Degree IN TEACHER OF PRIMARY EDUCATION.
Subject: Didactics of Experimental Sciences
Course: 17-18

Chapter 2.- Science Education. New Trends in Science Education

2.1. Introduction to the field of Didactics of Experimental Sciences.

The first question that we can raise is What is meant by "Didactics of Experimental Sciences"? To define what is the "Didactics of Experimental Sciences", it means to give meaning to each one of the terms that appear in its name. Thus, it is necessary to define what is meant by "Didactics", and what is meant by "Science".

Pérez (1989) defines the Didactics as the science of a particular type of communication system where the processes of teaching and learning are taking place. Therefore, we can say that the Didactics of Experimental Sciences is the science dedicated to the study of the systems of communication taking place in the teaching and learning processes of the Experimental Sciences. On the one hand, if we are going to study the processes of teaching and learning of science, it is necessary to delimit previously what is science and what is not, as at present there are different fields who call themselves "scientists" without the characteristics necessary to belong to science (Jimenez and Sanmartí, 1997).

On the other hand, it is necessary to delimit that fields of knowledge fall within what is called "Experimental Sciences". The classification of the sciences is a subject under study of the Philosophy of Sciences, which is not free of controversies, and always subject to revision. A science is presented to us as a set of knowledge about the Universe that seeks to explain and interpret it. The part of the Universe that a science pretends to explain constitutes its "field" or "object of study". The way in which each science interrogates itself about its "object of study", guides and carries out its investigations constitutes its "methodology".

As we commented previously, one way to classify the sciences is to attend to its "field" or "object of study". Thus, for example, the Sciences of Nature are those that try to elaborate a scientific knowledge about different natural phenomena. They are considered natural phenomena or processes, for example: movement, light, and sound (physical phenomena); the transformations of substances (chemical phenomena); the diversity of living beings and their vital functions (biological phenomena); or volcanism, earthquakes, changes in the surface of the Earth (geological phenomena).

Although the object of study is natural phenomena, the development and specialization of these sciences mean that today they go far beyond them, paying attention to phenomena and entities that do not exist naturally and have been created as products of Human Science and Technology itself.

Another way to approach the classification is to attend to methodological criteria, that is to the way to approach the problems and to work. In fact, by calling them "Experimental Sciences", the preponderant role that experimentation has in its ways of investigating reality is becoming evident.

Throughout the history, the sciences have been trying to move along from the Philosophy. Several classifications of science were made, depending on the needs of

scientists to specialize in their work, but this does not affect the phenomena of nature, which remain the same. It is important to remark that, throughout the history of Science, even the objects of study have not changed, we have considered the way of conceiving and studying them.

Traditionally the Experimental Sciences have been divided in Physics, Chemistry, Biology and Geology. This differentiation can still be useful as a reference for Science Teaching, but it must be keep in mind that scientific disciplines tend increasingly to specialization and division, creating new disciplines whose objects of study or working methods belong to more than one of the classic disciplines (for example: Biochemistry, Astrophysics, Geobotany, Biophysics, Physicochemistry, etc.), highlighting the eminently interdisciplinary nature of modern sciences.

Foundations

The discipline "Didactics of Sciences" is a field of study currently consolidated in developed countries, with its own research community, in which Spain occupies an increasingly important place.

The origin of the Didactics of Sciences, as an area of knowledge, goes back to the 1950s, associated with the institutional impulse given to science education in the Anglo-Saxon countries, and especially in the United States (Porlán, 1993). This impulse was mainly due to the concern for the training of students who in the future would be the scientists and technicians (elites training) as a basis for the scientific progress of their countries.

The beginning of its modern stage is placed by Gutiérrez (1987) in the debates held in 1974 in the major international congresses laying the foundations for an openness in the research methodology that had been followed up until then. It was to go beyond the “hard” models, characteristic of science, and make way for more qualitative methods.

Discussions were guided by the question: Can students really learn what we intend to teach them? As a result of these debates, the need for an interdisciplinary openness became more and more acute.

A key part of this opening was the importance given to Psychology, in general, and Psychology of Learning, in particular. The ideas of Piaget and Ausubel gained ground quickly. Since then, constructivism has had an enormous influence on the research in Science Teaching and its implications are also coming into practice.

At present, science education has raised major challenges, including the scientific education of all students at compulsory education levels, which has given rise to the "Science for all" movement (Fensham, 1983), with special emphasis, not forgetting the traditional goal of transmitting scientific knowledge, in the training necessary to be citizens in societies increasingly dependent on scientific and technical knowledge.

