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SCIENTIFIC LITERACY AT THE SCHOOL

Scientific literacy at the school: a proposal of a new methodology

Scientific literacy at the school: improving strategies and building new practices of science teaching in early years education (SciLit)

2016-1-ES01-KA201-025282

The joy of reading the first stories, finding the first friends and making our first discoveries as true scientists, will be part of the memories that remain attached to the name of our first friends and our first teacher.

All the partners of this SciLit Project.

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Scientific literacy at school: a proposal of a new methodology

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INTRODUCTION

INTRODUCTION

This work is the result of a close collaboration between the eight partners of this program, from five European countries, with their different values and cultures, working methods, needs, etc. This plurality reinforces what unites scientists and teachers: the love for knowledge, that both groups create and transmit in a common intellectual space that exceeds any type of borders. We want to thank this team of professors and scientists for their perseverance and interest in innovating throughout the project, reflected in the educational activities of the teachers and the pedagogical applications that they have carried out in their schools.

Structure of the document

The document has been structured into four parts.

The first part presents **A New Concept of Scientific Literacy**, considering the challenge of new technologies and their influence at school. After this reflection, we outline our proposal of the new didactic method carried out in this project.

The second part, **Scientific Competence of Teachers in the Countries of the Project**, analyzes the different educational systems of these countries in relation to the scientific competence of their pre-service and in-service teacher, in account of the initial training of the educators and the subsequent continuous training they receive. This analysis will allow us to reflect on the coincidences or divergences in the participating countries, to take into account when implementing the new methodology.

The third part**, A Proposal to Improve the Learning of Science in Early Stages**, presents a historical introduction of the methods of teaching science used in the near past, as well as the description of the new methodology with which the *CSIC at School* has trained teachers for many years. This proposal is developed in two specific cases: *What is the World Made of* and *Archeology in the Classroom*. We also include a study on the ideal social context for science teaching, framed in the European Cultural Heritage.

The fourth point, **Recommendations to Improve Scientific Learning at a Young Age**, contains a final analysis and a meditation with suggestions and recommendations to Improving the Teaching of Science in School, considering it as a real ingredient of the common European Cultural Heritage.

FIRST PART

A NEW CONCEPT OF SCIENTIFIC LITERACY

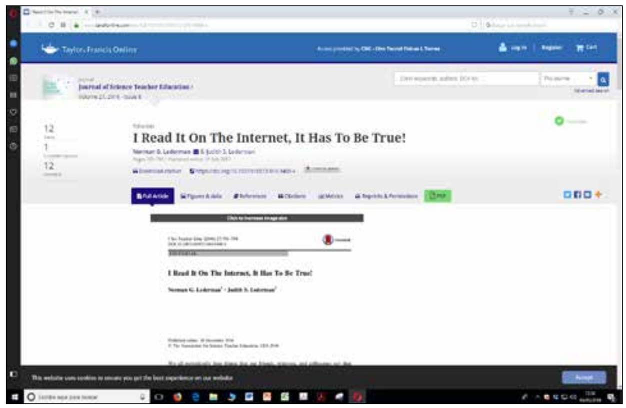
1. A NEW CONCEPT OF SCIENTIFIC LITERACY

1.1. SOCIAL PERCEPTION OF SCIENCE IN EUROPE: SCIENTIFIC LITERACY

The age of information

One of the hallmarks of today's society is the ease of access to information although, unfortunately, neither its didactic quality nor veracity is always guaranteed. This feature becomes important because even well-educated people have not yet abandoned what we might call the *power of the written word*, which is transferred into this digital age associating respect and credulity to the documents available on phones, tablets and computers. This prestige constitutes a relic of the past times (although not very distant) and of our first years of education, when the learning is done using books whose information is very well controlled. For this reason, teachers have no need to develop in the students a strong critical spirit, unnecessary when using schoolbooks but essential when surfing the Internet, full of dangers due to the interests of individuals, national governments and companies.

Nowadays, as everybody knows, the situation in the schoolroom concerning information is quickly changing, as the age at which children access Internet connections gets lower. Although surfing is necessary, both to master this tool and to look for useful information, children expose themselves to ideas and messages that are well beyond their readiness. In this sense, we think significant the study of Lederman and Lederman[1], which reveals the effect of the new credibility for the Internet and the undesirable effects it may produce in the formation of citizens. According to this article, the PEW reports[2] indicate that no less than 50% of citizens believe in spiritualism, 40% in astrology, 45% in ghosts and 30% in witches.



I read it in Internet, It has to be true!

For these reasons, in our society of webs and social network, the development of critical spirit is of paramount importance. But this critical spirit needs a wealth of previous knowledge, well established and impregnated with ethical values, impossible to acquire in a self-taught way, even less by simply surfing the Internet. This brings us to a situation reminiscent to the *Golden and graceful loop* of the type described by Hofstadter[3] from which we need to find a way out, as both, Internet and social networks, have come to our lives to stay for a long time.

[1] Lederman, N.G. & Lederman, J.S., 2016. *I read it in Internet, ¡It has to be true!* USA: The Association for Science Teacher Education. 27:795. Availible online at: <https://doi.org/10.1007/s10972-016-9488-x>.

[2] Pew Research Center. [online] Availible at: <http://www.pewresearch.org/>.

[3] Hofstadter, Douglas R., 1987. *Gödel, Escher, Bach: an eternal and graceful loop. Gödel, Escher, Bach: An Eternal Golden Braid*. New York, USA ©1979: Basic Books, Inc.

The need of scientific knowledge in society

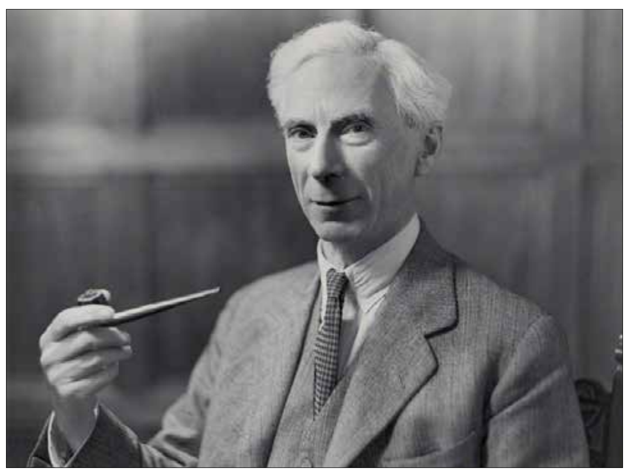
On the other hand, although it may seem a contradiction, this society of knowledge accepts that development of science and technology results in economic development and social progress. This belief rises the interest of the population on scientific knowledge (to be found mainly in Internet), even if its descriptions are understood only in a superficial way.

To simplify things, in this guide we will refer to mathematical knowledge, engineering, science and technology under the generic name of *Science*, since it is impossible (and even useless) to try to distinguish their effects on the history of science, as impossible as to make the society perceive them as different.

Another characteristic of democratic societies is the need for citizens to have the scientific understanding necessary to discern between the different options that technology could present to them, among which they must choose with their votes. Nuclear, solar, wind, geothermal and fossil fuels power, animal cloning or the use of transgenics in agriculture are examples of the level of issues on which voters must develop an opinion.

At a higher level of understanding, citizens must be aware not only of the characteristics of these technologies but also of the *Dynamic relationship between Science and Society*: on the one hand, the technologies you decide to apply determine the type of society you choose to live in, and, on the other, the type of society chosen influences the development and investments on Science and Technology. For this reason, it is imperative for the citizenship to be prepared with suitable scientific knowledge which allows them to know and decide among different proposals in democratic regimes. In words of Bertrand Russell, a thousand times cited, democracy is necessary but not sufficient. This ability to understand science deeply enough to make up your own opinion about different issues, received in the United States, in the mid-twentieth century, the name of **Scientific**

The debate on nuclear energy is always present in society.



Bertrand Russel, British philosopher, mathematician, logician and writer.

literacy. This concept, although never well-defined despite the various attempts[4] quickly spread throughout the western world, being nowadays found everywhere. At this respect we will propose a new working-definition a little further (according to the way humans learn), that we will develop in the third part of this guide and that is the central outcome of this project.

Science and humanities

The communication between the world of science and the society, whose beginnings we must seek in the French Encyclopedists, increased by the middle of the nineteenth century under the initiative of the great scientists of that time. These activities mark the birth of science popularization.

This permeation of both worlds began to decline at the beginning of the twentieth century, in the period between the two world wars, mainly due to the extinction of the ninety ninth century *savant*, being substituted by the more successful *specialist*, with a deeper knowledge but too limited in extent to attract the public interest. This situation changed again in the middle of the twentieth century with the introduction of perfunctory science education in the school and the resurgence of the scientific interest, as a response to the Russian satellite Sputnik in 1957, at the beginning of the Cold War.

