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The Pendulum as Presented in School Science Textbooks of Greece and Cyprus

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Abstract. When we refer to scientific knowledge, we, implicitly or explicitly, refer to its three components, namely its conceptual framework, its methodological principles and its cultural aspects. The pendulum is a topic of science teaching and learning where all three of these aspects can be examined with the aim of gaining a holistic appreciation of the transformation of a natural phenomenon into a phenomenon of the physical sciences and how this can then be recontextualized into a topic of school science learning. The main objective of this study is to examine whether this richness of the pendulum as a topic of teaching is revealed in the school science textbooks in Greece and Cyprus, for both primary and secondary education. We will use an analytical mapping instrument in order to determine, whether the pendulum is introduced at some grade level and, if so, in what context. We will then use an interpretive instrument, which relies on taxonomy of science curricula into traditional, innovative and constructivist programs, in order to attach meaning to the analysis. Finally, we will formulate a series of proposals in relation to the educational value of the simple pendulum at the Greek and Cypriot gymnasium level.

Key words: pendulum, science curriculum, science textbook

1. Introduction

The term *scientific knowledge* refers to wider appreciation of the three components of science, namely its concepts, methodology and cultural attributes (Bybee & DeBoer 1994). The pendulum constitutes an object of teaching and learning that makes it possible for someone to dwell equally well on all three dimensions of the scientific knowledge. On the other hand, there has been noted ‘a striking imbalance between the importance of the pendulum in the history of science and the meager attention it commands in science curricula’ (Matthews 2000, p. 3, ch.11).

The main objective of this study is to investigate if and how the above comment holds true in the case of the school science textbooks used in primary and secondary education in Greece and Cyprus. We use a model of analysis of school curricula and science textbooks, which is designed to investigate the way a thematic or conceptual topic is handled in the context of formal education. Based on this instrument, we shall prove that the study of the pendulum at all levels of the school system in both countries is restricted to the simple pendulum and reflects the main features of a traditional perspective to science curricula. The main attributes of the traditional approach are a mathematicized or 'pseudo-qualitative' conceptualization, an 'empiricist' methodological treatment and a minimal cultural emphasis. These features appear to contradict the opinion which regards the pendulum as an important object of teaching and learning by virtue of its conceptual, methodological and cultural richness.

Finally, based on the same model of analysis, we undertake to formulate proposals for improvement aimed at enhancing the role of pendulum study in Greek and Cypriot schools while at the same time providing practically feasible solutions in the context of established school curricula.

2. A Model of Analysis of School Curricula and Textbooks

Research in the field of science curricula and textbook analysis is multifaceted. A great number of research projects, conducted with the aim to analyze school science textbooks, concentrate on the content, while a substantially lower interest is in linguistic and sociological analysis (Koulaides & Tsatsaroni 1996). The model presented here is a model of analysis as to the content, revealing the epistemological and cultural features belonging to the school curricula and the textbooks. The originality of this model lies in that, as well as serving as a research tool, it can also operate as a teacher preparation tool for educators at all levels, since it has been designed as a medium for closing the gap between research and pedagogic practice. It is a generalized version of a model that was used, initially, for the analysis of school curricula and textbooks relevant to the concept of 'energy' (Koliopoulos & Ravanis 2000). This model proved to be especially useful in encouraging educators to appreciate the characteristics and constraints of their teaching, to be able to explain their practice and, potentially, to proceed in exploring alternative options for reorganizing their teaching (Koliopoulos & Ravanis 1998).[1]

The proposed model is based on the distinction between two frameworks[2] served by the school curricula and science textbooks that present a conceptual character (Driver & Millar 1986).[3] Each of these frameworks refers to the way a science school curriculum or a science school textbook manipulates the concepts, methodology or cultural characteristics of one or more thematic or conceptual units. At this point, we have to note that the proposed classification of frameworks, even though it derives from an empirical analysis of the existing school curricula, does not correspond to one or more specific curricula. Rather, it reflects an abstract entity integrating general epistemological characteristics which could appear partly or wholly in a concrete science curriculum or science textbook. The two frameworks are as follows:

(i) *The 'traditional' framework*. This framework is characterized by:

(a) the juxtaposition of small thematic units leading to *juxtaposition* or *dispersion* of various conceptual frameworks. A typical example is found in the study of the concepts of energy and light in Greek and international curricula of lower grades of education (elementary and secondary education). These concepts are dispersed in various thematic and/or conceptual unities. The dispersion is such that concepts acquire a different systemic meaning (i.e. a meaning that emanates from the relations of the concept with the other concepts of a conceptual system). They also acquire an empirical meaning (i.e. a meaning that emanates from assigning the concept to some real phenomenon in the course of the transformation of this phenomenon to a scientific object) in each of the thematic units (Baltas 1990).