Fields of action

The field of action of the Science Teaching will be all where the processes of teaching and learning of the Sciences take place.

In the first place, we find the framework of formal education, of education systems. In the specific case of Spain, the current educational system includes:

❖ **Compulsory Educations:** Primary and Secondary Schools

❖ **Non Compulsory Educations**: Childhood Education, High Secondary Schools, Vocational Training, University Teaching and Adult Education

In all these educational levels, in one way or another, contents are taught that fall within the sciences and, therefore, are object of attention and study by the Didactics of the Sciences.

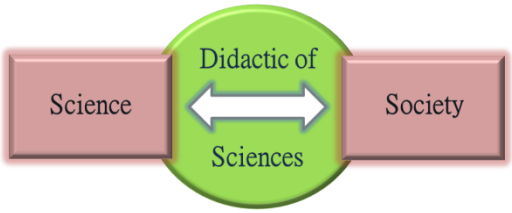
But his field of action does not end there. Every day, the importance of other sources of information in the formation of people, in addition to the school channels, is more established. In some cases, these extracurricular sources can become more important and impactful for students. Thus, Science Teaching has accepted, and indeed already does, as part of its study the learning process of the sciences that is produced through the so-called "non-formal education". Among them, and with special emphasis on those engaged in or including scientific outreach, for its relevance in this field are:

❖ **Museums** and Science Centres, Scientific Clubs…

❖ **Media: Internet,** television, newspaper, movies,…

Another important aspect when establishing the field of action of Science Teaching is to clarify the scope and meaning of its object of study: "the teaching and learning processes of science". The focus is much changed if, for example, we reduce our objectives to the problems of transmission of scientific knowledge or if we extend it to include other formative aspects, such as the development of skills and attitudes.

Some prestigious authors, such as Yager (1985), propose a broad view of the domain of Didactics of Sciences, considering it as an interface between science and society



This approach involves attending to new objectives of a science teaching that is now offered to the entire school population and therefore increasingly targeted at students who will never be scientists.

These new objectives relate to the most fundamental training needs of citizens and aim to give a broader approach to science education that includes values related to the link between science and society; the technology. Many of these aspects are included in what has been called the CTS (Science, Technology and Society) approach, which seeks to bring students closer to problems in which there is interaction between Science, Technology and Society.

2.2. Objectives and purposes of scientific education in the primary education.

Why teach science?

The inclusion of any curricular area in Primary Education aims to contribute to the achievement of the general objectives of the stage, *"...A tales efectos se pondrá especial énfasis en la adquisición de competencias básicas"* (artículo 1 del Decreto 230/2007 por el que se establecen la ordenación y las enseñanzas correspondientes a la Educación Primaria en Andalucía").

Including all the subjects of the curriculum, knowledge of the natural, social and cultural environment, students are expected to achieve educational objectives, and that these contribute to the acquisition of key competences skills (RD 1.513 / 2006 ANNEXO I).

In the LOE, key competences are defined as: "those that allow young people to achieve their personal fulfillment, exercise active citizenship, successfully enter adult life and be able to develop lifelong learning." These competences must be reached at the end of compulsory education, and therefore the contribution to them from Primary Education must be significant.

In the Spanish curriculum eight basic competences are defined:

1. Competence in linguistic communication.

2. Mathematical competence.

3. Competence in knowledge and interaction with the physical world.

4. Treatment of information and digital competence.

5. Social and civic competence.

6. Cultural and artistic competence.

7. Competence to learn to learn.

8. Autonomy and personal initiative.

The incorporation of the key competences into the curriculum allows to emphasize those learning that are considered essential, from an integrative approach and oriented to the application of acquired knowledge (Cañas, Martín-Díaz and Nieda, 2009).

Competence in the knowledge and interaction with the physical world and contribution to other competences from the teaching of the sciences.

The specific competence of the Nature Sciences in the LOE is called Knowledge and interaction with the physical world. It is defined as: "The ability to interact with the physical world, both in natural aspects and generated by human activity, in such a way as to enable understanding of events, prediction of consequences and activity aimed at the improvement and preservation of the conditions of life itself, other people and other living beings.