The citizens should understand and be prepared to expend funds lavishly and to make continuous investments to remain as the first world power all along the Cold War,

The space race during the Cold War.

one of whose fronts was the space race. Simultaneously to the science popularization emerged a pure intellectual movement, whose purpose was the integration of science in what had hither to been called cultural inheritance.

A few years after the launch of the first satellite, what we could take as the *Manifesto* of the new current of thought appeared: The Conference of C.P. Snow on *The two Cultures*[5]. This new idea in which the frontiers between sciences and humanities should disappear, is increasingly permeating the intellectual society to such a point that at present it is unthinkable to explain a historical (or prehistorical) situation or phenomenon without taking into account the role of scientific knowledge at the moment.

These ideas extended to other countries, addressing policies that support science popularization in the European Union, as reflected in the **Horizon 2020 program** (2014

[4] Holbrook, J., Rannikmae M., 2009. The Meaning of Scientific Literacy. *International Journal of Environmental & Science Education*, Vol.4, Nº3, pp. 275-288. Availible at: <https://www.pegem.net/dosyalar/dokuman/ 138340-20131231103513-6.pdf>.

[5] Wikipedia. The free enciclopedia. *The two cultures*. [online] Availible at: <https://en.wikipedia.org/wiki/The_Two_Cultures>.

to 2020) and in the European Commission initiative, *Europe needs more scientists*.

The aim of these actions is to increase European competitiveness supported on three pillars: *Excellent science, industrial leadership and social challenges*, as contemplated in Science *with and for the Society* (SWAFS)[6].

The world is flat

As we live ourselves in a *flat world*[7], thanks to the lack of borders and slopes up in communication, the impact of any increase in scientific knowledge is immediately transmitted, being able to modify the socio-economic scenario of any country unprepared for the appearance of new technologies. For this reason, students should receive a sufficiently broad education to allow a rapid adaptation when confronted with innovation.

To ensure that the results derived from research and technology anywhere abroad can be of advantage for our own European society, researchers, citizens, politicians, organizations, companies, etc. must work together. This is what is called RRI (Research and Responsible Innovation). In this context, the aim of *Science with and for society*[8] is to promote the understanding of the RRI with a high citizen participation in science, to not staying behind of possible future developments.

Another objective refers to making scientific and technological careers attractive for students of any gender, as well as to promote the interaction between schools, research centers, industry and other organizations. *Europe needs more scientists*[9] is an initiative of the European Commission to increase the number of scientists in Europe highlighting, among many other issues, the importance of the primary school stage for achieving that goal. The European Union, in the Report of the European Parliament and the Council on the key competences for lifelong learning includes mathematical competence and basic skills in science and technology in line with the primary curricula of the countries of the European Union[10], some of which will be discussed in this guide. These objectives, from our own perspective, *can only be accomplished by introducing science in the early stages of education*. We will deal with this issue later on.

From the early stages of education, scientific vocations can be encouraged.

[6] European comission. *Horizon 2020*. Availible at: <https://ec.europa.eu/programmes/horizon2020/>.
[7] Friedman, T. L., 2005. *The world is flat: A brief history of the twenty-first century*. New York: Farrar, Straus and Giroux.
[8] Comisión Europea. *Horizonte 2020*. Disponible en: <https://ec.europa.eu/programmes/horizon2020/en/h2020-section/science-and-society>.
[9] *European Comission Press Center.* Disponible en: <https://ec.europa.eu/research/press/2004/pr0204en.cfm>.
[10] Confederation of Scientific Societies of Spain. 2011. *ENCIENDE Research. Teaching of sciences in school didactics for early ages in Spain*. Availible at: <www.cosce.org/pdf/Informe_ENCIENDE.pdf>.

Social perception of science

Returning to the relationship between science and society, during the Cold War the social perception of science was greatly affected by projects such as atomic and hydrogen bombs, as well as by other military projects. As a result, ethics was introduced into debates about science, which led to fears of the effects of a negative image of science: the reduction of funding and scientific vocations among young people, which could affect the results of research and, therefore, productivity.

As a result, analyses of the social perception of science were introduced and developed based on the studies of consumer patterns developed and applied in the United States some 50 years ago. Nowadays, these tools have been adapted to measure public attitudes toward science as well as the social perception of the science, in the way this term is currently used. In Europe the Eurobarometer respond to the same aims.

In terms of scientific knowledge, the results of this measurement present an uneven situation in European countries, with Denmark and the Netherlands in the top positions of scientific knowledge, and Spain, Italy and Poland in the lowest levels.

To present a case study, the results of the social perception of Science of the Spanish Foundation of Science and Technology (FECYT) reveal a worrisome fact: 59.8% trust in acupuncture and 52.7% trust in homeopathic products. What is worse, people with higher levels of education rely more than average on these practices whose effectiveness has no scientific evidence. (Survey of social perception of science FECYT 2016). This indicates that something is not right.

For all these reasons it is necessary to reflect on how to increase the scientific culture of Europeans.

1.2. The purpose of this project: an outstanding revolution in attaining scientific literacy as a school's mission

Scientific literacy

As we said above, the term *scientific literacy* first appeared in the American press in 1957, right after the launching of the Sputnik, and became a current term since the economic boom in Japan, in the '80s. From that moment onwards, it was considered that democracy needed a citizenship that understood the scientific and technological problems, so that they could choose among the different proposals presented by the different political options, and national institutions began to discuss what really the meaning of scientific literacy was, and how could it be appropriately defined and imparted.

Initial definitions identified scientific literacy with scientific knowledge, beginning what can be called the *benchmark period*[11]. Its objective was to establish guidelines on *what a citizen should know* to be considered literate. And during the following years, the amount of contents you should learn to become literate increased non-stop, to the point of becoming ridiculous. Soon enough it became clear, as we shall see in the third part of this guide, that benchmarks were not a suitable way nor to attain neither to measure the desired degree of literacy of a

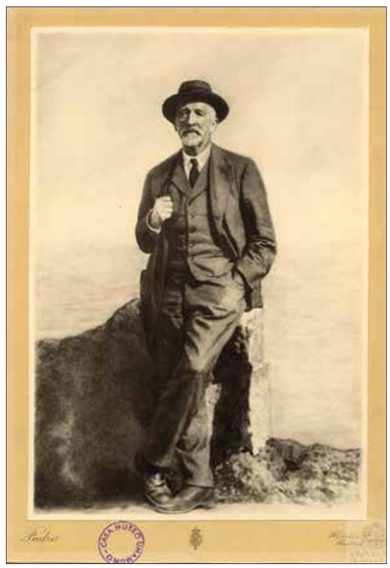
[11] American Association for the Advancement of Science. 1993. *Benchmarks for Science Literacy*. Oxford University Press.

citizen. Deeper and more practical definitions were needed.

And the American institutions entered a period we could call of definition, with a frantic production of descriptions of science literacy. To illustrate that we will consider two of the more relevant, correspondent to the beginning and the end of the definition period. The United States National Center for Education Statistics defines science literacy as *the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity*[12], while the OECD PISA Framework (2015) defines scientific literacy *as the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen*[13]. This model of scientific literacy, poorly defined, could only be poorly implemented[14]. Consequently, the search the perfect definition became a subject of big concern and deep reflection, becoming at the end of the '90s an important field of research[15].

How do we define scientific literacy in this project?

To define scientific literacy, we will follow the line of thought that leads to literary literacy, beginning with the Reformation and extending for a long period that lasts until the end of the XIX century. The goal of literary literacy is to provide students with the necessary knowledge to read and write in their mother tongue, so that they can understand any type of writing and express their thoughts correctly. To illustrate this idea, we will adapt the words of Bartolomé Cossio about literacy to this particular context: *When all citizens not only know how to read, which is not enough, but have a desire to read, to enjoy and have fun, yes, to have fun reading, we will have achieved our purpose*[16]. The main contribution of Cossio to the definition of literacy is, obviously, the developing of a taste for reading and writing, the only way to master the language to a degree that allows to appreciate reading and enjoy writing. In the case of scientific literacy, although the concept is a bit more complex, we will follow the same the way of thinking. The objective is that students understand the way in which scientific



Bartolomé Cossío, president of the pedagogical missions.

