biology. At level 11 they studied the basics of aminoacids and proteins in biology: Formulas of the aminoacids and the combination into peptides and proteins were taught. The secondary and tertiary structures of proteins were discussed. Experiments and the theoretical framework of enzymes were the main aspects in these lessons. Chemical properties regarding to functional groups were left out at that time.

The grade 12 lessons in chemistry were now supposed to focus on the chemical properties and reactions of aminoacids and proteins and to leave out the biological issues. Nevertheless last year's biology knowledge was to be used as a starting point. The topic of the parallel courses in biology is genetics, and the biosynthesis of proteins will be a main topic within the molecular genetics.

**The video shows the following steps of altogether 10 lessons.**

- Forming groups according to the students' choice of subsequent biology course, in which they will continue to work in the same groups
- Using mind-maps to recollect existing knowledge of the subject
- Reflecting the groupwork process
- Introducing the theme and explaining the rules
- Starting the journey into unknown territory
- Experimenting with aminoacids and proteins ...... e.g. proving the existence of N in aminoacids
- Two groups joining to do the same experiment
- Tutoring for particular content related questions
- Revisiting the mindmaps to organize new knowledge
- Anne was missing on Monday ...
- Tutoring for procedure and structuring further steps
- Reflecting the first 10 lessons

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