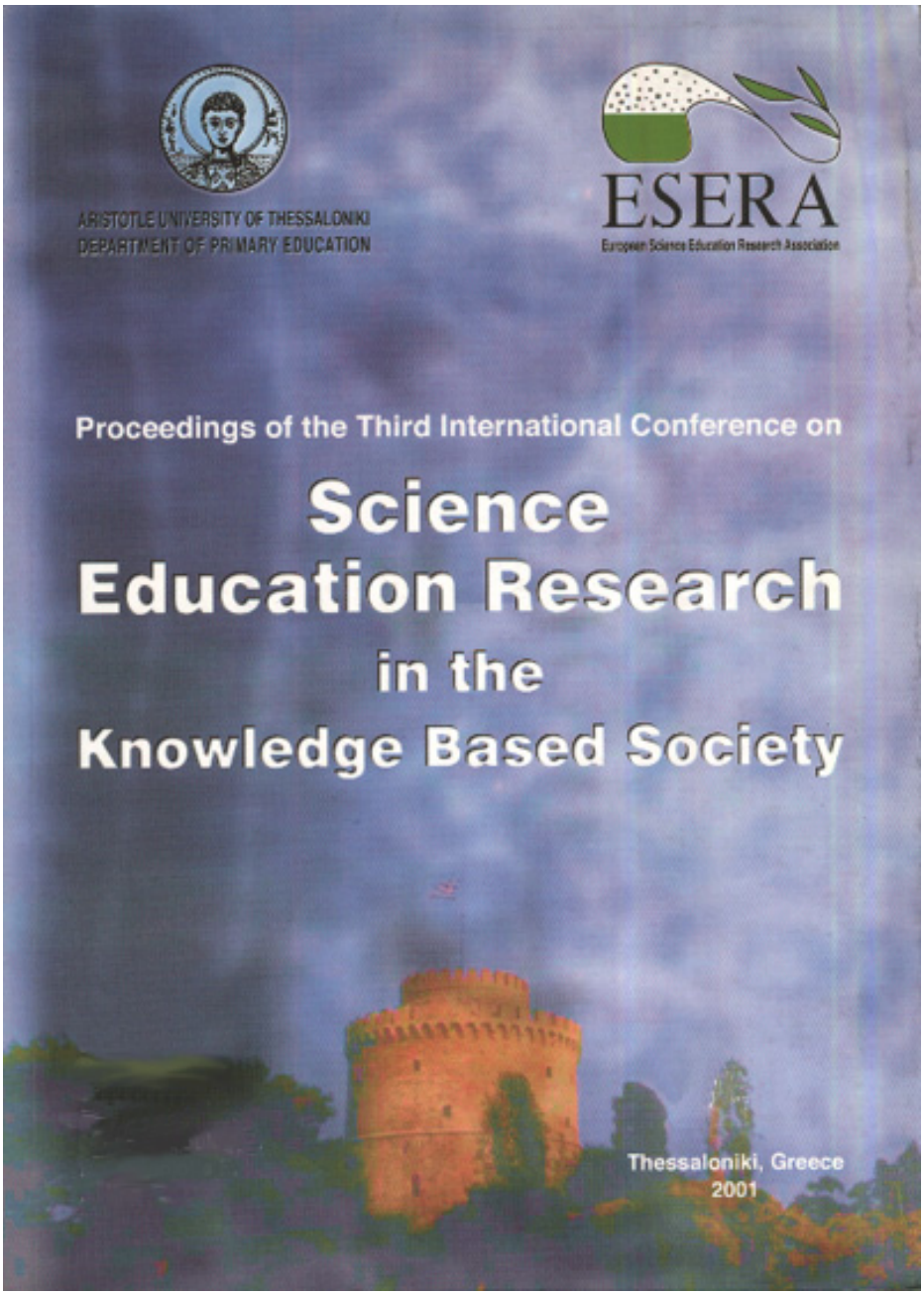

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A Research (and an Appeal) for a Radical Reform of the Content, the Instructional Approach and the Supporting Technology of Science Education: From Relativistic / Probabilistic Microkosmos to the Mechanistic / Almost Certain Macrokosmos – – The case of Science Teachers

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Abstract

According to literacy, significant scientific concepts of "modern" physics are practically omitted from science education content. In addition, traditional curricula fail to eliminate epistemological and cognitive obstacles to learners –especially of limited science and mathematical background, like primary teachers. The latter's acquisition of knowledge associated with both neoclassical (relativistic, quantum) and classical physics, might be a principal step towards the introduction of these models in earlier educational levels. An integrated attempt including reform of science content, instructional approach and supporting simulation / visualization software interacting with the real world through sensors / actuators, is supposed to address learners' misconceptions and provide them with a conceptual system facilitating the interpretation of macrokosmos based on microkosmos. A research, applied to over 7000 in-service primary, secondary and perspective teachers, was carried out aiming to design and evaluate the above mentioned approach. The outcomes are encouraging, legitimizing an appeal for application and evaluation to other target groups.

1. Background, Aims and Framework

As numerous researchers document, the science education content is, in general, organized in a scheme that mainly includes the knowledge of the 19th century, leaving limited space for the knowledge of 20th century, the so-called "modern" physics yet. Furthermore, neither the applied instruction approaches of the traditional curricula, nor the traditional educational materials seem to facilitate learners (mainly those of limited science and mathematics background) to avoid usual misconceptions due to the epistemological and cognitive obstacles, which appear to derive from their traditional pre-/in-university education. Some recent works propose a shift of the science content from classical (newtonian-, electromagnetism, thermodynamics) to neoclassical (relativistic, quantum-, astro-physics) to modern (quantum cosmology, quantum informatics, complex systems, thermodynamics of primordial / quark matter) physics [1] and the implementation of neoclassical models to early stages of science courses as well as a change to the instructional approach [eg 2,3], whilst numerous proposals have been published on educational material based on nowadays information technology [eg 4,5]. However, the pending questions on the feasibility and effectiveness of the various proposals viewing to confront the epistemological and cognitive obstacles, are currently waiting for the results of relevant applications.