[12] National Academy of Sciences, 1996. *National Science Education Standards (Report)*. National Academy Press.
[13] PISA, 2015. *Draft science framework*. PDF availible at: <http://www.oecd.org/callsfortenders/Annex%20IA_%20PISA%202015%20Science%20Framework%20.pdf>.
[14] Durant, J., 1994. What is scientific literacy? In: *European Review*, Vol. 2, Issue 1, pp. 83-89. DOI: 10.1017/S1062798700000922. Availible at: <https://www.cambridge.org/core/journals/european-review/article/what-is-scientific-literacy/D9FC3C75784F0E39327DD9A5533C8D39>.
[15] Abd-El-Khaalick et al. *Science Education*, Vol. 82, Issue 4, pp. 417-436.
[16] Jiménez-Landi, A., 1996. *La Institución Libre de Enseñanza y su ambiente: Período de expansión influyente*. Barcelona: Edicions Universitat.

knowledge is generated, how it is modified and what kind of mental representation is used. The new type of literacy must be taught in such a way to allow students to enjoy conducting experiments, extract laws of behavior from nature and design models, as well as read about science in general. Although it seems difficult for the layman, for a professional teacher of the early stages it is a relatively simple task once he is in possession of the necessary scientific culture, as we shall see later on.

What kind of knowledge do we have to teach our students?

The first question concerns the kind of scientific knowledge we havthesee to teach our students to meet our definition of scientific literacy; and the answer is: they must learn enough content, following the path marked by scientific inquiry, that allows them to unveil the structure and Nature of Science[17].

The Nature of Science answers the questions about the way in which we acquire, organize and modify scientific knowledge, the issues that appear in our definition of scientific literacy. Knowledge is acquired from observation and experimentation, after a process of identifying the relevant magnitudes. These magnitudes are suitable concepts for the description of the phenomenon (such as pressure, temperature, etc.) presenting the property of being measurable.

This is the first characteristic that delimits the limited part of the world susceptible of being studied by scientific methods: the part of the world formed exclusively by magnitudes. This requirement leaves out the most interesting part of the world, the one composed by beauty, justice, love, etc., too complicated to be treated by science.

The measurement of any magnitude always produces a number (sometimes more than one, as in vector magnitudes), always easy to handle by means of simple sentences or mathematical formulae, by means of which we enunciate the laws of nature. The principle of Archimedes is a magnificent example. These laws can lead to models, as the molecular theory or the standard model[18], which are always susceptible to be modified if later experimental results so require. This whole process corresponds to what we call the *Nature of Science*[19].

Teachers in Bydgoszcz counting drops (applying mathematics).

[17] National Research Council, 2000. *Inquiry and the national science education standards: a guide for teaching and learning*. Washington DC: National Academic Press.
[18] Frigg, R. and Hartmann, S., 2006 (revised 2012). Models in Science. *Standford Encyclopedia of Philosophy*, [online]. Availible at: <https://plato.stanford.edu/entries/models-science>.
[19] Lederman, N.G., 1986. *Understanding of students and teachers on the Nature of Science: a re-evaluation*. School Science and Mathematics, Vol. 86, pp. 91-99.

It is also essential that teachers know the basic ingredients of the physical world, a fairly limited number, as a matter of fact: energy and matter, space and time and, finally, information. All these ingredients are susceptible to be studied through measurements, since they are all magnitudes. In the same way that the disease cannot be studied without the patient, it is not possible to study science without locating it in the social context in which it appears and takes place. One of the most important points to consider a person as scientifically literate is his understanding of the interrelation between science and the characteristics of society at a given moment in history, both in the past and in the present.

Teachers experimenting in the first scientific training in Madrid.

How do we teach the Nature of Science in the schoolroom?

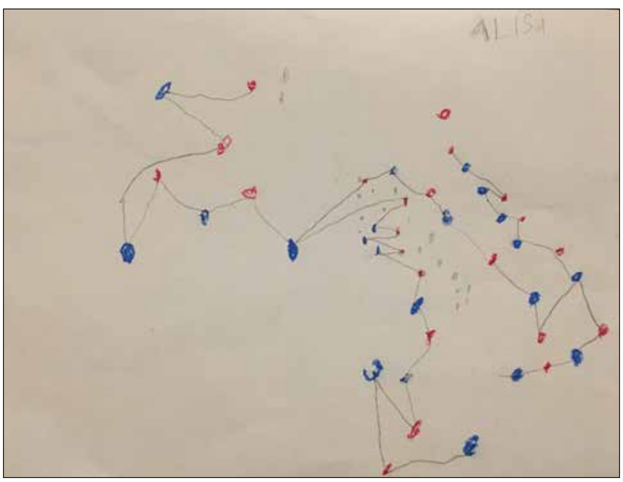
The second question is, how do we teach the Nature of Science to our students in the schoolrooms? As we all know, it is difficult (if not impossible) to define the meaning of a word or procedure without using a particular case as an example, and the method to acquire scientific literacy is no exception. Therefore, we will present an example in which we follow our method (CSIC) to achieve this, which has been in use all along this project.

We begin by following the evolution of a puddle or of clothes hanging out to dry. The first conclusion children reach is that *the water tends to evaporate*; the same will happen if we moisten the floor tiles with a mop or wet the surface of a glass. Students know from their experiences since they were babies, that things never appear or disappear; at most, they hide from sight. By putting this thought into words, they have achieved the first goal of any scientist, they have enunciated a law of nature, a true pill of knowledge.

With this law as a tool, after a process of meditation and following the inquiry method, they easily come to the conclusion that the water in the puddle or in the clothes *has had to pass* into the atmosphere, although in the

Children investigating on evaporation.

air it must stay under a form not visible for the human eye. Anyone who has played with a child knows that questions appear naturally. The only thing we must do is to guide his natural curiosity, as Plato tells us that Socrates did with the young slave of his friend Meno. We have verified that children over two and a half years accept the idea that water is in the air in the form of small particles, too small to be seen. In so doing, they have learned their first scientific model that allows them to imagine in their minds processes impossible to be seen but necessary to explain the fenomena that we actually observe with our eyes. As we shell show in the guides (*What the world is made of*), they easily became experts in handling the model, as demonstrated by the drawing they make in their laboratory notebooks. It is more than natural that they accept a name for those small particles, because they are accustomed to admitting names for unknown things, so, they will call these tiny particles by the funny name of molecules. Next, to practice using the model and get used to using it, we present them with the case of condensation occurring on a very cold soda can placed on a dish. On the surface of the can, initially dry, drops of water appear that slide towards the dish. They are asked to explain and represent in their notebooks what has happened, using the molecular model (or theory, as no difference between both concepts can be made at this level). Absolutely all children were able to describe and represent condensation applying their mental representation of water made of little molecules, also of water. And everyone enjoyed the process of evaporating water into the air and recovering it through the cold can. And everyone understood the need to modify or complete the first law: *water evaporates from objects at room temperature and condenses in cold surfaces* (Piagetian accommodation process). After



Representation of molecules by children.

Children observing the condensation and the representation of this phenomena in a drawing.

these warm-up exercises, the students easily understood the water cycle as an extension of the previous game (Piagetian assimilation), and imagine the molecules going from paddles to clouds and coming down again as water drops and so, they represented it in their notebooks. When students become aware of the process by which they understand phenomena with the help of mental models, the use of these models to explain new phenomena and how attractive and fun scientific research is, we can consider that they have acquired what we call *scientific literacy*.

This way of imagining the physical world in our minds by means of very simplified mental representations that we can use to solve problems, is not only the way in which humans build knowledge, but the only way we know how to do it. Artificial intelligence with all branches follows this same scheme.

What should teachers know?

Having demonstrated the innate ability of children to acquire scientific knowledge, we must reflect on the knowledge that teachers must have to carry out their work in the classroom. We will also have to design a method to assess teachers' knowledge and performance.

Teachers should be aware not only of the way scientific knowledge is elaborated from observation of natural phenomena and reproduction of this phenomena in our laboratories (experimentation), but also of the way this knowledge changes along the history of science.

This process, that can be considered as a social phenomenon in the society of scientists, was first studied by Kuhn in a process similar to the Piagetian construction of knowledge and will be mentioned later on.

The issue of the existence of a scientific method, THE METHOD, is an important point in teachers training. We have found out that, with very few exceptions, the existence of the METHOD appears as a misconception in the teacher's background. We must stress the importance of its deconstruction, in the sense given by Derrida (and Feyerabend) to the word. The reason of this misconception is the human desire of finding a method of generating knowledge *that guarantees* the truthfulness and validity of its findings through time.

First described by Bacon, it has been called the Scientific Method, its existence stayed among the teachers for some three hundred years. But this is no longer the case[20]. Bacon's method leaves astronomy out of the concept of science and dismisses the part of the physics developed using the famous Einstein's thought experiments[21] and the discoveries found by serendipity. As Feyerabend said, in science *anything goes* as long as it's useful. But we should not give the idea that the Bacon's method is wrong and invalid; it is simply one of the methods that is useful for building scientific knowledge. And it has the enormous merit of allowing us, scientists and teachers, to leave the loop of scholasticism, which is worth eternal gratitude.

[20] a) Feyerabend, P., 1993. *Against method*. New York: Verso. b) Bauer, H.H., 1994. *Scientific literacy and the myth of the scientific method*. USA: University of Illinois Press.
[21] Brown, J. R. and Fehige, Y., 1996 (revision 2014). Thought experiments. *Stanford Encyclopedia of Philosophy*, [online]. Availible at: <https://plato.stanford.edu/entries/thought-experiment>.