The acquisition of this competence is a priority from the areas of science in Primary Education. In that way, it is necessary to learn essential concepts and the relationships between them: causality, influence, quantitative and qualitative. It also requires the ability to analyze complex systems involving a multitude of factors; the ability to observe the physical world to obtain information and act accordingly. In addition, it is necessary to know the way in which the knowledge is generated, how scientifically the situations of interest are addressed taking into account the tentative and creative nature of the way scientists act. It is not only to know what is known, but how it is known, (meta-learning). For the acquisition of this competence, it is also necessary for students to be able to determine the interest of situations and to limit them, by raising conjectures and informed inferences, leading to conclusions.

In addition, scientific knowledge must also have repercussions on personal and community health and environmental behavior. Finally, students are expected to know, in order to participate and make decisions in tune with local and global problems.

In this section, emphasis has been placed on the aims of science education so that students can acquire a desirable degree of scientific competence (competence in knowledge and interaction with the physical world), but from science teaching we must not forget that we must contribute to the development of competences, especially mathematics, information and digital competence, social and citizenship, linguistics, learning to learn and development of autonomy and personal initiative.

According to the OECD as part of the 2006 PISA student assessment tests, it could be said that a scientifically competent person should be able to use scientific knowledge in everyday contexts, in addition to applying the proper way of acting the scientific method to such situations. They should be aware of the role of science and technology in solving problems and raising new questions. All this determines that the scientifically competent person shows interest in scientific and technological issues, reflects on their importance from a personal and social perspective and is willing to commit to them.

All that has to be said about the characteristics that scientifically competent persons should have should be taken as the aims to be achieved by students from the teaching of science throughout compulsory education, and as mentioned above the contribution of the Primary Education in this sense is essential to achieve the ultimate goal, competent citizens capable of participating actively and consistently in the decisions that are made in different areas of a truly democratic society.

Need for a scientific education in Primary Education.

Important aspects related to the need for early science education in the training of students can be highlighted. These aspects derive from well-established research, and therefore can be fairly rigorously accepted. Briefly stated are:

❖ *Most of the children's ideas about the world around them are built during the primary school years, independently they learn science or not. Without a scientific approach to their exploration of the world, the ideas they develop may be very different from those of science, which may hinder their learning in secondary education.*

The numerous investigations that have dealt with the children's understanding of some key concepts of the sciences have revealed that:

a) Children focus on the themes of their science classes based on very firm ideas and not free of prejudice or willing to accept the new ideas provided by the teacher.

b) These personal ideas are often different from the scientific ideas held by their teachers and for children they are more useful for understanding their world.

c) The science lessons in secondary education often fail to change the ideas of the pupils, and therefore much of what is taught to them makes little sense to them.

Sciences in primary education can, and should, do something to reduce the distances between the ideas of children and those that will allow them to take better advantage of their later scientific education.

❖ *The development of knowledge is not independent of the development of intellectual abilities. It is difficult to achieve a "scientific approach" if children are not helped to increase their skills in getting and dealing with information.*

In the past, it has been assumed that the development of skills was produced independently of knowledge. However, studies conducted in recent years show that the ways and grade of the skills used by the students when carry out school activities depend on previously acquired ideas; which contradicts the previous assumption.

Nowadays, it is more accepted the idea of what is learned is very much linked and depends on the context in which it is done. To a certain extent, children can think and research "scientifically" when undertaking a social project or study a local history theme, but their scientific thinking and research techniques will not be fully developed

as long as school activities do not include research on their physical environment and natural from an early age.

❖ *Children's attitudes towards the sciences are formed before those of many other subjects. Without the experience of scientific activity, many children may develop attitudes that are not suitable for their development in the secondary school sciences.*

Choose or not to study science, our students should leave school with serious attitudes regarding scientific activity. It seems that this will be more difficult if the first contacts with the sciences take place in secondary education, since the attitudes and interests of the students will already have begun to form.

Purposes of Science Teaching in Primary Education

Taking into account the above, the sciences must be present in Primary Education because it helps the children to:

I. *Contribute to the understanding of the world around them*:

Considering understanding as a developing mental structure that changes as the child experience expands.

II. *Develop ways to discover things, check ideas and use tests*.

Children's way of interacting with things around them supports their learning, not only in science, but also in other areas.

III. *Instituting ideas that help, rather than hinder, the later learning of the sciences*.

This does not mean that we must begin to learn the concepts of secondary scientific education in primary education, but to encourage exploration and research directed in such a way that the peculiar ideas of children can be called into question.

IV. *Generate more positive and conscious attitudes about science as a human activity; instead of unconsciously reacting to the popular image about it*.

