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On the Nature of Science Education Research and Development—A European Didaktik Position

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Abstract: A close cooperation between science and science education is essential for designing powerful courses that lead to the kind of critical scientific literacy that is necessary to allow students understanding and actively engaging in our society that is deeply shaped by science and technology. It holds, for instance, that science content as provided by science research may not be more or less directly transferred into science instruction. It needs to be significantly "reconstructed" taking into account educational issues.

Key words: Didaktik, teaching and learning science, educational reconstruction

1. The Didaktik Tradition

Didaktik stands for a multi-faceted view of planning and performing instruction. In Germany it is based on the concept of "Bildung" [1]. A literal translation of this term is formation. In fact, Bildung is viewed as a process. It stands for the formation of the learner as a whole person, i.e., for the development of the personality of the learner. Bildung hence does not only include the achievement of domain specific knowledge but also the formation of what may be called "cross curricular competencies". A key figure of thought concerning Bildung is that the content structure *of* a certain topic (such as energy) has to be transformed into a content structure *for* instruction. It has not only to be simplified—in order to make it *accessible* for the learners—but also enriched by putting it into contexts that *make sense* for the learners. These ideas are at the heart of the *Model of Educational Reconstruction* displayed in Figure 1.

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The essential feature of the *Educational Reconstruction* approach [2] is that in planning instruction—by teachers or curriculum developers—the science content to be learned *and* students' cognitive and affective variables, including their learning processes, should be given equal attention. In addition, the science content is not viewed as "given" but has to undergo certain *reconstruction* processes. The *science content structure* (e.g., for the concept of evolution) has to be transformed into a *content structure for instruction*. The two structures are fundamentally different. The first step of this reconstruction, called "elementarization" (see Figure 2), is to identify the elementary (fundamental) ideas that relate to the aims of instruction by seriously taking into account student perspectives (e.g., their pre-instructional conceptions). Then the content structure for instruction has to be developed. Finally, teaching and learning settings have to be designed. The tendency of many approaches aiming at more efficient science instruction to put the major emphasis on just instructional methods should be seen as problematic.

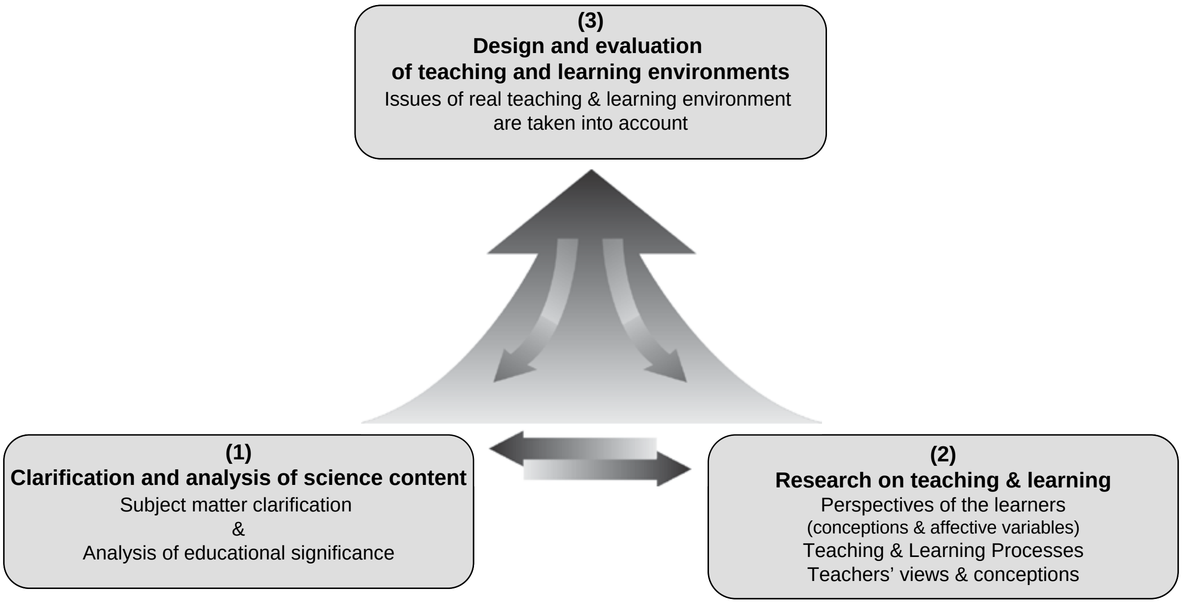

Fig 1. The three components of the Model of Educational Reconstruction (MER).

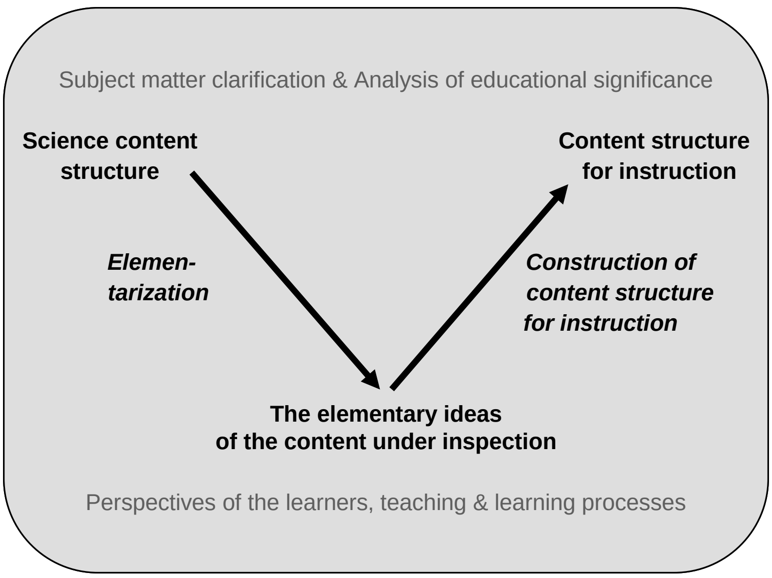

Fig 2. Steps towards a content structure for instruction.