Teacher's training of SciLit project in Madrid.

Any model or theory will, in all likelihood, be replaced by a more precise one with a more extended field of application. This mechanism of substitution of models or theories in an endless succession is the only way that allows us (according to Piaget's adaptation process or Kuhn's scientific revolutions), to build knowledge of the physical world. But we should not think that the old theories are useless garbage. On the contrary, many of them continue to apply when the old model provides the required precision. That is why we continue using Newton's Mechanics to place satellites in orbit or send people to the Moon. One of the PISA tests is to assess the student's ability to choose the most appropriate model, among those available, to solve a particular problem.

As important as the evolution of science is its inter-organization. If we take mathematics as the basic mental ingredient, a form of thought that can be translated into physical symbols (including information theory), it occupies the most fundamental place among the sciences. Over mathematics we can locate physics. We need physics to understand chemical, biological and geological processes, in the same way that we need chemistry to understand geological and biological phenomena. The world of science is also, as we have said of our current world, flat. Any discovery or advance in a science immediately impacts others.

In this project, to make clear the idea of permeability between sciences, we have use elemental physical processes, such as sedimentation (well known by children) to explain what has happened in archaeological processes, processes that led to a situation that was, hundreds or thousands of years ago, as present as it is today for us, to the situation in which the archaeologist finds it.

Teachers debating about a stratigraphy.

Evaluation of the training

In this project, the knowledge needed by a teacher to understand the Nature of Science at the desired level (according to the previous requirements) has been identified, in agreement with all partners, to the one needed to correctly answer the questionnaires of Lederman[22].

These questionnaires have been widely discussed and available to the partner teachers since the beginning of the training.

As for the final assessment, we have considered the quality of the works elaborated by the teachers and developed by their students in the classroom, as are presented in the corresponding guides: *What is the World made of* and *Archeology in the classroom*.

An important social ingredient in alphabetization: the role of teachers

Since knowledge is not inherited as money, real estate or the color of the eyes, it is essential that this knowledge passes from generation to generation in the most complete and efficient possible way. If this intergenerational knowledge transfer failed, we would return to the Stone Age in a couple of generations, a situation that we should avoid. Given that this transfer of knowledge is based on the work of teachers and on the relationship of respect and trust that students should have towards them, their place in the social scale should be the most appropriate to facilitate their work.

But this social appreciation is based on the cultural level of citizens. They should be aware that school teachers are the first support of the cultural heritage of their society which is, in turn, the only sign of their identity. For that reason, they need to be literate from a humanistic point of view. Once again, we find ourselves here with a golden braid, difficult to break, from which we will only emerge by integrating science into culture, forming an indivisible whole that will be learned simultaneously. We will discuss all of this in section 3 of this guide.

To conclude this section, we want to point out an important fact: it is fundamental that the learning of science takes place in the infantile stage, while we learn how to read, write and perform the first arithmetic operations. In this way, in addition to taking advantage of the moment of maximum permeability to learning and maximum curiosity about the world, it allows us to associate the emotion of the first scientific experiments with this special stage in our lives.

The joy of reading the first stories, finding the first friends and making our first discoveries as true scientists, will be part of the memories that remain attached to the name of our first friends and our first teacher.

[22] Schwartz, R., Lederman, N., Lederman, J. S., 2008. An instrument to assess views of scientific inquiry: The VOSI Questionnaire. Availible at: <https://www.researchgate.net/publication/251538349_An_Instrument_To_Assess_Views_Of_Scientific_Inquiry_The_VOSI_Questionnaire>.

SECOND PART

STATE OF THE ART OF SCIENCE EDUCATION IN THE EUROPEAN UNION

2. STATE OF THE ART OF THE SCIENCE EDUCATION IN EU

2.1. INTRODUCTION

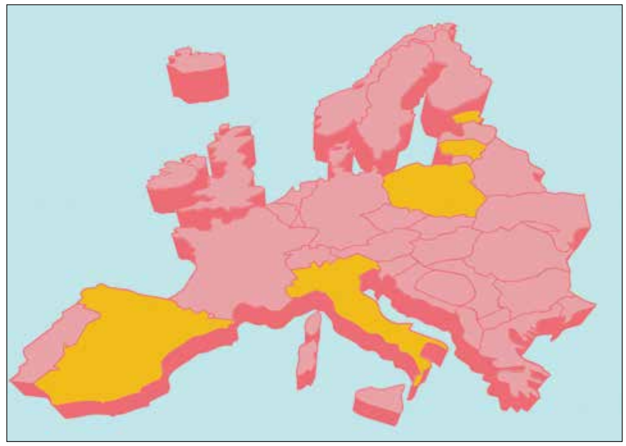
This State of the Art examines science education in pre-primary and primary schools in European Union, in particular in Italy, Spain, Estonia, Lithuania and Poland.

The State of Art presents an overview of the situation of science education in EU and a legal framework (how the national school systems are organized), a curricula structure, teacher education system (initial and continual), and the level of involvement of women in this learning process in SciLit partner countries.

The State of the Art will provide basis needed to identify critical aspects in educational systems across Europe concerning science education. Based on the conducted analysis recommendations for the national educational systems with the focus on science education will be developed.

This document will also be used as a stepping point to facilitate the creation of the Guide for policy makers, scientists, education professionals and national, regional and local authorities involved in education.

Therefore, it will be easier to lay the foundation for an improvement of science teaching in the pre-primary and primary schools at European and national levels.



Our partners's european countries.

2.2. SCIENCE EDUCATION IN KINDERGARTENS AND PRIMARY SCHOOLS IN EU

Legal framework

Improving science education has been a key objective of several European countries since the end of the 1990s, and a considerable number of programmes and projects have been set up to address this issue[1]. One of the key objectives has been to encourage more students to study science and also to promote a positive image of science and improve public knowledge on this subject.

To this end, a wide range of measures, starting in the earliest school years has been introduced to try to improve pupil and student interest in science. Some measures are: implementing curriculum reforms, creating partnerships between schools and companies, scientists and research centres and initializing projects focusing on continuing professional development.

[1] European Education, Audiovisual and Culture Executive Agency, 2011. *Science Education in Europe National Policies practices and research*. European Comission.

However, strategies for improving aspects of education may be broader or narrower. They may be general strategic programmes encompassing all stages of education and training (from early childhood to adult education) to programmes focusing on a particular stage of education and/or on very specific areas of learning.

Several European countries have developed specific policies and projects involving a diversified group of students and teachers. These initiatives include school partnerships, the establishment of science centres and guidance measures. Frequent collaboration among government institutions together with partners from higher education or from outside the education sector has been found.

Initial teacher training on science education in EU

Nowadays the roles of teachers and schools are changing, and so are expectations about them: Teachers are asked to teach in increasingly multicultural classrooms, integrate students with special needs, use ICT for teaching effectively, engage in evaluation and accountability processes, and involve parents in schools; but the most important competence addressed in teacher education at European level is knowledge and ability to teach the official mathematics/ science curriculum. It is very often included in the assessment of prospective teachers. Creating a rich spectrum of teaching situations, or applying various teaching techniques, usually forms part of a specific course in both generalist and specialist teacher education programmes. However, teaching staff nowadays need the competences to constantly innovate and adapt. Teachers have to deal with different situations, like teaching a diverse range of students, taking into account different interests of boys and girls, and avoiding gender stereotypes when interacting with students. These are complex but necessary competences to be addressed in European programmes. Strengthening teacher competences is considered a very important objective in European countries and supporting science education has become indispensable. Where national strategic frameworks for the promotion of science education exist, they normally include the improvement of science teacher education as one of their main objectives. France, Austria and the United Kingdom (Scotland), in particular, focus their attention on this issue. But if teachers' scientific background needs to be developed, attention needs to be focused on today's students' necessities too[2].

As far as the teaching approach is concerned, in the SciLit project partner countries, policy efforts concern with the issue of inclusion (minorities, gender, etc.) while in the other countries there is an emphasis on identifying and nurturing talented students.

This condition is reflected also in the priorities of the initial teacher training depending on the settings of the various national education systems.

These systems have started science promotion activities, often promoted by school partnerships that provide strong support for

[2] ALLEA Working Group on Science Education, 2012. *A renewal of science education in Europe. Views ad action of national academic,* [online]. Availible at: <https://www.allea.org>.

teacher professional development. In order to foster science education, the direct contact with applied research and additional resources provided by private companies or research institutions may be particularly beneficial. Good examples of this are the strong training component in the French programme *La main à la pâte*[3] as well as the Spanish CSIC at school[4].