Children need to experience scientific activity themselves at a time when their attitudes towards them are formed, which can have important influence for the rest of their lives.

2.3. Science for all.

One of the aspects in which there is a great consensus today is that scientific education must reach all students. The expression "science for all", which has become the current slogan, began to be used in the late 1970s as a reflection of the results obtained with the teaching of science and the analysis of the growing influence of science in society. The conclusions of these reflections established two important starting points for the renewal of scientific education:

❖ *It is not good to make an early difference between a science for a few and the kind of science that will be worth to the rest.*

"Scientific education is for everyone - not just for those who have the potential to become scientists, technologists or technicians. Everyone has the right to understand and take part in processes for solving problems of everyday life that need the knowledge and disciplines of the science course, therefore, it is an essential component of the curriculum of every boy and girl until the end of compulsory school. "

(Department of Education and Science- DES, England, 1977)

❖ *Science must be re-examined and recognized as a source of human activity and endeavor. Consequently, it is necessary to emphasize a series of aspects to introduce them pedagogically in the curriculum and contribute to a significant learning for the greater part of the students.*

"... Anyone needs a certain understanding of Science, its possibilities and limits whether or not scientists or engineers. This improvement is not a luxury, it is of vital importance in the future welfare of our society... "

(Royal Society, 1985a)

"Understanding (science) includes not only the facts of science, but the method and its limitations, as well as the estimation of its practical and social implications"

(Royal Society, 1985b).

The principle of "Science for all" should not only be understood as the introduction of science between the disciplines of the compulsory curriculum, but also involves a change in its contents and in the ways of presenting itself to be accessible, attractive and useful for all the students (Gutierrez et al., 1990). In fact, the objectives of science education must be at least twofold:

A. The acquisition of a certain degree of knowledge that we usually call "basic scientific knowledge" and "do not refer to the detailed knowledge of concepts such as those that come in textbooks of physics, chemistry, physiology or genetics but rather, to the understanding of what could be called "the scientific approach" or the scientific way of knowing... "(Ayala, 1996).

B. The awareness of issues of great relevance and importance, in which aspects such as the importance and the power of science and technology in determining social changes or the weight of public opinion in making of decisions in a democratic society.

"The aim of scientific training... will be to form scientifically literate individuals who understand how Science, Technology and Society influence each other, who will be able to use knowledge in decision-making in their daily lives. The person scientifically prepared must have sufficient knowledge base on the facts, concepts, conceptual

structures and skills that allow him to continue learning logically. This person will be able to appreciate the value of Science and Technology and understand its limitations. "

(NSTA, 1982).

Starting from these ideas it is necessary to follow a path of successive concretions until arriving to define specific guidelines to guide the work in the classes of sciences.

In this sense, "science for all" can be understood in at least two different ways:

1. All children should study some science, although this science may differ substantially from one school to another, and from one individual to another.

2. To provide the same science curriculum for all children; in other words, a common and compulsory curriculum for all students and all schools.

At present in our country has opted for this second, proposing a science curriculum that suits the needs, interests, aspirations and abilities of all children. However, this implies that the educational system should seek ways to provide:

- A basic science education for all

- An adequate basis to achieve the high levels for those who are scientifically more prepared, and we must expect more succes from them.

In short, the "science for all" approach must respond to the different needs that students may have in their daily lives, which could be summarized as:

- Preparation for the active exercise of the role of citizens of a democratic society, a society in the key of science and technology and in mutual dependence with them.
- Preparation, general and specific, for the development of professions that require a scientific-technological qualification at different levels.
- Training to be a user of science and technology and all the possibilities they offer.

2.4. Scientific and technological literacy for all people.

A century ago, literacy was raised in terms of learning to read and write, and it was a vindication of the working class that the rest of society viewed with good eyes. According to Fourez (1994), all found in it certain advantages. The businessmen because it provided a more prepared workforce. The workers because they considered it the key that opens the door to emancipation.

In developed societies literacy is considered an unquestionable good and necessary for the promotion of human dignity.

However, the demands of the new educational challenges for the 21st century make the previous literacy insufficient, and prevent the need of a different literacy to respond to the demands of today's society, so called scientific and technological literacy.

With the same unanimity with which literacy related to reading and writing was accepted at the time, the need for scientific and technological literacy for all citizens is now accepted. In fact, it is considered that some familiarity with the sciences and the technologies is essential to carry out the functions of a average citizen in the world of today. The level of public understanding of science, the dialogue about science, society and the directions of social change originated by the application of new technologies are considered to be determinants of democratic participation, (Marco, 2000).