(b) the *mathematical*, in higher grades of education, or the *'pseudo-qualitative'*, in lower grades, dealing of science concepts. In the mathematical approach the systemic meaning of concepts is favored. In contrast, in the 'pseudo-qualitative' approach, the systemic meaning of the concepts is totally cancelled, because of the lack of mathematical expressions, thus resulting to the domination of the empirical meaning of these concepts.[4] A typical example of this approach is the study of the concept of friction in Greek and international elementary curricula. In Greece, a research of analysis regarding the content of textbooks has shown that, at the elementary school, the concept of friction has been treated in the same way as at the university level. This means that mathematical language has been replaced by everyday language destroying the systemic meaning of the concept of friction.

(c) the *empirical – experimental* approach in which, carrying out one (usually) experiment is sufficient to introduce or confirm a conceptual framework (Joshua & Dupin 1993). In the school textbooks, this approach appears in the form of setting a sequence of instructions the students have to follow accurately in order 'for the experiment to work'. This framework is rooted in the empirical tradition according to which the methodological observation of a natural phenomenon leads to the formation of scientific models. It is found at all grades of education but, mostly, at the lower ones even for concepts that cannot be formed in that manner (Zogza et al. 2001).

(d) the *limited* use of cultural features which does not favor the possibility of developing scientific literature. A clear example of the limited use of cultural features in school textbooks is that, where everyday applications of science are mentioned, these are often not integrated into the main text but placed in a separate box.

(ii) *The 'innovative' framework*. This framework is rooted in the innovative changes on the science curriculum in the 1970s and 1980s and is characterized by:

(a) the formation of broad thematic/conceptual units in which the emphasis is placed on the structure of the unit or/and the so-called *directed theme*. A typical example of this framework is the unit of 'Optics' in the French school project *Sciences Physiques*, *Libres Parcours* (Chanut et al. 1979), which provides three alternative structures of teaching the unit. In the first, emphasis is placed on the construction of the conceptual model 'source – transmission – recipient', the second presents a more methodological character and is structured around the observation of astronomical phenomena while in the third, the approach is more technological with the study of various optical instruments. However, all three structures serve the same conceptual, methodological and cultural goals set by the curriculum. Another example is the American program *Physical Science II* (Physical Science Group 1972) where the concept of energy recommends an organized principle of the whole teaching program.

(b) The *'in-depth'* dealing with a conceptual framework which, at many times, is characterized by a 'qualitative/semi-quantitative' approach to science concepts trying to form a selected relation of the qualitative – quantitative. The approach of the energy concept through the conceptual framework of energy chains is a typical example of this approach.

(c) the effect of the '*hypothetico-deductive'* methodological approach showing the prime role of 'didactical activity – problem'. In this, the hypothetical substance of the science knowledge is shown, which arises out of the study of an open problem the students have to familiarize themselves with while participating, partly or wholly, in designing the experiments (Robardet 2001). Including this approach in the school textbooks is not easy. The example of the French school textbooks *Sciences Physiques, Libres Parcours* (Chanut et al. 1979), where the teaching activities play a prime role and which do not allow a lineal reading of the text, is indicative of this approach.

(d) the *organic enclosure* of the cultural dimension of science in the various thematic units. This means that daily/technological problems (e.g. energy saving, cooking, constructing a measuring instrument) or science historical texts support on their own starting points and frameworks within which the conceptual and methodological approach is formed (e.g. the German teaching project *Neue Physik, Das Energiebuch* (Falk & Herrmann 1981) and the American *Harvard Project Physics* – Holton et al. 1970).