Science centres and institutions also contribute to teachers' informal learning and may give valuable advice to teachers. In several countries these kind of activities are provided, such as in Ireland, Spain, France, Lithuania, Poland, Slovenia, Finland, Sweden, the United Kingdom and Norway. The field is complex since science teachers teach at different educational levels, are often educated in different science subjects, and belong to various cultures, both educationally and socially. However are not very frequent, specific national initiatives for initial science teacher education.

Continuing teacher training on science education

What teachers know about both science and pedagogical knowledge before they begin to teach, affects every programme of teachers' professional development (TPD) since they are the 'starting points' for participants; but the experiences acquired during the years reflect the ability to respond to the challenges involved in implementing science into the classrooms, and consequently in the necessity to encourage in the TDP programmes some aspects over others[5]. Past European evaluations of science promotion strategies have shown that strengthening teachers' competences is a particularly important concern[6]. As a matter of fact, countries with a strategic framework for the promotion of science education normally include the improvement of science teacher education as one of their measures. School partnerships, science centres and similar institutions all contribute to teachers' informal learning. Science centres in several countries also provide specific continuing professional development (CPD) activities for teachers.

Several countries such as Ireland, Spain, France, Lithuania, Poland, Slovenia, Finland, Sweden, the United Kingdom and Norway report that their educational authorities include specific CPD activities for science teachers in their official training for teachers in service[7]. National initiatives regarding pre-service science teacher education are, however, not very frequent.

Apparently initial training seems to be present in the principles of most European countries, the necessary in-service training and appropriate specific continuous professional development

[3] Foundation La main à la pâte. Availible at: <http://www.fondation-lamap.org> [Accessed 17 July 2017].
[4] CSIC at School Programme of The Spanish National Research Council (CSIC). Availible at: <http://www.csic.es/web/guest/el-csic-en-la-escuela>. [Accessed 17 July 2017].
[5] European Education, Audiovisual and Culture Executive Agency, 2011. *Science Education in Europe National Policies practices and research*. European Comission.
[6] Eurydice Network of Education, Audiovisual and Culture Executive Agency (EACEA), 2016. *Recommended Annual Instruction Time in Full-time Compulsory Education in Europe, 2016/17*, [online]. Availible at: <https://eacea.ec.europa.eu>.
[7] Education, Audiovisual and Culture Executive Agency (EACEA), 2011. *Science education in Europe national policies, practices and research*, [online]. European Comission. Disponible en: <http://education.stateuniversity.com/pages/1212/Poland-PREPRIMARY-PRIMARY-EDUCATION.html>.

(CPD) are huge challenges, not only because it is necessary to revisit pedagogical ideas, but also because ofthe financial means required to train high numbers of primary school teachers already in service.

In almost all European countries interventions at very high levels, both in the political sphere and in the business world, are necessary in order to motivate action by ministerial and political decision-makers[8].

2.3. SCIENCE EDUCATION IN ITALY, SPAIN, ESTONIA, LITHUANIA AND POLAND

Legal Framework

After having analyzed the Legal Framework in Italy, Spain, Estonia, Lithuania and Poland, and, a matter of fact is that pre-primary and primary school education follow similar paths.

In Estonia and Poland, for example, mandatory education starts at the age of 7. While in Italy, Spain and Lithuania mandatory education starts at the age of 6. In all these countries mandatory education ends at the age of 16-17.

Moreover, in Poland children at the age of 3-5 have the right to preschool education[9], and 6-year-old children are covered by mandatory preschool education. Preschool education in Poland is financed in part by state subsidies (5 hours a day) and partly by parents.

In all these countries, except for Poland, preschool education is not mandatory and it is not free of charge. In Italy and in Spain the system of early childhood education and care includes settings for children between 0 and 3 years and settings for children between 3 and 6 years. This latter is only partially covered by the State. In Estonia a rural municipality or city government have to enable all children in their area, between the ages of 1.5 and 7 go to kindergarten in their place of residence, if their parents want to[10]. In Lithuania preschool is for children from age 3 to 6[11]. In Poland early childhood education includes 2 settings for children aged 0-3 and for children aged 3-6.

In all these countries science teaching in pre-school education is a part of daily routine activity (experiments, observations, manipulation).

The table below presents the age (in years) of pupils to attend primary school in SciLit partner countries:

Table 1. **Primary School's Students Age**

	ITALY	SPAIN	ESTONIA	LITHUANIA	POLAND
Primary School	6-11	6-12	7-16	7-11	7-15

In primary school children learn to read and write and study a wide range of subjects including Maths, Geography and Science.

[8] ALLEA Working Group on Science Education, 2012. *A renewal of science education in Europe. Views ad action of national academic,* [online]. Availible at: <https://www.allea.org>.
[9] State University. *Poland – Pre-primary & Primary Education*, [online]. Availible at: <http://education.stateuniversity.com/pages/1212/Poland-PREPRIMARY-PRIMARY-EDUCATION.html>. [Accessed 14 September 2017].
[10] Ministerio de Educación e Investigación de Estonia. Disponible en: <https://www.hm.ee/et>.
[11] Ministry of Education and Science of the Republic of Lithuania, 2004. *Education in Lithuania*. Disponible en: <https://www.european-agency.org/sites/default/files/education_lithuania.pdf>.

The Scientific content at this stage consists of different areas:

- Science of Nature.
- Social Sciences which help the students to develop different competences. Some of these competences are: maths skills, basic skills in science and technology, digital skills, etc.

There are different types of implementation in each country as presented below.

Italy

In Italy the Ministry of Education, University and Research (MIUR) is responsible for general administration at national level. School education is organised at a decentralised level by the MIUR through the Regional School Offices, which operate at provincial level in Local Offices. There are no decentralised offices of the MIUR at municipal level, nor are there any decentralised offices of the MIUR for higher education[12].

In Italy, the implementation of the National System for Evaluation of Schools started in 2014/15 with the introduction of mandatory school self-evaluation, where student performance data (results of the annual INVALSI tests[13] are one of the elements taken into consideration). From the 2015/16 school year, the school self-evaluation report has been followed by an external evaluation, coordinated by an inspector. The external teams aim to visit up to 10 per cent of all schools each year. The school self-assessment report and the results of the improvement process over a three-year evaluation cycle are available online.

Spain

In Spain the Education system depends on separate administrations.

– The State General Authority is in charge of proposing and implementing through the State Secretariat for Education, the policies of the government on education matters. The education competences of the Ministry ensure the homogeneity and basic unity of the Education System.

–The Autonomous Communities are the authorities in charge of the legislative development and management of education in the jurisdiction of each Autonomous Community. They have executive and administrative competences for managing education in its own territory, except from those reserved to the State. Their competencies are: administrative ownership of the schools, Service for Technique Inspectorate on Education, staff administration, design, approval and development of experimental and pedagogical research plans and powers in the design of the basic curriculum for primary education and compulsory secondary education[14].

Estonia

In Estonia the development and implementation of national development programs is organized by the Ministry of Education and Research. Estonia's research and development activities are financed from the state budget, as well as enterprises, foreign and other sources.

[12] Ministero dell'Istruzione, dell'Università, e della Ricerca, 2014. *El sistema educativo italiano*. Availible at: <http://www.indire.it/lucabas/lkmw_img/eurydice/quaderno_eurydice_30_per_web.pdf>.
[13] Proveinvalsi.net. Disponible en: <https://www.proveinvalsi.net>.
[14] Eurypedia, 2017. *Sistema Educativo Español. Panorama general*. Disponible en: <https://eacea.ec.europa.eu/national-policies/eurydice/content/spain_en>.

Lithuania

In Lithuania the Ministry of Education and Science formulates and executes the national policy in the areas of education, science and studies, drafts strategic education plans, annual programmes, approves the general content of teaching, training and studies under the framework of formal education (general programmes and subject programmes as well as teaching, training and study plans)[15].

Poland

In Poland governance of school education reflects the territorial organisation of the Polish state. The regional education authorities are included in the regional administration and are responsible for pedagogical supervision over schools. The local authorities take part in exercising public authority. Responsible for the administration of the school education system is the Minister of National Education. The Minister co-ordinates and pursues the national education policy, cooperating in this respect with regional authorities and other organisational units responsible for the school education system[16].

2.4. CURRICULA STRUCTURE IN ITALY, SPAIN, ESTONIA, LITHUANIA AND POLAND

In Italy, Spain, Estonia, Lithuania and Poland science teaching in pre-primary and primary schools is a part of daily routine activity. Experimentation encourages the child to excel and discover something new, develops creativity, enriches vocabulary, teaches to collaborate and communicate with others and in this way children learn how to achieve a common goal. Skills, such as observation, manipulation, classification and experimentation, permit to interact with the physical and natural world working on scientific concepts as for instance, density, weight, energy.

Italy

In Italy the learning objectives defined by the "Ministero dell'Istruzione, dell'Università e della Ricerca" aim to specify the level of learning of pupils expected at the end of each school cycle (pre-primary and primary).

