which may provide frameworks for analyzing classroom discourse or conceptualizing learning science as an introduction into a new language or ethics for framing instruction on moral issues.

The interdisciplinary nature of science education is responsible for the particular challenges to carry out science education research and development. Of course, sound competencies in science are necessary but also substantial competencies in a rather large set of additional disciplines. It is noteworthy that in principle, science teachers need the same broad spectrum of competencies as well. Moreover, for teachers to know science well is not sufficient to teach this subject. At least basic knowledge on the nature of science provided by philosophy of science and history of science as well as familiarity with recent views of efficient teaching and learning provided by pedagogy and psychology are necessary.

Shulman (1987) argued that teachers need a large spectrum of rather different competencies. His conception of "*content specific pedagogical knowledge*" (or briefly: PCK - Pedagogical Content Knowledge) has been widely adopted in science education (Gess-Newsome & Lederman, 1999). The idea is the following. Traditionally, in teacher education programs teachers are taught content knowledge and pedagogical knowledge. The link between the two kinds of knowledge, the content specific pedagogical knowledge, is usually missing. Shulman is of the opinion that this kind of knowledge, the PCK, is the major key to successful teaching. The conception of science education outlined in Figure 1 includes Shulman's idea of PCK. Linking competencies provided by the content domain and competencies from various other disciplines (among them especially pedagogy and psychology) is at the heart of the conception of science education discussed here.

A preliminary explication of the interdisciplinary discipline science education addressing these issues may read as follows:[1]

> *Science education is the discipline dealing with teaching and learning science in schools and outside schools. Science education research includes selection, legitimation and educational reconstruction of topics to be learned, selection and justification of general aims of teaching and learning science, as well as instructional sequencing that takes the learners' cognitive, affective and social preconditions into account. A further domain of science education work is research-based development as well as evaluation of teaching and learning approaches and materials.*

Clearly, the focus of this explication is research on actual teaching and learning situations. However, research on the various contexts in which the teaching and learning situation is embedded should also be included as will be more fully argued in a subsequent section.

TRADITIONS OF SCIENCE EDUCATION RESEARCH AND DEVELOPMENT

In a recent review of science education research, Jenkins (2001) distinguishes two different traditions in research within the past thirty years; he calls them *pedagogical* and *empirical*. "*The pedagogical tradition has, at its primary focus, the direct improvement of practice, practice here being understood as the teaching of science*" (p. 20). "*The empirical tradition, always much more evident in the USA than in Europe, has weakened considerably in the last thirty years. It is associated with positivism and seeks the 'objective data' needed to understand and influence an assumed educational reality, close familiarity with which lies at the heart of the pedagogical tradition*" (p. 21). Using chemistry education as his example Jenkins claims that the followers of the pedagogic tradition are those that teach chemistry in schools, colleges and universities, and who publish in journals like *Education in Chemistry* or *Journal of Chemical Education*. These researchers remain close to the academic discipline of chemistry and many of them "*would strongly resist any attempt to classify them as social, rather than natural, scientists*" (p. 21).

There is no doubt that this is a valuable distinction that indicates main "schools" of science education as a research discipline. It appears however that somewhat different emphases of the two schools' characteristics are necessary. Clearly, on the one side, there is a group of science education researchers who are close to the particular science domain. Their attention is not only near to teaching practice but they also put main emphasis on science content issues in designing new teaching and learning sequences. Sadly enough, however, quite frequently a balance between science orientation and orientation on the students' needs, interests and learning processes is missing. Further, research (especially empirical research on teaching and learning) and development are often badly integrated. On the other side, we find an emphasis on the students' needs in various respects and a strong emphasis on improvement of learning environments often accompanied by a neglect of science subject matter issues. A significant number of conceptual change approaches (Schnotz, Vosniadou, & Carretero, 1999) seem to fall into this category. One could summarize the distinction of the two traditions discussed by calling the one *science-oriented*, the other *student-oriented*. Progress in understanding and learning science appears only possible if there is a balance between the two perspectives. Successful design of science teaching and learning sequences needs to merge the two positions.

[1] This explication is based on a statement by a German association for content specific education (KVFF, 1998, 13f).