3. The Approach of the Pendulum in Greek and Cypriot Teaching Programs

3.1. METHOD

A first step to analyzing the school textbooks was using an *inventory instrument* of the position, content and form of the pendulum study in every educational level.[5] The structure of the study defines the *unit of analysis* and supports information relevant to the thematic units or sub-units dealing with the pendulum and the coherence or dispersion level of the pendulum study in one or more educational levels. The content provides information on the conceptual, methodological and cultural approach of the pendulum. The *key – phrases* used in this part of analysis code the conceptual framework, the methodological approach and the cultural features of the unit. Finally, the form of the study refers to the *means of expression* (mostly texts, issues, exercises/problems, pictures/figures, experimental activities etc.) and the *way of studying* (simple reference, detailed study) the unit and offers information concerning the importance given by the school textbook to the specific unit. In Table I we give an extract of the instrument used.

The information collected for each analysis unit and coded underneath the column 'Comments/Remarks' could lead to conclusions which can be interpreted through the model of analysis already described in the previous unit.

3.2. RESULTS

3.2.1 *The pendulum study in different educational levels*

Both in Greece and Cyprus, the pendulum study is confined mainly to the study of a simple pendulum and never introduces a comprehensive unit with *its own character*. The simple pendulum is introduced in various units in each of which the conceptual framework of its study is different. The following conceptual frames of study have been identified:[6]

- [a] application of Newton's 2nd law or/and measurement of the pendulum period within the study of the phenomenon of oscillation (circular or/and cycloid curve of a simple pendulum or/and torsional pendulum, measure of frequencies of a system of matched pendula, qualitative approach of wave transmission through the analogy of matched pendula),
- [b] tracing interactions or/and measuring forces during the motion or/and the equilibrium of a pendulum,

Table I. Extract out of the inventory tool used during the analysis of a Greek school textbook

GRADE	STRUCTURE		CONTENT			FORM		COMMENTS REMARKS
	Unit	*Sub-Unit*	*Conceptual frame*	*Methodological approach*	*Cultural features*	*Expression means*	*Ways of study*	
3rd grade of gymnasium	Electromagnetism		–	–	–	–	–	
3rd grade of gymnasium	Electronic particles		–	–	–	–	–	
3rd grade of gymnasium	Motion – Force – Energy	…	…	…	…	…	…	…
3rd grade of gymnasium	Motion – Force – Energy	Force measure	'In which of the two pictures the glass stick and the plastic sphere have same electric charges?'			Question – figures	Simple reference	Conceptual frame (b)
	Motion – Force – Energy	Force features	'Name the forces acting on the iron ball in pictures 1 and 2'			Question – figures	Simple reference	Conceptual frame (b)
	Motion – Force – Energy	…	…	…	…	…	…	…
3rd grade of gymnasium	Swings	Periodic moves			What is the resemblance of a back – forth	Photographs (2)	Simple reference	

				swing move in a playground and a heart's rhythmical move?				
3rd grade of gymnasium	Swings	Swing study – Period	'Timing the move of the simple pendulum, estimating the time needed for a complete swing (or circle). This time is the pendulum period'	Activity 4.1: Swing timing (instructions of performing the experimental activity)		Experimental activity (issue)	Whole paragraph	Conceptual frame (a) Totally guiding experimental activity defined by the definition of the concept 'pendulum period'
3rd grade of gymnasium	Swings	. . .	. . .	. . .	. . .	. . .	. . .	. . .
3rd grade of gymnasium	Particles of matter structure		–	–	–	–		

- [c] qualitative representation of energy transfer or/and application of the laws of momentum and energy conservation (simple and/or torsional and/or ballistic pendulum),
- [d] tracing a noninertial frame of reference system or/and measuring the rotation period of the earth (Foucault's pendulum),
- [e] measurement of the gravitational constant or/and gravitational acceleration (Cavendish' torsion balance or/and acceleration meters) and
- [f] tracing or/and measuring the electric/magnetic force or/and of the electric charge (use of pendulum for detecting electric or magnetic field/Coulomb's balance).