The following subdivision in learning outcomes is used:

– Explore and Describe Objects and Materials.

– Observe and Experiment on the Field.

– The Human Being and the Environment.

For every learning objective, a range of skills to be obtained by pupils is defined[17.] Science is one of the disciplines provided by the new guidelines for the 5 years of primary school, along with Italian, English, History, Geography, Mathematics, Technology, Computer Science, Music, Art and Image, Physical Education. According

[15] Ministry of Education and Science of the Republic of Lithuania, 2004. *Education in Lithuania*. Availible at: <https://www.european-agency.org/sites/default/files/education_lithuania.pdf>.
[16] Polish Eurydice Unit: Foundation for the Development of the Education System (FRSE), 2014. *The System of Education in Poland, The System of Education in Poland,* Warsaw. Availible at: <http://eurydice.org.pl/wp-content/uploads/2014/10/THE-SYSTEM_2014_www.pdf>.
[17] Cerini, G., Mazzoli, P., Previtali, D., Silvestro, M. R., 2012. *Indicazioni nazionali per il curricolo della scuola dell'infanzia e del primo ciclo d'istruzione*, [online]. Italia: Ministero dell'Istruzione, dell'Università e della Ricerca. Availible at: <http://www.indicazioninazionali.it/documenti_Indicazioni_nazionali/indicazioni_nazionali_infanzia_primo_ciclo.pdf>.

Table 2. **Learning objectives for science education in primary school in Italy***

1º (6 year olds)	2º (7 year olds)	3º (8 year olds)	4º (9 year olds)	5º (10 year olds)
Matter and its characteristics; Environment; Objects: differences and similarities; Correct nutrition basis	Solid, liquid and gas status; Living and non-living things; The seasons change; The water cycle; Animals and plants	The animals and their vital functions; Vertebrate & invertebrate; Ecosystems & ecology; Environment protection	Water, air & soil; Pollution; Plants: structure, nutrition and reproduction; Heat and combustion; Hygiene & health	The Earth in the universe; Energy and its shapes; The human body; Optical and acoustic phenomena; Origin of food

* Istituto Comprensivo Statale 15 di Bologna; Curricolo verticale di Scienze, Bologna, (2017). Available online: <http://www.ic15bologna.it/images/pages/3031-6634-Curricolo_Scienze.pdf>.

Table 3. **Concepts and scientific methods in primary school in Spain**

1º (6 year olds)	2º (7 year olds)	3º (8 year olds)	4º (9 year olds)	5º (10 year olds)	6º (11 year olds)
Observation, description, classification	Observation, description, measures, classification	Observation, description, measures, experimentation, classification	Observation, description, measures, experimentation, classification	Observation, description, measures, experimentation, classification	Observation, description, measures, experimentation, classification
Plants, respiration, materials	Vital functions, hardness, energy, mass	Change of the state of matter, heat, substances	Weight, matter, mass, deformation, lever, magnets	Ecosystem, transformation of energy, types of energy, light, electricity	Combustion, oxidation, magnetism, computer

to the Ministry of Education, the teaching of scientific subjects would directly involve pupils in asking questions about phenomena and things, planning experiments by following work hypotheses and building their interpretative models without intellectual restriction. The main aim is to realize concrete experiences in suitable spaces such as school laboratories, but also natural environments easy to reach.

The learning objectives for science in primary school are shown below (Table 2).

Spain

In Spain scientific content in primary school consists of different areas: Science of Nature, Social Sciences and Mathematics which help the students to develop different competencies, such as maths skills, basic skills in science and technology, digital skills, etc.

In the following chart below (Table 3), some of the concepts, scientific methods and courses for the primary school in Spain are shown[18].

Estonia

In Estonia, based on the national curriculum of preschool facilities, children who start school master the following science-related skills: expressing surprise, asking, comparing, focusing and measuring, classifying, and remembering facts[19]. Scientific education is included in the general curriculum as lessons of physics, chemistry, biology and geography.

For those interested, there are various hobby groups available. In Estonia, subjects like physics, chemistry and biology are studied by students in classes 7–12, natural science or geography lessons start in the first class already.

[18] Agencia Estatal Boletín Oficial del Estado, 2017. *Currículo de la Educación Primaria en la Comunidad de Madrid*, [online]. España: Gobierno de España. Availible at: <http://www.madrid.org/dat_capital/loe/pdf/curriculo_primaria_madrid.pdf>.
[19] Kehittämiskeskus Opinkirjo, 2015. *Arenev teadushuviharidus. Õpime kogemustest*. Estonia: Eesti Teadusagentuur.

Lithuania

In Lithuania in primary school (Grades 1 to 4), the curriculum divides integrated social and natural science into several content areas: humans living together, humans' development, humans' environment, humans' health and safety, humans and nature, and humans and natural phenomena. Science education in basic school (Grades 5 to 10) aims to help students acquire foundational knowledge in the natural sciences, master essential concepts and ideas in the natural sciences, acquire skills that will help them develop an understanding of the world around them, and develop certain values and attitudes.

The curriculum aims to help students mature as citizens able to live healthy lives and solve sustainable development problems.

In Grades 5 and 6 of basic school, science is taught as an integrated subject, and geography only is taught as a separate subject in Grade 6. From Grade 7, biology, chemistry, and physics are taught as separate subjects.

Overall, the science curriculum focuses on knowledge and understanding, problem solving, practical skills, scientific communication, and skills for learning science[20].

Poland

In Poland according to the National Curriculum, science is a mandatory content area at all education levels and in all types of schools. In Grades 1 to 3, science as part and parcel of integrated teaching content is expected to yield 10 learning outcomes (written in "can do" statements).

Among these, there are research skills (e.g., students observe and conduct simple scientific experiments, analyse them, and associate the reason with the result), explanations (e.g., students explain how natural phenomena depend on the seasons), knowledge of facts (e.g., students name body parts and internal organs of humans and animals), and practical knowledge (e.g., students know the basic rules of healthy nutrition and the basic threats in the world of plants and the world of animals, and actively participate in environmental protection in their local area). In Grades 4 to 6, there is a separate subject called Nature.

The National Curriculum lists five teaching objectives for this subject:

- Arousing curiosity about nature.
- Respect for nature.
- Constructing and verifying hypotheses of natural phenomena and processes.
- Observation, measurement, and experimentation.
- Practical use of knowledge about nature.

The National Curriculum emphasizes the use of the scientific method in class (e.g., posing questions or putting forward hypotheses, making observations, and taking measurements). At the lower secondary level (Grades 7 to 9), science is divided into four subjects: Geography, Biology, Chemistry, and Physics.

[20] TIMSS & PIRLS International Study Center. *TIMSS 2015 ENCYCLOPEDIA*. Availible at: <http://timss2015.org/timss-2015/about-timss-2015/>. [Accesed: 13 September 2017].

2.5. TEACHER TRAINING IN ITALY, SPAIN, ESTONIA, LITHUANIA AND POLAND

In primary and pre-primary school, the presence of motivated, prepared teachers, attentive to pupils' specificities, is an indispensable quality factor for the construction of a comfortable, secure, well-organized educational environment capable of generating the trust of parents and the community. Teachers' educational training is inspired by criteria of listening, accompaniment, participatory interaction, communicative mediation, continuous observation of pupils, taking charge of their "world", reading of their discoveries, support, and encourage the evolution of their learning towards more and more autonomous and conscious forms of knowledge.

Italy, Spain, Estonia, Lithuania and Poland have all well-defined criteria for teachers' training. It is described in details below:

Italy

In Italy for preschool and primary school teaching there is a five-year, numerus clausus degree course, Sciences of Primary Education.

The situation is different for secondary school teachers. Decree n. 249 established that future teachers must achieve a master degree and complete a subsequent year of "active internship" (TFA). Given the fact that it is possible to attend a master degree program only after earning a three-year degree, the total duration of the training is six years[21].

The Degree in Sciences of Primary Education includes several hours of Science; i.e. in the University of Bologna's curriculum[22], scientific subjects such as geometry, basic maths, chemistry, biology and maths with elements of statistics take an important place as number of course credits[23].