Aiming to overcome these epistemological and cognitive obstacles in the acquisition of "modern" / neoclassical physics knowledge by science teachers (both in service and perspective), a research process was undertaken. Its main objectives included a radical reform in the content of the traditional science course (offered to undergraduate students / perspective teachers and in-service training teachers), as well as the designing of an instructional approach and the development of supporting

educational materials in their most optimized possible mode. One intermediate goal was a feasible and effective shift of neoclassical (relativistic, quantum physics) models to early parts of the courses. A second intermediate goal was the formation of two independent conceptual systems / paradigms corresponding to neoclassical (quantum) and classical models for microkosmos and macrokosmos, whilst at the same time, the highlighted interrelation between them. A third intermediate goal was the designing and development of feasible and effective educational materials in order to support the above instruction. Ultimately, we aimed at a new worldview, from the relativistic / probabilistic view of microkosmos to the deterministic, mechanistic / almost certain view of macrokosmos. This achievement could consequently promote an interdisciplinary perception of knowledge, using the structure, the interactions and processes of microkosmos as the unifying element. The latter could also promote the unified / cohesive character of science as accepted by the contemporary theories.

The framework of the research was divided into various –interconnected by means of feedback– subframeworks, namely designing, implementation, evaluation. They were serving the three main objectives: the science content, the instructional approach and the supporting materials. Regarding the science content, the idea and effort to shift the basic aspects of quantum physics, which are usually just tacked on at the end of the courses –if taught at all– as “modern” physics, to early courses as neoclassical physics even qualitatively was applied / tested progressively to earlier and earlier stages of the courses in a more and more thorough or advanced mode and then was evaluated / redesigned. Regarding the instructional approach, the models of the classical and neoclassical (quantum) physics were taken into consideration and introduced as two totally independent conceptual systems [3]. This consideration does not allow any explanation or metaphor between the two different systems, thus, therefore, leading to a complete distinction between them and imposing a precisely determined meaning on the concepts. That meaning requires understanding “wholes” and “parts”, the latter classified and understood in the context of wholes inside of each conceptual system. It is assumed that any juxtaposition of the two paradigms’ concepts should cause a “crisis” situation, similar to the historical one and capable to reveal any conceptual mixing, which corresponds to a radical reconstruction of learners’ knowledge. The addition of new knowledge and any further enlargement should be corresponded to a weak reconstruction. The basic concepts of each system, functioning as the nodes of the relevant conceptual network, acquire their meaning as parts of a whole system. Finally, regarding the supporting material, it was presumed that computer software, simulating / visualizing by animation the probabilistic and stochastic processes of the many particles systems of microkosmos, is a valuable educational tool, mainly when the computer is synchronously fed from / reacts with the real world by sensors / actuators.

2. Mode of Inquiry

The inquiry consisted of the designing, implementation, evaluation and feedback processes. It was applied to a sample of more than 6000 in-service primary teachers (currently teaching science among other subjects) and about 1000 undergraduate university student / perspective primary teachers, as well as to a sample of about 90 in-service secondary science teachers. During the inquiry, all participating teachers were taking an official training in the university (30h on science for primary teachers between 1997-2001, 200h for secondary teachers between 1998-2001); the university students were taking the obligatory physics course (2 semesters between

1998-2001). The primary teachers and university students were examined in a pen-and-paper form; the science teachers were interviewed.

3. Outcomes

Early outcomes of the research revealed the necessity of a reformation of the traditional science content, whilst they were in favor of the proposed instructional approach. Thus, the neoclassical models instruction shifted progressively –and successfully according to the evaluation– to the very early parts of the courses. This success indicated that learners' main misconceptions were rooted in their pre-/in-university traditional courses, which dictate a sequential introduction of classical and neoclassical models, thus provoking the overlapping or mixing-up of the associated conceptual systems, since learners usually adopt a mechanical approach of quantum physics models.

The early introduction and study of microkosmos –in all of its aspects and views–, was also proved to be feasible and successful, since it offers an educationally valuable unifying element for an interdisciplinary presentation of our kosmos. Furthermore, the evaluation indicated that the microscopic explanations of the macroscopic phenomena were valuable and indispensable for learners with a limited background in science and mathematics.

However, the various microscopic structures and processes, as modeled either by classical or neoclassical (relativistic, quantum) physics, operate in a probabilistic and stochastic way. Thus, due to the lack of any other way of perception, they inevitably had to be simulated / visualized by computer animation, with the use of Monte Carlo methods / techniques [4,5]. This software, opening inside the classroom a window to non-observable parts and phenomena of our (micro)kosmos and following step by step its processes –even those of the greatest complexity–, proved indispensable. Applications of such type were optimized progressively, after successive evaluation. In some of those applications, the computer was synchronously interfacing with the real world, through sensors and actuators, an advantage of great educational value.

4. Conclusions and Implications

The up to now outcomes are encouraging and implicate the adaption, implementation and evaluation of the reformed content, the instructional approach and the educational material on other target groups as well. Furthermore, the vast majority of teachers / learners expressed the opinion that this integrated scheme, might be applied, as well, to even early stages of upper secondary education, whilst simplified images of selective microscopic structures and processes might be implemented and tested to earlier stages, expecting encouraging results.

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