Table II presents a general picture of pendulum study in Greek and Cypriot curricula at all three educational levels (elementary, gymnasium, lyceum), based on the conceptual frameworks of this study. In this Table we can see that, in both countries, the pendulum is introduced quite early in science teaching as an instrument, which is appropriate while dealing with various conceptual frameworks. This does not signify that there is always a detailed study of the pendulum. In most conceptual frameworks, the study of the pendulum is incidental and limited. For instance, even though the simple pendulum forms one of the usual phenomena of the Newtonian study concerning the equilibrium of a material point, in Greek and Cypriot school textbooks, is not mean that it is also essential. The same applies to the study of the energy conservation of a mechanical system. It is quite a different thing to chose the simple pendulum chosen as the main phenomenon to introduce this concept (Holton 1985) than for it to simply be one of a number of examples of its application, as occurs in Greek and Cypriot textbooks. In these cases there is a *simple reference* for the simple pendulum also relating to

Table II. A general picture of the conceptual frameworks (see Section 3.2.1) within which the pendulum study is conducted in Greek and Cypriot school textbooks in different educational levels

	Greece		Cyprus	
5th Grade of elementary	[c]		–	
6th Grade of elementary	–		–	
2nd Grade of gymnasium	[f]		[a], [f]	
3rd Grade of gymnasium	[a], [c], [e]		[b]	
	General education	Direction	General education	Direction
1st Grade of lyceum	[b], [c]	–	[c], [b]	–
2nd Grade of lyceum	[a]	–	–	[b], [c], [f]
3rd Grade of lyceum	–	[a]	–	[a], [e], [c]

the conceptual dimension of scientific knowledge. In opposition, the simple pendulum on its own forms an object of detailed study only in the units of ‘Oscillations’ and ‘Waves’. This appears in the 3rd grade of the gymnasium and the 2nd grade of the lyceum in the Greek curriculum and the 3rd grade of the lyceum in the Cypriot curriculum.

3.2.2 *The content of a detailed study of the pendulum*

In the Greek curriculum the detailed study of the pendulum occurs within the core curriculum. In contrast, to the Cypriot curriculum this study takes place within an optional curriculum for students of practical studies. Table III gives a comparative picture of detailed study of the pendulum.

Two approaches are apparent: the first in Greek textbook in the 3rd grade of the gymnasium and the second in the 2nd grade of lyceum in Greece and 3rd grade of lyceum in Cyprus. The first approach gives special meaning to the pendulum study since the pendulum is chosen as the favored phenomenological field for the study of the phenomenon of oscillation and especially the definition of the period of oscillation. This does not appear in the second approach in which the introduction to the phenomenon of oscillation and the study of its modeling (simple harmonic oscillation) is done based on the retrogressive motion of a sphere aided by a spring (spring-mass pendulum).[7] The second point on which the two approaches differ is the absence of the cultural dimension in the second approach. That is, we do not have these experiential features, which endow the concepts with what Baltas (1990) call ‘excess meaning’. In contrast, in the first approach the cultural dimension appears in the form of historical or contemporary references to the sundial and Foucault’s pendulum, however, without a thorough study. Finally, a

Table III. Comparison of the textbooks in those levels where the pendulum study is done in a detailed manner (see & Section 3.2.1)

	3rd Grade of gymnasium (Greece)	2nd Grade of lyceum (Greece)	3rd grade of lyceum (Cyprus)
A. Introduction and study of the oscillation phenomenon and the simple harmonic oscillation	X [a]	–	–
B. Study of the pendulum movement			
B1. Conceptual approach	X [a], [c], [e]	X [a]	X [a], [e], [c]
B2. Methodological approach	X	–	X
B3. Cultural approach	X	–	–
C. Study of matched oscillations	–	X [a]	X [a]
D. Introduction to waves	X	X [a]	X [a]

third difference is relative to the quantitative or qualitative character of the conceptual framework. (In the first approach, in both circumstances, there is an introduction of texts simply using common language to describe mathematical equations. In the second approach the treatment of force and energy analysis is carried out exclusively in mathematical terms.

Similarities are also apparent between the two approaches. One similarity concerns the methodological study of measuring the period of the simple pendulum as well as the study of the relation between the period and the measures 'length of string' and 'gravitational acceleration'. More specifically, the derivation of this relation seems to occur in a 'natural way' through the experimental activity whereas the students are directed to check the nature of the relationship since the relation has been announced by naming the factors on which the pendulum period depends. Another similarity is related to the use of simple matching pendula for the qualitative study of the energy and elastic wave transmission.

4. Conclusions – Proposals

Both in Greece and Cyprus, the study of the pendulum occurs within the traditional framework over the school curricula and science textbooks.