In primary and pre-primary school, the presence of motivated, prepared teachers, attentive to pupils' specificities, is an indispensable quality factor for the construction of a comfortable, secure, well-organized educational environment capable of generating the trust of parents and the community. Teachers' educational training is inspired by criteria of listening, accompaniment, participatory interaction, communicative mediation, continuous observation of pupils, taking charge of their "world", reading of their discoveries, support, and encourage the evolution of their learning towards more and more autonomous and conscious forms of knowledge[24]. Teachers are free to choose teaching methods. However, the National

[21] Pusztai, G. and Engler, A. (ed.), 2014. *Teacher Education Case Studies in Comparative Perspective*. Debrecen, Hungary: Center for Higher Education Research and Development Hungary (CHERD-H). Availible at: <http://real.mtak.hu/15409/1/volume_teacher_education.pdf>.
[22] The curriculum offered by the University of Bologna for Science of Primary Education is very similar to the curriculum offered by the other Italian universities for the same university degree.
[23] Università degli Studi di Bologna. *Scienze della Formazione Primaria, LMCU por Matricole 2017/18,* [online]. Availible at: <http://corsi.unibo.it/laurea/scienzeformazioneprimaria/Pagine/PianiDidattici.aspx?CodCorso=8540&AnnoAccademico=2017yOrientamento=000=000yINDIRIZZOyProgressivo=2,017>. [Accessed: 9 September 2017].
[24] Cerini, G., Mazzoli, P., Previtali, D., Silvestro, M. R., 2012. *Indicazioni nazionali per il curricolo della scuola dell'infanzia e del primo ciclo d'istruzione*, [online]. Italia: Ministero dell'Istruzione, dell'Università e della Ricerca. Availible at: <http://www.indicazioninazionali.it/documenti_Indicazioni_nazionali/indicazioni_nazionali_infanzia_primo_ciclo.pdf>.

guidelines for the teacher training establish some general criteria for the organization of the learning environment.

Spain

In Spain in order to become teachers it is needed to obtain the academic qualifications and attend the necessary pedagogical and educational trainings. The necessary university degrees for teachers are Infant Education degree (for 0-6 aged children) and Primary Education degree. The Ministry of Education decides on the verification of qualifications for the official university degrees which qualify teachers and decides on the minimum contents of the curricula. The universities are an Autonomous Communities' competency, can decide to modify or extend the educational curricula of the future teachers always following the minimum requirements of the Ministry of Education[25].

The trainings the future teachers in the Faculty of Education attend in four universities in Spain can slightly vary according to the university. These universities are: Universidad Complutense de Madrid (UCM); Universidad Autónoma de Barcelona (UAB); Universidad *Pública de Navarra (UPNA) and* Universidad de Oviedo (UNIOVI). In some of their curricula science is studied under the perspective of social and natural sciences, in some others a practical approach is included too (Lab of Physical-chemical Sciences)[26].

Estonia

In Estonia teachers are trained at higher educational establishments. Class teachers training is based on the integrated curricula for Bachelor and Master studies. Training for university lecturers is carried out as Master or doctoral studies or in-service training. For the commencement of teacher training, the conditions for the commencement of the corresponding level of higher education are applied. The pre-condition for starting training for class teachers is secondary education or equivalent foreign qualification. The pre-condition for the commencement of teacher training for teaching an additional subject or a profession, is the completion of the curriculum belonging to the study field of teacher training and educational sciences at higher education level.

An additional pre-condition for starting teacher training for a pre-school facility teacher, class teacher, basic school subject teacher, secondary school subject teacher, teacher of general education subjects at vocational education institutions, vocational teacher, activities leader, hobby school teacher and special teacher, is completing professional suitability tests[27]. In Estonia future teachers can study in Tallinn University at the Educational Sciences course; here the study of science focuses on subjects such as: Mathematics, Health Care, Science Didactic & Nature Studies[28].

[25] Spanish Ministry of Education. *Formación Inicial del Profesorado*. Availible at: <http://www.mecd.gob.es/educacion-mecd/areas-educacion/profesorado/no-universitarios/formacion/formacion-inicial.html>.
[26] UCM. *Plan de Estudios Maestro en Educación Primaria 2017-2018*, [online]. Availible at: <http://educacion.ucm.es/estudios/grado-educacionprimaria-estudios-estructura>.
[27] Ministry of Education and Science, 2016. *Koolitus- ja arendustegevus.* Estonia.
[28] Tallina Ülikool. Availible at: <http://ois.tlu.ee/pls/portal/ois2.ois_public.main>.

Lithuania

In Lithuania, training of pre-primary and primary/ basic school teachers. Pre-primary and primary school teachers are trained at higher education institutions. Secondary school teachers are trained at Vilnius University, Vilnius Pedagogical University, Šiauliai Pedagogical University, Vytautas Magnus University (in Kaunas) and Klaipėda University. Here future teachers study several scientific subjects: Algebra and Statistics elements, Modern Mathematics, Geometry and Health Science[29]. Four-year course programmes are offered in certain other tertiary institutions. Master's degrees confer the right to teach in gymnasiums and colleges. Admission is on the basis of a Bachelor's degree and at least one year of teaching experience. Some higher education institutions offer study programmes leading directly to a teacher's qualification, others one-year courses to obtain the qualification of teacher after completing the regular study programme[30].

Poland

In Poland initial training of teachers is provided within two sectors of the education system:

1) Within the higher education sector: degree programmes, including first, second and long cycle programmes; non-degree postgraduate programmes.
2) Within the school education sector (until 2015): college programmes (now being phased out), including teacher training colleges and foreign language teacher training colleges.

All educational institutions operate in both the public and non-public education sectors. Teacher training in Poland is organised according to two models, i.e. a concurrent model and a consecutive one. The concurrent model predominates in Poland. As part of degree programmes in individual fields of study at HEIs, students may choose a teacher specialisation track, which means that they can undertake teacher professional training (pedagogical training) as part of their degree programmes, in parallel to their general subject-specific training. Those who have not taken a teacher specialisation track and choose the teaching profession later may obtain a teaching qualification upon the completion of a non-degree postgraduate programme or a qualification course.

The latter option represents the consecutive model of teacher training. Teacher education and training standards are formulated in the 2012 Regulation by the Ministry of Science and Higher Education. Teacher education and training consists of preparation in a given subject matter (biology, mathematics, etc.) and pedagogical training (teaching methods, psychology, pedagogy). Under the above-mentioned regulation, teachers employed in pre-primary and primary schools ought to have as minimum qualifications a Bachelor's degree, whereas teachers employed in lower-secondary and upper-secondary schools as well as basic vocational schools ought to hold, at the minimum, a Master's degree or equivalent[31]. At the University of Warsaw in

[29] The curricula offered by the courses of Educational Science in Lithuanian universities present the similar focus on scientific subjects.
[30] Euro Education. Availible at: <http://www.euroeducation.net/prof/lithuaco.htm>.
[31] Polish Eurydice Unit: Foundation for the Development of the Education System, 2014. *The System of Education in Poland, Warsaw*. Availible at: <http://eurydice.org.pl/wp-content/uploads/2014/10/THE-SYSTEM_2014_www.pdf>.

the Faculty of Education, future teachers study several scientific subjects in the 3-year course Early Childhood Education, such as Science & Technology for teachers, Mathematics for teachers, Mathematics Education, Natural Science Education[32]. At UMCS University in Lublin in the Faculty of Education future teachers study scientific subjects, too: Pedagogics and Didactics, Mathematics, Natural and Social Sciences[33].

2.6. WOMEN'S PARTICIPATION IN SCIENCE EDUCATION IN ITALY, SPAIN, LITHUANIA, ESTONIA AND POLAND

A greater presence of women in the world of science and technology is essential for scientific excellence and also for the economic development of the country. These facts mean we must work hard to correct the imbalance produced by the absence of women in the world of science. Women have to participate in the spheres of science creation and dissemination not only for the sake of their own career, but for the benefit of society as well. The European Research Area Strategic Vision adopted in 2010 sets a target for half of all scientific personnel, in all disciplines and at all levels of the scientific system, to be women by 2030. This is an attempt to break the horizontal and vertical segregation that currently exists in European science.

In Europe there are several programmes available for women, such as the "European Girls in STEM" that is a study commissioned by Microsoft and Professor Martin W. Bauer of the Department of Psychological and Behavioral Science at the London School of Economics (LSE). It is the first truly comprehensive study on females in STEM38. It surveyed 11,000 young women from ages 11 to 30 from 12 European countries: Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands, Poland, the Czech Republic, the United Kingdom, Russia, and Slovakia.

Women involvement in science education in Italy, Spain, Estonia, Lithuania and Poland is analyzed below.

Italy

In Italy according to "European Girls in STEM" study only 12.6% of the Italian female students who go to university attend a STEM. The starting point would seem to suggest a different outcome. 42.1% of Italian female students say they are passionate about math lessons and 41.7% are said to be up for numbers, against a European average of 37.6. While 49.2% say they appreciate computer science, 42.2% of European peers support. Still, 59% of young Italian girls believe that they can achieve excellent results in the study of STEM subjects and more than 60% are not afraid of being afflicted as nerd by enrolling in a scientific faculty. More specifically, 66.1% of Italian respondents, compared with a 59% European average, said they would feel more comfortable knowing that once entered the labor market, they would get the same treatment as men. Although there are numerous

[32] University of Warsaw. Availible at: <http://informatorects.uw.edu.pl/en/programmes-all/PEMD/NZ1-PEMD/>.
[33] Although University students are not the target of SCILIT project, future teachers' scientific training at their universities has been reported in this State of the Art in order to have a more detailed and complete overview on the scientific background teachers have.

examples of Italian women that have contributed to revolutionizing the world of science (Rita Levi Montalcini, Margherita Hack, Samantha Cristoforetti, Elena Cattaneo, Fabiola Gianotti, etc.) one of the biggest obstacle to a career in science for young women in Italy is the lack of female models to be inspired. A problem that has been found only in Italy is the so-called peer group pressure.

