CHEMISTRY EDUCATION: RESEARCH AND PRACTICE IN EUROPE
2001, Vol. 2, No. 1, pp. 1-4

EDITORIAL

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THEORIES IN SCIENCE EDUCATION AT THE THRESHOLD OF THE THIRD MILLENNIUM

If we accept that the year 2001 marks the entrance to the third millennium, it is in order to take stock of what science education research has achieved during the past century. Science education constitutes a branch of the social sciences, but is closely connected with the parent sciences, physics, chemistry, and biology. However, to be a true scientific field, scholarship in science education must be supported with suitable theory or theories ('a clearly developed and articulated theoretical framework"), otherwise it would not be different from journalism (Caliendo & Kyle, 1996).

Educational and cognitive psychology as well as philosophy-epistemology have so far provided science education with a number of supporting theories. First, there was behaviourism, which favoured the direct transmission of knowledge from the knowledgeable (the teacher) to the ignorant (the student). The transmitted load (the scientific knowledge) was taken to exist as an unquestionable corpus - objective, complete, precise, and invariant, independent of teacher and student, and consistent with *realism* (see below). Behaviourism however remained external to science teaching and learning. It only provided the means (that is praise or punishment) that facilitated or even enforced the transmission of intact knowledge.

The advent of Piagetian cognitive psychology caused a paradigm shift (in the Kuhnian sense) in the research programmes of science education. Although not a learning theory itself, but only a theory of cognitive development, Piagetian theory dominated science education research for about two decades. For instance, the special issue of the *Journal of Research in Science Teaching* (Vol. 2, Issue 3, 1964) was dedicated to Piaget. This domination was also evident in the specific chemical education literature of the seventies and early eighties, as demonstrated by numerous articles in the *Journal of Chemical Education* and *Education in Chemistry* that applied Piagetian ideas. The specific physics education journals, such as *The Physics Teacher* and *Physics Education* showed a similar emphasis. The writer of this editorial has to admit that it was through such readings that he was 'enticed' into a systematic professional engagement with science education research. It is noteworthy, that Piagetian theory became internal to science education; thus, not only were students categorised as concrete or formal etc., but chemical concepts were also characterised in the same ways (Herron, 1978; Shayer & Adey, 1981).

Mention should be made here of some neo-Piagetian theories, such as the one of mental operators by Pascual-Leone; and the application to science education of this and other information-processing theories, such as the theory of working memory, by Johnstone and by Niaz.

Piagetian theory met with strong criticism by numerous psychological researchers at least with respect to its developmental-stage component. As a result, in the eighties, many science educators and new-comers into the field, opted to distance themselves from Piagetian theory. Furthermore, some became hostile to it, so that by the end of the eighties, the mention of Piaget's name came to become a taboo in the science-education literature. [I have experienced a staggering comment by a reviewer of one of my own manuscripts; "he (the author) mentions Piaget!] As an alternative, researchers turned to the systematic study of how students understood scientific concepts across the school spectrum. It is known, of course, that the literature (e.g. *the Journal of Chemical Education*) has always abounded with articles that dealt with chemical concepts, students' conceptual difficulties, and suggestions for better teaching. However, the eighties showed firstly a preoccupation with the study of concepts, and secondly the organisation of these studies into a coherent research movement - the *alternative frameworks* or *alternative conceptions* or *students' misconceptions* movement. Within science education, the late Rosalind Driver is considered to be the leader of this movement.

The alternative conceptions movement needed a theory to back it, and found a suitable and effective one in *constructivism*. Constructivism is basically a philosophical-epistemological theory (synonymous to *empiricism*), which is in contrast to another theory, that of *realism*. Realism maintains that the physical laws exist autonomously in nature, the work of scientists being to find/discover them. Followers of constructivism, on the other hand, suggest that what we consider as science is but the scientists' constructions that are subject to subjectivity and fallibility. The existence of such a dichotomy, at least as far the status of scientific laws and concepts is concerned, is nowadays being questioned. Realism and empiricism must be considered as two extremes in a continuum. It is certain that in its early years (certainly until the beginnings of the twentieth century), science was closer to empiricism, but as time went past, it approached more closely the outlook of realism.

Educational constructivism extended the realism-empiricism dichotomy into how individuals learn, and assumed two forms (Matthews, 2000, p. 496): (i) *personal constructivism*, which is associated with Piaget; and (ii) *social-cultural constructivism* which is linked to Vygotsky. It is then widely accepted today, that students are often closer to an empiricist state, which is at odds with the accepted scientific views. As a consequence, it is the duty of teachers, firstly to recognise their students' alternative ideas, and secondly to take them into account in planning and performing their teaching, so that the aim of *conceptual change* is fulfilled.