Awareness has been opened that, if education is not acted upon properly, a type of "scientific-technological illiteracy" will be consolidated, extended to large sectors of the population and related to the inability to understand current issues of great importance, and to set their own postures and attitudes before them. These are crucial problems that will ultimately affect the model of democratic society, and even the future of persons on the planet, whose sphere of decision is democratic and social.

But *what is a scientifically and technologically literate individual?*

For Zoller (1992), it is considered that an educated person is

A thinking person, able to make decisions independently and based on their analysis and reasoning. He is a curious individual, interested in learning, capable of acquiring information and of informing, capable of handling himself in a wide sphere of knowledge and considerations. An individual who has interpersonal skills, moral principles and values, respect others especially those who are different, and understands the rights and responsibilities of the individual within the family, the community, the nation and the world.

2.5. New trends in Science Education.

Values and Attitudes in Science

The educational system has undergone a paradigm shift. While in the century XX was oriented fundamentally to the cognitive development and the acquisition of knowledge; actually it is considered the need to conceive the human being as an cognitive, affective and moral aspects that interact permanently with the environment. For that reason, education takes on an increasingly integral role and the current crisis of values makes revise the role of teachers and the objectives of the education system.

Remind that:

❖ The purpose of education is to form responsible and critical citizens, which implies educate on values.
❖ Education in values has a transversal carácter

❖ Values are defined in rules, whose compliance creates favorable attitudes

Therefore, the current curricula include within the current contents the promotion certain values and attitudes, and their acquisition will help future citizens to think, do, act, coexist and be responsible and critical. In relation to scientific education, the current tendency is to distinguish between:

- *Attitudes towards science*, with a strong affective character, related to feelings and views on science and its learning and which have a direct impact on the student performance (Palacios, Del Moral and Varela, 1996).

- *Scientific attitudes* are those that (without being exclusive to science) underlie the most outstanding features of scientific endeavor, such as curiosity, honesty, skepticism, objectivity,... In the field of school science, are understood as predispositions to interact in a certain way with the activities involved in the sciences. Thus, attitudes towards the use of evidence are important, before the creation and revision of ideas, flexibility and openness of mind and treatment of the environment in certain ways.

Promotion of Competences

At the end of the twentieth century, it is recognized that meaningful knowledge student as an active agent in their own learning, thus appearing the concept of competition. Competences are the ways in which a person uses all his resources (knowledge, skills, attitudes and experiences) to solve adequate and satisfactory task in a defined context. In this sense, we can talk of a competent person, capable of satisfactorily solving a problem.

The key competences are those that the current societies demand to the individuals who live in it. The European Union defines eight key competences and the LOE. establishes eight core competences.

A normative definition of key competences can be found in the Real Decreto 1513/2006 (Anexo I, p. 43058) y en el Real Decreto 1631/2006 (p. 685) defines:

"The basic competences would be those that must have acquired every person at the to finish the education stage, are those learning that are considered essential, from an integrative and oriented approach to the application of acquired knowledge, and there its basic character. The basic competences are those that must have developed a young or young at the end of compulsory education in order to achieve their personal fulfillment, to exercise active citizenship, to enter adult life satisfactorily and to be able to to develop lifelong learning." (Translation from the law)

The LOE does not relate each competition to a particular area or subject, but all they contribute to the development of the different competences and, in turn, each of the competences will be achieved as a result of work in several areas or subjects. In other words, competences are transversal.

Key competences are one of the elements of the curriculum of the obligatory stage, perhaps the most important or vertebrate, since the purpose, the tendency of education, is to get our students to learn to be truly competent in the challenges they face.

In the current educational model education is the engine of change in society, so the teachers aspire to transform the students in persons who can think and act to achieve a better world, but the question could be…How? Answer is easy…Through the acquisition of skills.

In scientific education, which is provided in the area of Knowledge of the Environment, the most directly related basic competence is knowledge and interaction with the physical world. We must educate to achieve competent students, through the acquisition of knowledge, procedures, attitudes, ways of thinking and acting, to enable them to achieve the scientific and technological literacy in order to live, act and improve society, but again… How? Through changes in the approach or vision of science teaching, incorporating the social and emotional dimension of knowledge and working on a model based on the transversality. And how can we concretise it in praxis? Through the restructuring of the curricula and their presentation in the design of the didactic units.

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