(a) Whether in the case of a simple reference, or the case of a detailed study of the pendulum, the options of the educational grade and its position in the school curriculum and the relevant school textbook, do not seem to be derived from a specific pedagogical plan but rather follow the material separation into traditional thematic units as this appears in classic introductory university textbooks. Similar to these textbooks, in the traditional school curriculum all subjects, and mainly the concepts, have the same pedagogical value considering there is not some kind of 'external' criterion to the scientific knowledge (e.g. the social importance of a theme) that will give greater or lesser importance to a conceptual framework. At the same time, the feature of setting different conceptual frameworks within which the pendulum study occurs is apparent, even though a favored field seems to be the one of Newtonian analysis, at least in the lyceum grades. Nevertheless, the effort to elevate the simple pendulum into favored field of studying the phenomenon of oscillation, in the gymnasium grades, shows that innovative framework for the school curricula and science textbooks has influenced the authors of the corresponding school textbook.

(b) In the gymnasium grades, the 'pseudo – qualitative', conceptual approach is followed, considering this approach does not differ in anything from the one used in the lyceum but the exchange of the mathematical language with everyday language. So, the phrase 'in extreme positions of oscillation the sphere acquires its maximum gravitational dynamic energy as to the equilibrium position and zero kinetic energy' can not acquire any meaning if not included in the quantitative/mathematical approach of the conservation of the mechanical energy. On the other hand, in the lyceum, we find a totally mathematicized approach. A series of mathematical equations replace the problem that can give meaning to the concepts corresponding to mathematical symbols. Issues such as 'which problem leads to the Newtonian analysis of the simple pendulum motion' or 'how did the connection of the motion of the simple pendulum with the law of energy conservation occur' (Matthews 2000, ch.8) are not included in any of the three educational levels.

(c) In the gymnasium, one more clearly sees the empirical methodological approach to the simple pendulum. For example, the dependence of the period on the length of the string of the simple pendulum and the acceleration of gravity does not appear as a conceptual problem, but as a technical problem solved through a series of instructions for the 'successful' performance of an experimental activity. Thus, the impression is given that the relation of period with the other physical entities emerges from a simple (however, systematic) observation of the pendulum motion. This impression leads to the empirical logic that scientific knowledge, especially mathematical relations expressing it, is 'hidden' within the natural phenomenon. In the two grades of the lyceum we find, apart from the specific experimental activity, the derivation of the formula $T = 2\pi\sqrt{\frac{l}{g}}$ from a series of mathematical relations.

(d) Lastly, the absence of any cultural reference relating to the pendulum in the lyceum as well as the loose connection between the scientific knowledge of the pendulum and the everyday/technological or/and historical applications in the gymnasium, sets all three approaches within the traditional framework for school curriculum and science textbooks. Still, the reference to time measuring and the Foucault's pendulum supports the possibility of curriculum change so as to attain the features of an innovative framework. This change from the traditional to the innovative framework will be occupying us afterwards.

As already pointed out, the instrument of analysis and interpretation of school textbooks we presented has another value since it can be used as a learning tool for educators of science of different grades. In a previous study relevant to how educators can modify the traditional tradition of the school curriculum in science and move towards the innovative framework (Koliopoulos & Ravanis 1998), the following ways of intervention were identified:

(*A*) Part or whole modification of the curriculum which relates to the union of thematic units or the formation of a broad unit over a directed theme and

(*B*) Modification of one or some features of the traditional framework within a certain thematic unit like the modification of the methodological framework for the introduction of experimental activities.

In the following, we are about to present an example of transformation of the traditional framework to an innovative one for teaching about the pendulum. Firstly, this example cannot be generalized because it refers to the existing Greek curriculum. This approach can replace or complete, if there is enough time, the traditional approach of the 3rd grade of the gymnasium (case *A*). In Table IV is presented a sequence of didactical units, based on didactical activities – problems while for each unit we propose the basic conceptual, methodological and cultural elements of the concerned study. This approach differs from the traditional approach as to the following points:

(a) A broad unit is formed in which time measurement constitutes the main theme, that is the (cultural) framework within which the desired conceptual and methodological features of the pendulum study acquire meaning.

