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and Lutz Stäudel

Reform and Counterreform in the Teaching of Natural Sciences

Michael Ewers died before the printing of our joint article. We have lost in him a colleague whose readiness for political dialogue on the teaching of natural sciences in the schools, even at the risk of being branded an outsider, united him with his many colleagues. We have much for which to thank Michael Ewers.

In the hubbub surrounding the policy debates on the general overhaul of the structures and content of the educational system in the Federal Republic, the steady expansion of teaching in the natural sciences over the past two decades at all school levels and in all types of schools has gone on almost unnoticed.

Specialists in science teaching have been able to mold the teaching of science in the form of separate specialized subjects, presented in discrete classroom units and conforming to the systematic classification of the parent sciences—in some cases even at the elementary school level. Qualitatively what this has meant is an almost doubling of the number of hours devoted to natural sciences in the *Volkschule* and the *Hauptschule* (of course this also reflects the lengthening period of mandatory schooling), while in the lower secondary and upper secondary schools the number of hours per week increased by 75 percent and 50 percent (average for all the states of the Federal Republic), respectively from the mid-50s to the mid-70s [1]. The most usual reasons

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given by professional organizations of teachers and educators for the expansion and more classical orientation of science teaching is the growing role of scientific and technical progress in not only economic competition among nations, but in fact in almost all areas of life within a "modern industrial society" and accordingly, the necessity of a higher general level of scientific and technical competence for anyone involved in the manufacture of modern technical products or using them in their work.

In addition, the training that science gives in "logical" and "rational," but also "abstract" and "objective" thinking was repeatedly pointed out as the special strong point of science instruction, along with being an indispensable condition for political and cultural engagement in the social problems of the future.

The tailoring of science teaching to the traditional classification of the natural sciences school, and of teaching method into discrete specialized methods specific to each particular science, which has led to a colonialization of general education [5, 25], encountered no noteworthy resistance from the ranks of general educational theory. On the contrary, the professional educators involved in determining the course of the educational reform in the 70s with the support of broad social groups, proclaimed scientific education to be a social task, for which they also claimed competence; it was their concern to prune away some of the traditional educational subjects, and prepare students for the modern era, characterized by new developments in natural science and technology. The majority of natural science teachers and methodologists as well as most educators in general were able to identify with this project in their professional self-concept; hence they called for more science in secondary school education, goals attuned to the exigencies of science, and a rational organization guided by the expertise of specialists and practitioners in education. Since general educational theory also underscored everyone's right to a scientifically grounded education, and at the same time claimed the right to define the learning process, it for the first time became a political ally of the specialized art of science teaching.

Although a "scientific orientation" in classroom instruction is certainly not an unambiguous formula [18], in the curricular reform in the natural sciences it came to be generally interpreted to mean that classroom instruction was supposed to convey directly the results and methods of physics, chemistry, and biology, etc. writ large, albeit in simplified form as the

Physics deals with the processes in nature around us . . . but man is not satisfied with merely observing the plenitude of natural phenomena conveyed to him by his sense organs . . . he asks how and why . . . every thinking person again and again poses such questions. They derive from man's striving to know nature and to understand its inner connections. The task of physics is to answer all these questions. Thus physics is primarily a pure science whose roots and driving force reside in man's striving for knowledge. O. Höfling: *Physik*, vol. 2, part 1, Bonn 1981, p. 1.

Biology is the science of living nature. This simple statement requires clarification in several respects. It says that biology is a science: this means first that it is pursued for the sake of knowledge, and second that it is bound to a specific way of thinking and specific methods. To quote the trenchant description of a modern philosopher: "Science offers that which is binding on every mind." In biology, only what our understanding has made intelligible with compelling arguments can be called knowledge. We can call nature the intrinsic content of objects which are given to us in experience, to the extent that they are not the work of men. This means that everything that does not derive from experience is excluded from natural science. G. Felds, et al.: *Der Organismus*, Stuttgart, 1978–80, 2d edition, p. 7.

practical teaching of them required at that level.

In addition, this concept was based on the fundamental view that the natural sciences were value-free, i.e., research in the natural sciences was reductionistically interpreted as a purely cognitive process and not as a kind of social labor which was susceptible of politicization and "economization" and in the case of the natural sciences, of an increasing militarization as well.

This understanding of science largely determines the concept of natural science as it exists today, and has been adopted almost wholesale in curricula and textbooks. In elementary school, oriented toward the natural sciences, the traditional divisions of the discipline and its procedures already dominate (see [23]), the rationale for this being to concentrate on those characteristics of the natural sciences that are suitable for early learning and, on the other hand, to create the requisite foundations for "systematic" specialized instruction at the secondary level.

Accordingly, instruction at the secondary school levels I and II is designed similar to the Bruner model of a spiral curriculum, i.e., the same topics of instruction return several times in the course of the school career; the result is that classes in the upper levels of secondary school tend increasingly not only to feature continually updated material in line with the current state of the scientific discussion in the specialized disciplines, but also to introduce new special subjects and specialized disciplines. In physics instruction, for example, these are relativity theory and quantum mechanics, geophysics, astronomy, and electronics; in chemistry, physical chemistry, apparatus analysis; and in biology, biotechnology.

