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Chapter 2. Science Education. New Trends in Science Education

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

2.1.1. What does “Didactics of Experimental Sciences” mean?

To define “Didactics of Experimental Sciences”, we need to know the meaning of “Didactics” and “Science” separately. On the one hand, Didactics is a theoretical-practical education discipline, whose object of study is the teaching-learning processes. On the other hand, if we are going to study the teaching and learning processes of Sciences, it is necessary to delimit beforehand what is Science and not. Mostly, we need to delimit which fields of knowledge fall within what is called “Experimental Sciences”.

The classification of science is not without controversy and is always subject to review. **Science is as a set of knowledge about the Universe to explain and interpret it.** The corresponding part of the Universe constitutes its “field” or “object of study”. Accordingly, **one way to classify science is to look at its “field” or “object of study”.** Thus, for example, the natural sciences seek to develop scientific knowledge about different natural phenomena (movement, light and sound (physical phenomena); 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)).

Another way to classify the sciences is to look at methodological criteria, that is, the way to approach the problems and to work. Its name, “Experimental Sciences”, shows the critical role that experimentation plays in its ways of investigating reality. Traditionally **the Experimental Sciences have been divided in Physics, Chemistry, Biology and Geology.** However, scientific disciplines are becoming more specialised and divided, creating new disciplines with objects of study or working methods from more than one of the classical disciplines (e.g. Biochemistry, Astrophysics, Geobotany, Biophysics, Physicochemistry).

Therefore, **the Didactics of Experimental Sciences is the education discipline dedicated to the study of the Experimental Sciences teaching-learning processes.**

2.1.2. Fields of action

The field of action of the Science Education will be all where the processes of teaching and learning of the Sciences take place. In the specific case of Spain, the current educational system (**formal Education**) includes:

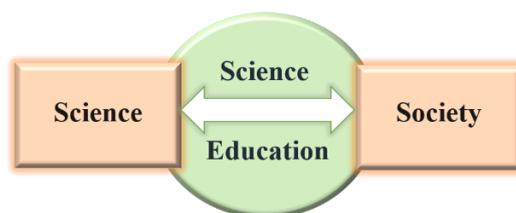
- ❖ **Compulsory Educations:** Primary and Secondary Schools.

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

However, today, there are other sources of information in the formation of people, which, in some cases, can be more valuable and impact for students. Thus, science education has accepted the so-called “**non-formal education**” as a logical process to carry out learning of Science, among which they stand out:

- ❖ **Museums** and Science Centres, Scientific Clubs, ...
- ❖ **Media: Internet**, television, newspaper, movies, ...

Another essential aspect in the field of action of science education is to clarify the scope and meaning of its object of study: “the teaching and learning processes of science”. The focus changes a lot if, for example, we reduce its objectives to the transmission of scientific knowledge or if we expand them to include other formative aspects, such as the development of skills and attitudes. Some authors, such as Yager (1985), propose a broad view of the domain of science education, considering it as an interface between Science and society:



This approach involves to attend and include new objectives in science education 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, namely, **the CTS (Science, Technology and Society) approach**. It seeks to bring students closer to problems in which there is an interaction between Science, Technology and Society.

2.2. Objectives and purposes of science education in primary Education.

2.2.1. Contributions to general educational purposes

The inclusion of any curricular area in Primary Education aims to contribute to the achievement of the general objectives of the stage, “...*contribuir al pleno desarrollo de la personalidad de los alumnos y las alumnas, a su preparación para participar activamente en la vida social y cultural y a la compensación de las desigualdades sociales.*” (Artículo 2 del

Decreto 105/92 por el que se establecen las enseñanzas correspondientes a la Educación Primaria en Andalucía). In this sense, can science education make contributions to general and valuable educational purposes? In 1983, UNESCO issued the following statements on the incorporation of science and technology in primary school (Harlen, 1989):

- I. The sciences can help children to think logically about everyday events and to solve practical problems. Such intellectual techniques will be valuable to them wherever they live and in whatever work they do.
- II. The sciences, like thought, can promote the intellectual development of children.
- III. The sciences can help children positively in other areas, especially in language and mathematics.
- IV. Science and its technological applications can help improve people's quality of life. Science and technology are socially useful activities that we hope will become familiar to children.
- V. Future citizens must prepare to live in a world more and more oriented in a scientific and technological sense.
- VI. Many children drop out after primary school, which is the only opportunity they have to explore their environment logically and systematically.
- VII. Science in primary schools can be fun. Children are always intrigued by the simple problems, whether invented or real, of the world around them. If science education can focus on these problems by exploring ways of engaging children, no subject can be more appealing or exciting to them.

2.2.2. Need for scientific Education in Primary Education.

We can highlight some important aspects related to the need for early science education in the training of students. These aspects derive from well-established research, and therefore can be reasonably rigorously accepted. Briefly stated is:

❖ Most of the children build their ideas about their world around 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.