Table IV. A sequence of units relevant to the teaching of the simple pendulum, which is based on the 'innovative' framework for the school curriculum

Activity – Problem	Conceptual Frame	Methodological Frame	Cultural Frame
Why is it needed for time measuring to be accurate?	Periodicity	Measuring accuracy	Sundial, mechanisms in Ancient Greece and Cyprus, pendulum clock, modern clocks
How can we measure time in the pendulum clock?	Period/frequency	Measuring accuracy Measuring the pendulum period, measuring faults	
From a true pendulum clock to the simple mathematical pendulum	Period/frequency Period – length of string relation	Measuring accuracy Measuring the pendulum period, measuring faults Showing factors on which the pendulum period depends	
Once again the issue of accuracy in time measuring	Period/frequency Period – gravity relation	Showing factors on which the pendulum period depends	Examples derived from science history (The differences in time measurement)

(b) There is an in-depth analysis of a conceptual framework that, in the specific occasion, relates to showing a qualitative/semi-quantitative relation between the period of the simple pendulum, the string length of the pendulum and gravitational acceleration. The mathematical approach to this relation is not necessary in this grade. At the same time, the paragraphs relating to other conceptual frameworks, like the Newtonian analysis, energy analysis and measure of gravitational acceleration, are omitted.
(c) A hypothetico-deductive approach to the relation between the period and the string length of the pendulum and gravitational acceleration is attempted. Concerning the length of the string, a practical problem is raised concerning the explanation of how a clock 'ticks the seconds'. This problem, with the educator's guidance, can lead the students to plan on their own the same experimental activity imposed by the school textbooks in the traditional approach.[8] In gravitational acceleration, a problem is presented through science history (Matthews 2000, ch.6) that can lead students to realize primarily, the qualitative relation between the pendulum period and the force of gravity. If there is also an analogy between the gravitational field and the magnetic field or one can be established, teaching practice can include an experimental activity of measuring the period while placing a magnet under the pendulum.
(d) The cultural dimension is specified as an essential element of the educational procedure. The cultural dimension not only (a) acts as a means for approaching the everyday/technological reality and of getting familiarized with the scientific/technological tradition (e.g. in Greece and Cyprus, familiarization with the sundial and the mechanism of Antikythera) and (b) constitutes a guiding principle of the broad unit but also (c) acquires an organic relation with the conceptual and methodological dimension thus attributing meaning to the study of these two dimensions. Hence, the function of the clock is not viewed as a simple application of the pendulum study. Instead, the study of the technological and natural phenomenon of the clock's operation leads to the procedure of its conversion to a physical phenomenon (study of the modeled simple pendulum) (Baltas 1990).

As we have already noted the limits of the above approach relate to the school curriculum tradition (see Table III) and its pedagogical frameworks (e.g. teaching methods and means) within which it is called to function. Another factor influencing this approach can be the mental representations the students acquire for the concepts of time measurement, pendulum period or/and for representing patterns/models in selected data. If this factor is also considered, then it is possible to have radical changes in the sequence and context of the approach proposed.

Epilogue

We consider this article as a small contribution to the area of research in science education by showing how a conceptually, methodologically and, most importantly, culturally rich object of teaching, such as the pendulum, is limited through the traditional framework for science school curricula. At the same time, the same instruments of analysis used in this case study seem to be suitable for identifying specific ways of reorganizing this framework. The transformation of this new framework into educational practice by suitably prepared teachers is the next phase of our research.

Notes

[1] The generalized version of the model was presented in a series of lectures given to the students of the Department of Educational Sciences of the University of Cyprus during the academic year 1999–2000. A preliminary evaluation of the results of these courses indicates the potential of this model as an effective teacher preparation tool for primary education.

[2] The complete version of the proposed model includes a third framework, the 'constructivist' framework, which is conceptualized not so much as a teaching methodology but more as a framework that determines the sequencing of many innovative teaching programs (Tiberghien et al. 1995, Koliopoulos & Ravanis 2000). Such programs are mostly experimental in nature and have not in general been transformed to established school curricula. It is for this reason that we have chosen to omit this third perspective in the context of the present paper.

[3] We do not include here curricula that emphasize other attributes such as STS or those that emphasize methodological process skills

[4] In the 'pseudo-qualitative' approach the replacement of mathematical language by everyday language leads to the breakdown of any logical connection between the two concepts. This occurs because this connection results exclusively from a mathematical model. That is, someone who is trying to comprehend a text belonging to the 'pseudo-qualitative' approach should have priorily comprehended the corresponding mathematical model. In contrast, in a 'qualitative' approach the natural language or other symbolic representation is used in such a way as to favor the construction of different forms of physical causality (e.g., the establishment of series of intermediaries and series ordered in time – Antoine 1982)

[5] In both Greece and Cyprus teaching is entirely implemented through one officially approved textbook. The fact that the last two years there are two officially approved textbooks for the primary school doesn't change anything in our research since only one of these textbooks refers to pendulum.