It is therefore no wonder if Flessau and Reinert come to their conclusion in their analysis of "constructive forms and concepts of teaching in the natural sciences and technology curricula in secondary levels I and II" that "the 'pedagogical purpose' . . . recedes conspicuously into the background compared with the acquisition of knowledge, insights, skills and abilities, and that the 'preparation for life and science'. . . has such unequivocally and one-sidedly cognitive features as if the preparation of pupils for their present and future lives had to take place exclusively in accordance with the principles of scientific propaedeutics" [14, p. 3]. Nor is it surprising to read their observation that in the vast majority of physics curricula in the *Hauptschule* and *Realschule* "everything that is oriented toward practical application in the end serves only as a vehicle to convey specialized knowledge" [14, p. 66] and that in the physics curricula for the basic course and the advanced course "burning questions such as environmental pollution, nuclear power stations, problems of radioactive waste deposits are absent" [14, p. 36]. On the other hand, environmental problems have found a place in the biology curricula (see [17]).

When the tendencies here described in the development of curricula began to make themselves evident in the natural science subjects, a group of reform-minded specialists in the teaching of natural sciences, science teachers, and educators in vocational colleges and secondary schools (including comprehensive schools) formed not only to deal critically with the justification and legitimization of the reform of science teaching (see [12, 2, 32, 31]) but also to develop general ideas and conceptions which had their origins in the criticism of existing general educational and classroom practice (see [27, 35, 28, 8, 15, 21]).

Most of these are schoolteachers in the natural sciences who understand the art of teaching a particular subject not from the standpoint of that particular subject, but rather in the broader sense as a social science, i.e., a discipline embedded in the broader concepts of social theory and curriculum theory, which are influenced in their educational theory by the pedagogy of "critical theory."

Above all the most innovative school experiments, e.g., the laboratory school and the upper-level secondary school in Bielefeld, the school experiment Glocksee in Hanover, the comprehensive schools, always ready to experiment with their model experiments, and the project "curriculum research and development in the natural sciences," sponsored by the Volkswagen Foundation, have been supported ideologically by this group. Numerous theoretical concepts for justifying and shaping appropriate natural science curricula and, increasingly, examples of instruction, already practically tested in secondary schools for instruction in natural sciences at the secondary school levels I and II, have been published under headings such as "interdisciplinary instruction," "historical-genetic instruction," "project methods and project instruction," "learning through investigation and discovery," "problem-oriented and use-oriented," as well as pupil-oriented instruction (see [1]).

Even if many of the questions touched upon have remained unclarified, e.g., the practical scope of interdisciplinary instruction or the sketches for practical learning, which are favored forms in many localities, this should have been no reason for underestimating the actual influence of critical specialized teaching methods on the shaping of natural science teaching in the Federal Republic. The reasons probably lie elsewhere, in the unsolved problems that confronted efforts at cooperation between school, research, and educational administration, and on the other hand, in the situation in which critical alternative teaching found itself then and now. The majority of specialists in science teaching, which became entrenched in the 1970s, then as well as now is to be found on the staffs of the relevant specialized periodicals, publishers, societies, institutions, and curricula committees, and in professorships, and disregards the critical minority. Between these two camps in the art of science teaching are a few "liberals," who usually belong to the older generation, and as a rule owe their distance from the established art of teaching science to a special pedagogical engagement and an understanding of how pupils think and what their needs are (for example Wagenschein, Schietzel, Freise; see [6]).

In the last ten years, no qualitative progress has been made in the natural science subjects; all that has taken place is a systemization of the approaches of the 1970s, stagnation, or even regression. Phenomena such as the advance of computer technology in the schools (see [22]) and the inclusion of environmental problems in school curricula do nothing to alter this overall picture. The growing resistance to the educational reform would certainly not have been so successful had it not been able to tie in with phenomena and developments within the school that were attributed to the educational reform itself. Complaints over the pressure to achieve in the school has, because of the numerus clausus (limitations on university admissions) and unemployment, spread from the upper level of the Gymnasium into the *Grundschule* and has produced backlashes such as the refusal to achieve, and the debate on reform experiments and on overburdening pupils with too much material. Science teaching, too, was in a crisis—so goes the general cry then as well as now—a crisis discernible, in particular, in pupils' negative reaction to the material offered in physics and chemistry classes, and especially the upper level of the Gymnasium, and in the propensity to criticize, denounced as "hostility to technology," of increasingly larger segments of youth with regard to the consequences of (major) research in natural sciences and technology [33, 36, 3].