Many studies of children's understanding of some scientific concepts have revealed that:

- a) Children focus on the themes of their science classes based on substantial 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, some of the scientific contents do not make any 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 cannot increase their skills in getting and dealing with information.*

In the past, the development of skills was produced independently of knowledge. However, recent studies show that the skills used by the students carrying out school activities depend on previously acquired ideas; which contradicts the previous assumption.

Nowadays, the idea of the influence of context on student learning is becoming a reality. To a certain extent, children can think and research “scientifically” when undertaking a social project or study a local history theme. However, their development of scientific thinking and research techniques will not be complete if school activities do not include research on their physical environment and nature from an early age.

❖ *Children form their attitudes toward Science 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 attitudes regarding scientific activity. It seems that this will be more difficult if the first contact with the sciences take place in secondary Education since the attitudes and interests of the students will already have begun to form.

2.2.3. Purposes of Science Education in Primary Education

Sciences must be present in Primary Education because it helps the children to:

1. *Contribute to the understanding of the world around them:* Considering understanding as a developing mental structure that changes as the child experience expands.

2. *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.
3. *Instituting ideas that help, rather than hinder, the later learning of the Science:* This does not mean that we should start learning scientific concepts from secondary education in primary education, but instead that we should encourage students to question their initial ideas about certain scientific concepts.
4. *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 some point when they start to form their attitudes towards them, which can have significant influence for the rest of their lives.

2.3. New trends in Science Education.

2.3.1. Science for all

One of the aspects in which there is a high consensus today is that science education must reach all students. In this sense, the concept of "science for all" emerged as reflections of science education and the science's influence in society. The conclusions of these reflections established two essential starting points for the renewal of science education:

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

"Science 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 recognised as a source of human activity and endeavour. Consequently, it is necessary to emphasise a series of aspects to introduce them pedagogically in the curriculum and contribute to significant learning for the greater part of the students.*

“... Anyone needs a precise 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” is not only the introduction of Science between the disciplines of the compulsory curriculum. It also involves a change in its contents and in the ways of presenting itself to be accessible, attractive and useful for all the students (Gutiérrez et al., 1990). 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. To promote awareness of aspects of great relevance and importance, such as the power of science and technology in determining social changes or the weight of public opinion in decision-making in a democratic society.

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 that 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 standard 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, it implies that the educational system should seek ways to provide:

- 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 success from them.

In summary, the “science for all” approach must respond to the different needs that students in their daily lives as:

- ❖ To prepare them for the active exercise of the role of citizens of a democratic society, a society in the key of Science and technology and mutual dependence with them.
- ❖ To prepare them for the development of professions that require a scientific-technological qualification at different levels.
- ❖ To train them to be a user of Science and technology and all the possibilities they offer.

Primary Education is a critical stage that aims to develop the same skills in all students and ensure access to essential contents in our social culture. Therefore, it is necessary to introduce specific mechanisms that make accessible to all students the essential cultural product (in this case, the scientific contents), namely, **attention to diversity**. Teachers must be aware of possible differences among their students and their habitual use as reasons for their different performance and attitudes to learning. Teachers should articulate the attention to the diversity as mechanisms for adjusting the pedagogical offer to their abilities, interests and needs. In this sense, it acts as a corrective element of possible inequalities in the conditions of access to scientific knowledge and, at the same time, an instrument to increase efficiency, adjusting teaching as much as possible to what students can learn at each moment.

2.3.2. Education of citizens, Science and society

Science education is part of a General Education linked to the social, economic and political reality of the moment. Education must be an integral education that provides knowledge and ways of thinking to achieve a better life. Therefore, **science education must provide knowledge and ways of thinking that allow us to address natural phenomena and scientific-technological progress through the formulation of questions and with a critical and constructive spirit.**

To describe and analyse the new trends in science education, we must consider that our current society is dominated by economic relations, which leads to social injustice and ecological unsustainability. This reality affects science education, which must change teaching and evaluation to respond to the challenges of building a new ethic, a new style of thinking and new ways of acting to solve the mentioned problems. It will allow us to acquire a creative and active vision of life at the individual and collective level, necessary to address the

challenges of today's society. In other words, education and science education must participate in the formation of citizenship.

a) Building a new ethic

Science education can and must provide elements to solve or alleviate these problems. How? Through educational models that promote the ideas of dependence, equity and rejection of uniformity:

- Dependence: living beings are interdependent from each other (basic concept for ecological sustainability)
- Equity, a fundamental concept for solidarity justice
- Rejection of uniformity, promoting alternatives of social organisation based on self-sufficiency and that allows the preservation of cultural identity

b) Construction of a new style of thinking

Science education must abandon the framework of deterministic thought, which fragments phenomena into parts and replaces them with a systemic vision, which allows the whole to be related to the parts and vice versa, to understand and solve the interconnected global problems of our society. It promotes a scheme of thought to reflect on these points in the primary stage:

- Dialogue between natural sciences and social sciences, to address the human relationship with nature and social organisation
- Promote the integration of the parts of the sciences, key to a systemic vision of Education, abandoning disconnected and summative approaches
- Strengthening the concepts of complementarity (abandoning the concept of antagonism)
- Integration of knowledge and feeling, Science and art are human constructions that follow different rules, but both activate creativity; Science is not in opposition or divergence with art. An example would be the identification of concrete forms in nature and in human constructions that follow the same pattern.

c) Construction of a new transforming action

Scientific Education must provide tools and skills such as critical thinking, reflection and participation, which enable decision-making, transformative actions at the individual and collective levels and promote change. This option leads to a school model that favours

socialisation, the non-imposition of uniform models, and the search for alternative models (for which reflection and analysis are necessary first).