As a result of the alternative conceptions movement, a vast literature on students' ideas at all school ages has built up during the eighties and the nineties, to the point that many followers of the movement argue now against the further accumulation of such data. They point instead to various possible directions to which research should turn. After all, numerous attempts at correcting students' misconceptions have met with limited or no success, and the situation seems to many to be stagnant and even problematic.

It is no surprise then that a criticism of contructivism as applied to science education has been initiated during the last few years. The most recent addition to this discussion is the latest issue of the journal *Science & Education* (Vol. 9, No. 6, November 2000), which is dedicated to constructivism, epistemology and the teaching of science. A major argument of critics of constructivism in science education is that constructivists pay attention to how students learn (how they construct their concepts), but not to what knowledge (wrong or correct) they construct (Matthews, 2000, p. 493).

In the personal, partly intuitive, opinion of the writer of this editorial, it may be that students' ideas are a necessary stage through which scientific concepts have to go before stabilising to the accepted scientific views (a shift from *spontaneous* to *non-spontaneous concepts* according to Piaget, or from *everyday* to *scientific concepts* according to Vygostky).

The situation may be analogous to the well-known facts that a five-year old will fail to apply mass or number conservation (which constitute Piagetian tasks that require the use of concrete operations); or a ten-year old will fail to apply formal operations, such as proportional or functional reasoning, control of variables, or hypothetico-deductive reasoning. Needless to add that a stage-theory of the development of alternative conceptions has been suggested and tested quantitatively by Eckstein & Shemesh (1993).

Finally, during the last decade, a new movement has been initiated which pays special attention to the role of *history and philosophy of science* in science teaching (Matthews, 1994). Connected to this movement is the journal *Science & Education*: it publishes research informed by the history, philosophy and sociology of science that seeks to promote better teaching, learning, and curricula in science.

What is the moral of the above state-of-affairs in theories of science education? Certainly most theories are not complete or perfect. They need constant revision and improvement; they may even need replacement. But unless a theory can explain the success of a previous one, it cannot be considered as a superior rival (Niaz, 1993). At any rate, even if for some researchers various theories are conflicting, there is surely benefit to be gained from an exposure to, and a use of the successes of, each one of them. We must stand away from polemics and hostilities, but instead make efforts towards a compromise and even a combination of the theories. Thus, Adey (1987) refuses to view Piagetian theory and the alternative conceptions movement as irreconcilable rivals, and thinks it very likely that they will eventually be combined. On the other hand, critics of constructivism, consider that "*it has done a service to science and mathematics education by re-emphasising the importance of prior learning,… by stressing the importance of understanding as a goal of science instruction, by fostering pupil engagement in lessons, and other such progressive matters.*" (Matthews, 2000, p. 501) They warn, however, against the idea that constructivism has all the answers.

The present writer considers, both in his teaching and his research, that all theoretical perspectives in science education are useful and precious tools for advancing our understanding of the learning and the teaching of science. His research work and agenda cover a multitude of theories and techniques. In particular (Tsaparlis, 1997) he has tried to demonstrate that various perspectives of science education though providing different explanations for students' understanding of the structural concepts, lead to identical conclusions with respect to the difficulties students encounter in learning these concepts. Finally, it is worth mentioning how the present writer treated a comment by a reviewer of one paper of his (Tsaparlis & Kampourakis, 2000, p. 286), who argued against the use of teaching and methodology that is based on multiple theoretical approaches:

> "The use of various and different theoretical perspectives, such as the spiral curriculum (from Brurner's theory of learning), Ausubel's theory of meaningful learning, the application of Piagetian theory to education, and constructivist methods of teaching and learning, are all utilised with the purpose of achieving the highest possible positive cognitive and affective outcome. In other words, we have tried to exploit as much as possible from the 'arsenal' that is open to us through the science education literature. It is our opinion that the use (sometimes separately, sometimes together) of different - even for some researchers conflicting - perspectives leads to complementary positive results."

Surely, it is the business of science education researchers to move the field into various research directions. It is expected that some directions may be more trendy at one time than others. What is more important however is that researchers working on non-trendy fields should not be considered out-of-fashion, or further, be looked down upon. Such an approach makes it imperative that journals in the field should be open to all research traditions and movements. *CERAPIE* is definitively consistent with such an attitude.

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