[6] This is a synthetic description of many conceptual frameworks, which include both quantitative and qualitative approaches. Usually only some of the attributes of each framework appear in the school textbooks under examination. For instance, the reference in frame (c) to the level of primary education concerns the implementation of an experimental activity where a simple pendulum is used to familiarize children with the transfer of the sound that is generated when a glass is hit with a spoon.

[7] In the French bibliography the system of spring-sphere with vertical motion is called the «elastic pendulum».

[8] In Greece, a corresponding activity has been implemented successfully in the case of Hooke's law of elasticity. In this case, 8th grade students propose by themselves the well

known experimental procedure with a coiled spring which results in an analogical relation between weight and extension, in the context of project work in response to the problem «How can we make a force meter?»

References

Antoine, M.: 1982, 'Le Niveau Qualitatif dans l'Initiation aux Sciences Physiques', *Bulletin de l'Union des Physiciens* **643**, 783–798.

Baltas, A.: 1990, 'Once Again on the Meaning of Physical Concepts', in Nikolakopoulos, P. (ed.), *Greek Studies in the Philosophy and History of Science*, Kluwer Academic Publishers, pp. 293–313.

Bybee, R. & DeBoer, G.: 1994, 'Research on Goals for the Science Curriculum', in Gabel, D. (ed.), *Handbook of Research on Science Teaching and Learning*, McMillan Publishing Co, pp. 357–387.

Chanut, Y., Charles, M., Dargencourt, A., Guesne, E. & Pezet, R.: 1979, *Sciences Physiques 4^e^, Collection Libres Parcours*, Hachette, Paris.

Driver, R. & Millar, R.: 1986, 'Teaching Energy in Schools: Towards an Analysis of Curriculum Approaches', in Driver, R. & Millar, R. (eds), *Energy Matters*, University of Leeds, pp. 9–24.

Falk, G. & Herrmann, F.: 1981, *Neue Physik, Das Energiebuch*, Hermann Schroedel Verlag KG, Hannover.

Holton, G., Rutherford, J. & Watson, F.: 1970, *The Project Physics Course*, Holt, Rinehart & Winston, New York.

Holton, G.: 1985, *Introduction to Concepts and Theories in Physical Science*, Princeton University Press, New Jersey.

Joshua, S. & Dupin, J.J.: 1993, *Introduction à la Didactique des Sciences et des Mathématiques*, Presses Universitaires de France.

Koliopoulos, D. & Ravanis, K.: 1998, 'L'Enseignement de l'Energie au CollÈge vu par les Enseignants. Grille d'Analyse de leurs Conceptions', *ASTER Recherches en Didactique des Sciences Expérimentales* (26), Institut National de Recherche Pédagogique, 165–182.

Koliopoulos, D. & Ravanis, K.: 2000, 'Réflexions Méthodologiques sur la Formation d'une Culture concernant le Concept d'Energie à travers l'Education formelle', *SPIRALE Revue de Recherches en Education* **26**, 73–86.

Koulaides, V. & Tsatsaroni, A.: 1996, 'A Pedagogical Analysis of Science Textbooks: How can we proceed?' *Research in Science Education* **26**, 55–71.

Matthews, M.R.: 2000, *Time for Science Education. How Teaching the History and Philosophy of Pendulum Motion Can Contribute to Science Literacy*, Kluwer Academic/Plenum Publishers, New York.

Physical Science Group: 1972, *Physical Science II*, Prentice-Hall, Inc. New Jersey.

Robardet, G.: 2001, 'Quelle Démarche Expérimentale en Classe de Physique? Notion de Situation – ProblÈme', *Bulletin de l'Union des Physiciens* **836**, 1173–1213.

Tiberghien, A., Psillos, D. & Koumaras, P.: 1995, 'Physics Instruction from Epistemological and Didactical Bases', *Instructional Science* **22**, 423–444.

Zogza, V., Ravanis, K., Bagakis, G. & Koliopoulos, D.: 2001, 'Working with Sciences in Kindergarten: Didactic Strategies', in *Proceedings of the 3rd International Conference on Science Education Research in the Knowledge Based Society*. Thessaloniki, pp. 709–711.