2.3.3. Experimental Sciences and Transversal Subjects

The so-called transversal topics refer to educational elements integrated into the different areas and the society demands. Their name has evolved in the regulations. Currently, instead of transversal topics, we talk about transversality or transversal character to allude to educational elements (contents, values, attitudes) dealt in more than one area, and not only in one. The current educational model advocates a concept of transversality that goes beyond multidisciplinary integration:

- ❖ Fosters a school model to allow an integral formation of students and the development of all their abilities.
- ❖ Implies the social dimension of knowledge, schools must take into account the external reality and educate to live and act in it, promoting a critical and constructive spirit through Education in values.

A simple definition of transversality or transversal topics goes beyond elements or aspects integrated into all curricular areas, to their summative incorporation or interdisciplinary integration. In definition, transversal topics are a set of elements or aspects that should permeate all educational tasks, with a strong attitudinal character, not associated with specific contents and which entail changes in the development of educational actions and the concept of educational centre (Pujol, 2003).

Transversal character: The contents do not appear associated with any area of knowledge, but with all of them, and in all their prescriptive elements (objectives, contents, key competences and evaluation criteria).

Social relevance: The issues or problems that integrate the transversal contents have an important social significance. All environmental issues, as well as those related to health, peace, solidarity, consumption, new technologies..., are consistently being demanded by society to be incorporated into educational action.

Value charge: The student must not only ask and analyse the mentioned questions, but above all, to acquire individual attitudes about them, and to develop specific behaviours based on freely assumed values. The transversal contents suppose an opportunity to globalise teaching and to carry out correct interdisciplinary programming. From this perspective, learning related

to transversal contents contributes significantly to Education in moral and civic values, to the integral formation of students.

2.3.4. 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; it is considered the need to conceive the human being as 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 character.
- ❖ The rules define the values; whose compliance creates favourable attitudes.

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

- *Attitudes towards Science* are related to feelings and views on Science and its learning. They have a robust affective character and a direct impact on student performance (Palacios, Del Moral and Varela, 1996).
- *Scientific attitudes* are related to the most outstanding features of scientific endeavours, such as curiosity, honesty, scepticism, objectivity. They are not exclusive to science and show a willingness to interact in some way with the activities involved in science. Thus, attitudes towards the use of evidence are essential, before the creation and revision of ideas, flexibility and openness of mind and treatment of the environment in specific ways.

2.3.5. Promotion of Competences

At the end of the twentieth century, students are active agents in their learning of significant knowledge, thus appearing in the concept of competence. Competences are how a person uses all his/her resources (knowledge, skills, attitudes and experiences) to solve a task in a defined context adequately and successfully. 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 seven competences. According to the Real Decreto 1513/2006 (Anexo I, p. 43058) y en el Real Decreto 1631/2006 (p. 685) the normative definition of key competences is:

“Las competencias básicas serían las que deben haber adquirido todas las personas al finalizar la etapa educativa, son aquellas que se consideran esenciales, desde un enfoque integrador y orientado a la aplicación de los conocimientos adquiridos, y que tienen un carácter básico. Las competencias básicas son aquellas que deben haber desarrollado un joven o una joven al final de la educación obligatoria para lograr su realización, para ejercer la ciudadanía activa, para entrar satisfactoriamente en la vida adulta y para poder desarrollar el aprendizaje permanente.”

The LOE does not relate each competence to a particular area or subject, since all of them contribute to the development of the different competences and, in turn, the result of work in several areas or subjects will be the achievement of the competences. In other words, **competences are transversal.**

Key competences are one of the elements of the curriculum of the compulsory 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? The answer is easy: **through the acquisition of skills.**

2.3.6. Scientific and technological literacy

A century ago, literacy raised in terms of learning to read and write, and it was a vindication of the working class. According to Fourez (1994), everyone found certain advantages. The employers because it provided prepared workers. The workers because they considered it the key that opens the door to emancipation. In developed societies, literacy is considered necessary for the promotion of human dignity. However, the demands of the new educational challenges make the previous literacy insufficient and prevent the need for a different literacy to respond to the demands of today's society, so-called **scientific and technological literacy.**

Nowadays, everybody accepts the need for scientific and technological literacy for all citizens with the same unanimity as before. A certain familiarity with Science and technology is essential to perform the functions of an average citizen in today's world. 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 determinants of democratic participation, (Marco, 2000). We can think that if we start from an inadequate performance in Education, we can reach “scientific-technological illiteracy”. Also, this will reach a large population and will be related to the inability to understand current issues of great importance and to expose their positions and attitudes towards them. However, *what is a scientifically and technologically literate individual?* For Zoller (1992), 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 full 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.”

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