But there is also a growing discontent, not unaffected by the above-described developments, among specialized teachers with a kind of classroom instruction that merely uncritically conforms to the dominant picture of science, and indeed often enough has been all too willing to be dragged into counterpropaganda against the steadily growing instances of curricula critical of science and technology. But the reservations manifested by these teachers are restricted above all to the principle of a scientific orientation which by and large precludes genuinely taking up the social and economic consequences of developments in science and technology on the one hand, and the experiences and problems of youth with nature and technology, by forcing teaching in the classroom to follow the lines marked out by the existing classification of the "pure" sciences.

These problems are also seen by the established profession of science teaching methods. Hitherto, the above problems had by and large been blamed on shortcomings in teaching method. The strong "systematic specialization and science-oriented construction" of curricula in the natural sciences is criticized just as much as the overemphasis placed on mathematical formalisms and the superabundance of materials in the curricula. But reasons from the affective sphere are also mentioned: the inability of many teachers to "present their subject in an interesting, gripping, and attractive way" is seen as a decisive reason for the dullness and lack of effectiveness of instruction in physics and chemistry (see [4, 26, 16, 24]).

The negative showing of science as a school subject as regards being liked and being effective (gender-related differences are also evident) was probably responsible for the fact that the past few years have seen a number of studies of pupils' conceptions of phenomena from nature and technology and their notions of scientific concepts (see [9, 10, 30]).

These studies unanimously concur that it is often not possible to teach pupils to think in the manner proper to physics, chemistry, or biology. In other words, pupils (and adults as well) usually have a highly unique everyday understanding of nature (regardless of any school knowledge) which differs fundamentally from how professionals involved in this sphere see nature. However harsh the diagnosis may seem, the essential discoveries made by these studies are not new.

Specialists in science teaching methods frequently embark upon (again) traditional paths in answering the question of whether there are any possibilities of change. According to their own professional self-concept, they view this first and foremost as something that is characteristic of the discipline. Thus as early as 1982 the German Society for the Promotion of Instruction in Mathematics and the Natural Sciences, the most traditional guild for Gymnasium teachers in mathematics and the natural sciences, demanded:

—"elementarized," instruction less oriented toward the existing classification of the disciplines;

—a reduction in the level of mathematical requirements;

—a stronger consideration to school experiments;

—a narrowing of the distance between the classroom and applied science [19].

The absence, noted a decade ago, of a systematic connection between general teaching methods, curriculum research, and the educational sciences, on the one hand, and the specialized art and methods of teaching mathematics and natural sciences on the other, is still as conspicuous as before.

The ascribed poverty in science teaching will find no remedy in a recourse to specialized teaching methods in the traditional sense. The momentum for escaping from this poverty requires teachers to take critical initiatives with regard to professional practice; for example, to engage in a "critique within the profession," i.e., a practical professional reflection on everyday work within the profession, with practical conclusions being drawn! Whether such initiatives can be taken within the established art of science teaching seems very doubtful after what we have said. This doubt is above all warranted by the fact that different educational institutions are by and large controlled by supporters of conservative (professional and status) interests (see [20]). Such initiatives would require taking leave of the fetish of "science" and a kind of teaching with pedagogical engagement, with understanding of the social reality in which pupils live, and a comprehension of how they think and their needs. Then even those pupils could be motivated who had earlier been deterred from the traditional instruction.

Statements by students such as "nothing is said in the classroom about what real life is all about. No word about Nukem and Chernobyl" show how often problems that affect pupils (as us all!) are simply shut out of classroom science. The list of problems can be expanded to include those that have to do with armaments, environmental pollution, contaminants and toxins of all kinds, biotechnology, and gene technology. No one can seriously dispute that these are "key problems" which "extend into and affect a child's world and a youth's experience and leave a permanent mark on the behavior, judgments and prejudices, and attitudes of children and young people—and moreover in an unenlightened and problematic way" [18, pp. 83ff]. Biology instruction, in contrast to the other natural sciences, does show an increased emphasis on problems concerning the environment, health, and sexuality (see [11]). Still, the important anthropological questions are often reduced to biologistic terms in this subject.

As experience shows, teachers must not only articulate the political themes relevant to their discipline, they must also make clear that in all conflicts, the political and social aspects of the problem are the more significant, and that the scientific and technical aspects are of secondary importance. The key question of didactic interest is then for classroom instruction: to what extent is knowledge of physics, chemistry, and biology necessary to make these problematic aspects perceptible (by means of examples!), and intelligible, and to make the student capable of discernment, criticism, and action? Learning processes can only be fruitful if they start out from what pupils know from their everyday lives. Then one can of course go on to professional modes of thought insofar as everyday experiences are made more transparent and the specific explanatory power of the scientific paradigm becomes clearly discernible. Ideas of an alternative way to teach physics, chemistry, and biology, which for a while had been cast into oblivion by the turn in the educational reform, as well as the experience accumulated in this area, must be reactivated and further developed. They offer a multitude of practical incentives and as well as knowledgeable progress, based on broad experience, as regards a definition, differentiation, realization, and determination of criteria of, for example, teaching by projects, pupil-directed teaching, and learning by discovery.

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