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The significance of microbes for biology teaching - A study of scientific and students' conceptions

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Abstract. The task of the study presented here is to investigate the conceptions of students as well as those of scientists to get a solid basis for teaching subjects of microbiology at school. Accordingly the study is conducted within the model of Educational Reconstruction which comprehends three components of research: Investigation of Students' Conceptions, Scientific Clarification, and Construction of Instruction. The mutual comparison between the students' and the scientific conceptions shows different kinds of correspondences. Besides particularities and limitations, similarities and congruities between students' and scientific conceptions were identified. On the basis of the correspondences guidelines for teaching microbiology as well as some basic principles for teaching biology were formulated. Additionally, the results of the investigation elucidate the aspects of domain specificity and theory-like character of students' conceptions, which are relevant to conceptual change.

Subject. Microbial processes play a fundamental role in many biological domains. The importance of microorganisms can hardly be overestimated if the understanding of human life and the biosphere in general are considered. Therefore the subject is of great importance for education. However, in German curricula microbiology plays a subordinate role. If microorganisms are mentioned, usually the students get to know them as pathogenic agents or as decomposers only. The question is, how biology teaching has to be changed, on the one hand to do justice to the microbes and their fundamental role concerning basic processes in nature, and on the other hand to meet the students' conceptions in an adequate and fruitful way. For this aim it is of special interest which conceptions of microorganisms the students have and how they understand processes in which microorganisms are involved (cf. Bayrhuber and Stolte, 1995; Knox, 1993). Guiding questions of the project are the following ones:

- Which processes do students and scientists assume to be connected with microorganisms and microbial processes?

- What does this connection look like?

- Which are the conditions that have to be arranged in order to support learning microbiology?

Design. The epistemological and educational framework of the project is part of the recent conceptual change approaches of science education. The design of the project is derived from the model of Educational Reconstruction (Kattmann, Duit & Gropengießer 1998; Gropengießer, 1997). Accordingly the project consists of three interrelated components: the Scientific Clarification, the Empirical Investigation of Students' Conceptions, and the Construction of Instruction.

The Scientific Clarification concerns important elements of scientific theories and concepts on microbiology and microbial processes, their genesis, function and meanings. Also the use of terms and their meaning towards learning processes are part of the analysis.

The Empirical Investigation of students' conceptions aims at conceptions, i. e. conceptual frameworks (notions and principles) used by the students.

The close interrelation between Scientific Clarification and Empirical Investigation within the model of Educational Reconstruction leads to the third step, the Construction of Instruction. Students' and scientific notions and principles are brought into correspondence to each other. Consequently, the conditions which have to be arranged in order to support learning microbiology have to be discussed.

Procedure. The method of qualitative content analysis (Mayring, 1990) was adapted for the scientific clarification of monographs as sources of the history of science and of leading scientific textbooks as well as for the interpretation of semistructured interviews.

The Scientific Clarification was conducted with four historical monographs by Ehrenberg, Liebig, Pasteur, and Cohn and with two leading up-to-date scientific textbooks by Schlegel, and by Brock et al.

In the Empirical Investigation students of grades 11 to 13 of a German Grammar School (Gymnasium) were interviewed individually. The interviews are characterised by an open and problem centred form. The statements of audio-taped interviews were analysed following the adapted method of qualitative content analysis (cf. Mayring, 1990; Gropengießer, 1997). The students‘ notions and principles were identified, named and put into a structured sequence. Considering all interviews the notions and principles were summarised and generalisations were made, yielding a framework that contains a number of generalised students’ conceptions and principles.

In the next step students' and scientific conceptions were brought into correspondence to each other. The disclosed correspondences formed the basis for the formulation of guidelines for the Construction of Instruction.

Data analysis and findings. In the process of investigation three main paragraphs were used to structure the students’ and the scientists’ conceptions: 1. microorganisms as living beings (morphology, metabolism etc.), 2. processes of decomposition, 3. microorganisms in the balance of nature. Wide ranges of different conceptions have been found on both sides, the students' and the scientific conceptions.

Most students think that microorganisms are simple-structured organisms. Correspondingly, microbial metabolism is regarded as plain and undifferentiated. This predominant conception has fundamental consequences in the fields of microbial processes and the balance of nature, as most students describe the microbial metabolism as limited to the decomposition of organic matter.

In comparison, a similar relation between the size and the degree of complexity exists in the scientific world, too. However, in both modern textbooks analysed a differentiation is made between the »morphological uniformity« and the »physiological versatility«.

A considerable part of the students' conceptions concerning decomposition of organic matter is on an abiotic level mentioning physical and chemical processes only. Even if microorganisms are included in their conceptions, notions concerning abiotic processes still seem to be dominant. These results support the findings of Helldén (1997).

Among the scientists only Liebig explains processes of decomposition exclusively by chemical reactions. Here, similarities are observable between the students' and the scientific conceptions.

From the outlined results guidelines have been derived in order to enable a better and more fruitful way of teaching microbiology, e.g.:

- Contents from different fields of microbiology have to be connected in order to give the students a broader basis for conceptual change.

- Abiotic patterns of explanation regarding processes of decomposition have to be turned into biotic patterns.

- Microbes have to be characterised as living beings not only on a morphological and physiological, but also on an ecological level.

General interest. The results of the study demonstrate how the model of Educational Reconstruction can be used to develop guidelines for teaching. Furthermore, general conclusions can be derived with regard to the structure of students' conceptions. There is evidence that the students' conceptions are domain-specific to some extent on the one hand. On the other hand, interrelations between different fields of microbiology demonstrate that students' conceptions have the character of implicit theories. Both characteristics are important for developing treatments to support conceptual change.

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