Peter Fensham (2001) who is well known for his contributions to a student-oriented science education (Fensham, 2000) points to the necessity of research on teaching and learning to rethink science content, to view it also as problematic[2] (and not only the way the content is taught) and to reconstruct it from educational perspectives. His considerations are integrated into a discussion on the continental European Didaktik tradition versus the Curriculum tradition (Hopmann & Riquarts, 1995). Whereas the curriculum tradition has a certain focus on Jenkins' (2001) *empirical* side and on what has been called *student orientation* above the Didaktik tradition tries to bring key features of the science-oriented and student-oriented sides into balance.

Also Dahncke, Duit, Gilbert, Östman, Psillos and Pushkin (2001) argue in favour of such an integrated view. They claim that the science education community so far has been split into the above two groups and that there are considerable clashes between the groups that even seriously hamper the progress that is so much needed. It is also pointed out that there are clashes between science education and the educational sciences, pedagogy and psychology, and between science education and school practice. They argue in favor of emancipation of science education from both the science reference domains *and* the educational sciences with a particular focus on improving school practice. Science education should be seen as an interdisciplinary research domain in its own right as outlined here in Figure 1.

Psillos (2001) also points to the significance of this conception of science education. He distinguishes three "modes" of research. The *practical* mode denoting issues of the actual classroom, the *technological* mode addressing policy makers' attempts to improve science education, and finally the *scientific* mode representing science education as a research domain in its own right. He argues "*that it is necessary to link the major concerns of all three modes in order to meet the various difficulties of improving science teaching and learning*" (Psillos, 2001, 11).

It is common sense among science educators that improving practice is the primary aim of science education research. However, Millar (2003) is of the opinion, drawing also on arguments by Jenkins (2001), that much research is restricted to "what works in practice". He claims: "*The role of research is not only to tell us 'what works'. Some of the most valuable research studies have been ones that made people aware of problems in current practices. Research can inform practice in a range of ways that stop short of providing clear and definite answers: by providing the kinds of insights that enable us to see the familiar in a new way, by sharpening thinking, by directing attention to important issues, by clarifying problems, challenging established views, encouraging debate and stimulating curiosity*" (Millar, 2003, 7-8).

[2] s. also Fensham, Gunstone, and White (1994)

The conception of science education research outlined in the subsequent sections draws on such a more inclusive idea of improving practice.

THE MODEL OF EDUCATIONAL RECONSTRUCTION

The Model of Educational Reconstruction (Duit, Gropengießer, & Kattmann, 2005) presented in Figure 2 may provide a deeper insight into the interdisciplinary nature of science education research as has been outlined so far. The model has been developed as a theoretical framework for studies as to whether it is worthwhile and possible to teach particular areas of science. It draws on the need to bring science content related issues and educational issues into balance when teaching and learning sequences are designed that aim at the improvement of understanding science and hence may foster the development of sufficient levels of scientific literacy.[3] The model can also be used to structure teacher education attempts as teachers may also be viewed as learners. Furthermore, it provides a framework for the conception of science education research outlined above.

The model is based on the German educational tradition of "Bildung" and "Didaktik" (Westbury, Hopmann, & Riquarts, 2000). Both terms are difficult to translate into English properly. A literal translation of *Bildung* is formation. In fact *Bildung* is viewed as a process. *Bildung* stands for the formation of the learner as a whole person, i.e. for the development of the personality of the learner. The meaning of *Didaktik*[4] is based on the conception of *Bildung*. It concerns the analytical process of transposing (or transforming) human knowledge (the cultural heritage) like domain specific knowledge into knowledge for schooling which contributes to the above formation (*Bildung*) of young people. Briefly put, the content structure of a certain domain (e.g. physics) has to be transformed into a

[3] The Model of Educational Reconstruction has been developed in close cooperation of Ulrich Kattman (University of Oldenburg), Harald Gropengießer (University of Hannover) as well as Reinders Duit and Michael Komorek (IPN Kiel) (Kattmann, Duit, Gropengießer, & Komorek, 1995). A brief overview of the model is presented by Duit, Kattmann and Gropengießer (2005). The model has been the frame of various projects at the IPN in Kiel, e.g. on the educational reconstruction of non-linear systems (Komorek & Duit, 2004). At the University of Oldenburg the model serves as theoretical framework of a science education graduate student program: http://www.diz.uni-oldenburg.de/forschung/ProDid/Prodid-Programm-E.htm.

[4] It is essential to take into consideration that the word "didactic" if used in educational concerns in English has a much more narrow meaning than the German "Didaktik". Didactic (or didactical) merely denotes issues of educational technology.