2. A Theoretical Perspective for Science Education Research and Development

Figure 3 summarizes the position outlined so far from the perspective of reference disciplines of science education research and development [3]. It becomes apparent that science education is an *interdisciplinary* research domain. Science educators need a wide range of competencies stemming from rather different reference disciplines. It is essential that the cooperation between Science and Science Education needs to be given particular attention.

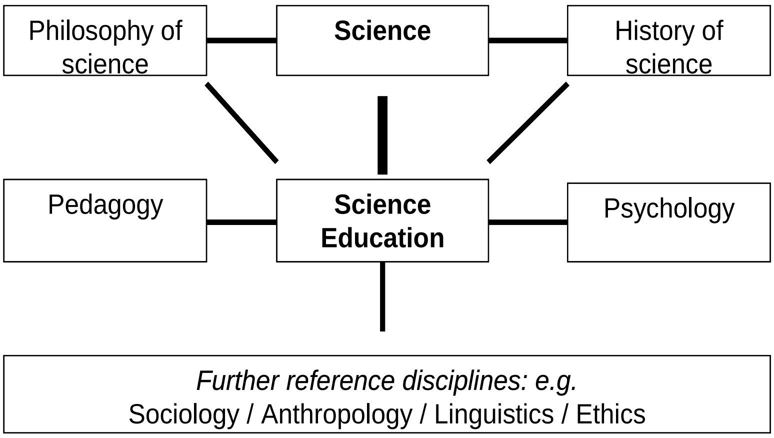

Fig. 3. Reference Disciplines of Science Education.

3. Major Domains of Science Education Research and Development

The Model of Educational Reconstruction as outlined above (Figures 1 and 2) also allows identifying key kinds of science education research and development [3]:

(1) Analytical (Hermeneutical) Research:
Subject matter clarification / Analysis of educational significance

(2) Empirical Research on Teaching and Learning
Students' perspectives / Teachers' views / Teaching and learning processes

(3) Instructional Design
Intimate link between R&D (Research and Development)

(4) Research on curricular issues and science education policies

In a nutshell, science education research that is relevant for improving instructional practice needs to include a wide spectrum of research methods. This conception shares major features of Linjse's "*Developmental Research*" [4] and "*Design Based Research*" [5, 11].

4. The Case of Teaching and Learning Energy

It is hardly possible to overestimate the significance of the energy concept in science. Energy provides powerful ways of thinking about and modelling processes in nature and technology [6-7]. Major aims of teaching energy comprise to make students familiar with this concept as part of the cultural heritage, as tool to understand everyday life-world, to understand issues of energy supply and to make students able to participate in decisions concerning energy issues in society.

As a first step towards designing the content structure for instruction (see Figure 2) the elementary ideas of the science energy concept need to be identified. There seems to be a wide agreement in the literature that the four closely interrelated ideas in Figure 4 should be taken into account. However, concerning the content structure for instruction on which the instructional design is based there is still

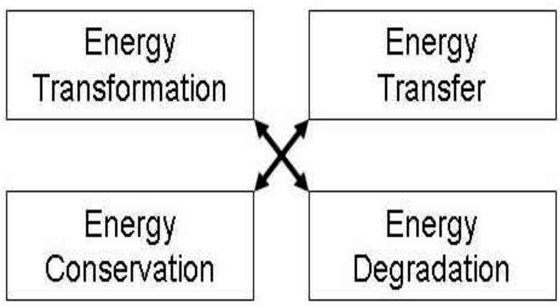

Fig. 4 Four basic ideas of the energy concept [7].

much less agreement. Clearly, it very much depends on the specific aims given the major attention and the particular circumstances (e.g., students' pre-instructional conceptions, their interests, the conditions the teaching and learning site provides) available which instructional design may be set into practice.

5. The Case of Teaching and Learning key Ideas of Non-Linear Systems

The study of non-linear systems has become a major area in science as well as in domains outside science [8]. This research has led to a shift in the emphasis concerning fundamental scientific concepts. *Determinism*, *Predictability*, *Causality* and *Order*, for instance, now have an expanded, differentiated meaning in modern science. There are the following major basic insights that non-linear systems allow. First, there are systems, among them very simple ones, that are rather "sensitive" to small changes of the starting conditions and small disturbances when the process is running (chaotic systems). Minute changes or disturbances lead to exponential deviation of the paths so that detailed predictability of the systems' behaviour is not possible. Second a number of nonlinear systems develop—in a self-organizing manner—complex structures. Third, many of these self-organizing systems can be described by the self-similar fractal model. The Model of Educational Reconstruction served as a the frame for a number of studies developing on the one side instructional approaches allowing student to understand the dynamics of these systems and investigating learning student processes (see cf. [9-10]).

6. Concluding Remarks

The Model of Educational Reconstruction briefly outlined above has proven a valuable tool in small scale and large scale development of instructional approaches in various domains. A particular feature of the model is that the science content structure may not directly serve as the major orientation of instructional planning but has to be reconstructed from educational perspectives. In this process, however, the scientists' perspectives play a key role. The process called "Elementarization" (Figure 2 above) is essential. A rather difficult balance between the science point of view (what is correct from the perspective of science) and educational concerns (e.g. what students may be able to learn) is needed. Quite frequently, it seems that a course between Scylla and Charybdis has to be found. In closing, I would like to mention that the Educational Reconstruction approach as outlined here shares major features with the *Learning Progression* perspective developed the past decade (see cf. [11-12]).

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