That is if a girl is interested in STEM subjects, but her group of friends is not, she will also lose interest. In this sense, women are the main enemies of their own and then there is a theme that concerns the way science subjects are taught at school. This theme is related to the excessive burden of theoretical studies compared to the lack of practical experience. It is a fundamental element in creating a passion for science.

Spain

In Spain there is a legal framework incorporating a considerable number of the recommendations proposed in Europe and the United States. Together, the Law on Equality of 2007, the Law on Universities (LOMLOU) of 2007 and the Law on Science, Technology and Innovation (Chapter 3 of *Libro Blanco. Situación de las Mujeres en la Ciencia Española* -White Paper on the Position of Women in Science in Spain-*)*, cover the areas on which it is necessary to base specific measures in order to eliminate the biases and barriers and in order to reduce the waste of highly qualified human capital[34].

The Law on Science, Technology and Innovation includes specific measures in these six fields:

1. The composition of the bodies, boards and committees regulated by this law, and the assessment and selection bodies in the Spanish Science and Technology System, will conform to the principles of composition and equal presence of men and women as established in Organic Law 3/2007, of the 22nd March, on effective equality between men and women.

2. The Spanish Science and Technology Strategy and the State Scientific and Technical Research Plan will promote the incorporation of the gender perspective as a cross-functional category in research and technology, in such a way that it is considered relevant to all aspects of the process, from the definition of scientific/technical research priorities, research problems, theoretical and explicative frameworks, methods, data collection and interpretation, conclusions, technological applications and developments, to proposals for future studies. It will also promote gender and women's studies, and specific measures to boost the presence of women in research teams and ensure they receive recognition.

3. The Science, Technology and Innovation Information System will collect, handle and release all the data broken down by sex, and will include presence and productivity indicators.

[34] Sánchez de Madariaga, I., de la Rica, S. and Dolado, J. J. (coord.), 2012. *Libro Blanco sobre la Situación de la Mujer en la Ciencia en España,* [online]. Madrid: Ministerio de Ciencia e Innovación. Availible at: <http://www.idi.mineco.gob.es/stfls/MICINN/Ministerio/FICHEROS/UMYC/WhitePaper_Interactive.pdf>.

4. The research personnel selection and assessment procedures for Public Universities is based on the study *Libro Blanco. Situación de las Mujeres en la Ciencia Española* (White Paper on the Position of Women in Science in Spain). General State Administration, and the procedures for grants and subsidies awarded by research funding agents, will establish mechanisms to eliminate gender bias that will include, wherever possible, confidential assessment mechanisms that prevent the assessor knowing the personal characteristics of the applicant, in particular their sex or race.

5. The State Innovation Strategy will promote the incorporation of gender perspective as a cross functional category in all development areas.

6. The Public Research Bodies will adopt Equality Plans within a maximum of two years from the publication of this law, and these will be monitored on a yearly basis. These plans must include incentives for centres to improve their gender indicators in the annual review.

Estonia

In Estonia education in general and science education are gender specific. Compared to men, women attend school longer and have higher educational level. Men tend to end their educational career earlier and they acquire less likely higher education. Women and men are in different fields of study and this tendency is not decreasing. In addition to that, most of the educational workers are women; they dominate every educational level, except in higher education. Less young men are accepted to institutions of higher education because they cannot compete with young women at admission. In 2012, 130 females were admitted per one hundred men.

The share of women in the total number of students acquiring higher education was 58%. The gender disproportion is certainly caused by the predominance of intended curricula for women as well. For example, women prevailed in five out of eight fields of studies in bachelor's studies; the female predominance was the highest in the fields of study of education and of health and humanitarian. More young men studied in natural and exact sciences (especially info technology) and in services. This is a common tendency in EU countries[35].

According to Article 12 of the Constitution of Estonia everyone is equal before the law and no one shall be discriminated against on the basis of nationality, race, colour, sex, language, origin, religion, political or other opinion, property or social status, or on other grounds.

According to amendment in the Government of the Republic Act in 2000, the Ministry of Social Affairs is responsible for promoting gender equality, coordinating work in this field and compiling drafts for corresponding legal acts. In 1996 the Gender Equality Bureau was established in Ministry of Social Affairs (in 2004 it was renamed as Gender Equality Department). A Law on Gender Equality has been enacted in Estonia since 2004. It prohibits discrimination on the basis of gender

[35] Wiki Gender. Availible at: <http://www.wikigender.org/countries/europe-and-central-asia/gender-equality-in-estonia/>. [Accessed: 14/09/2017].

and obliges public bodies and employers to promote gender equality.

Lithuania

In Lithuania the main measures used to encourage women to participate in scientific activities more actively are the following: Stimulation of young women to reach for the scientific career; Stimulation of women to reach for the higher scientific qualification and to carry out the scientific research with better outcomes and productivity; Urging women to take part in science administration and to apply for the high positions within the structures of science administration; Enlightenment and information of the society about women's situation in science and science administration structures. Main tools to translate those measures into reality are organisational and financial.

Organisational tools:

In many Lithuanian institutions of science and high education, the mechanism of open competitions for the positions of scientists is still functioning far from perfection. So the Government of the Republic of Lithuania is going to adopt, in the nearest future, deeds, to regulate minimal qualification requirements for the teaching staff and researchers of the state science and high education institutions, as well as the order of organising competitions to hold positions, certifying, awarding pedagogical scientific titles in high schools.

These deeds are among the most important documents that would help to implement principles of equal opportunities within the structures of science and high education. Laws of the Republic of Lithuania provide additional social guarantees for women, who have to temporarily suspend their work activities due to childbirth or childcare. These social guarantees help women to keep their positions and provide them with opportunity to study further and raise their qualification.

There are 63 science and high education institutions in Lithuania (29 states science institutes, 15 state high schools and 4 private high schools, 15 state science institutions). In these science and high education institutions, only 4 women hold a director's position. There are 23 fellows in Lithuanian Science Council, 2 of them are women. If the overall ratio of female scientists is 45%, and in some science and high education institutions, depending on science branch, it fluctuates from 10% to 75%, there are only a few female scientists holding high positions within science administration structures.

Main financial tools:

Lithuanian scientists by competition order may get the following financial support from the state: State Scholarship for Young Scientists, which is granted for scientists up to 35 years old; State Scholarship of the Highest Degree, granted to the distinctive scientists; Scholarships granted by Lithuanian State Research and High Education Fund, individual scientists, groups of scientists for various scientific projects and scientific publications; Support of international studies and scientific work abroad (travel expenses, per diem allowances, scholarships) according the signed agreements of co-operation in the fields of science and high education, provided by the Department of Science and High Education under Ministry of Education and Science. At present, Government of Lithuania is not able to establish additional scholarships for female scientists. However, only 25% of participants of the competitions to get the above mentioned scholarships are women. To fully use every existing opportunity, the Plan of equal opportunities for men and women of Lithuanian Women Progress program (2001-2005), mentioned above, provides for the presentation of the additional information to the institutions of science and high education about the male/female scientists ratio in the competitions and encourages the administration of the science and high education institutions to induce female scientists to more actively apply for the above mentioned scholarships and reach better scientific results[36].

Poland

In Poland, according to the Polish Press Agency, 69% of women are of the opinion that they are discriminated. It is unknown to what extent this opinion is shared by women scientists as this issue has never been explored and successful women researchers, who could address this problem in the competent way, are too much involved in different occupations to raise this topic. However, statistical data indicate that formal equality of women in the field of science is not fully reflected in their academic career. Disparity in the development of scientific careers between men and women in Poland is much less visible than the one regarding women's participation in the science administration and shaping science policy, which is even considered as the negative segregation. The latter issue is of utmost importance and seems to be more visible. In the State Committee for Scientific Research, the supreme administration body to shape the foundations of national science policy, established by the Act of 12 January 1991 –there are 4 women out of a total of 60 elected representatives of the science community (6.6%). In the Polish Academy of Sciences, another decisive and consultative body in the area of scientific research, there are 9 women out of 328; deciding in the Parliament male female (38.7 million inhabitants) 2 members (2.7%); in the board of management of Academy we find 1 woman out of 31 members (3.2%)[37].

According to the new Constitution adopted in 1997, Poland assures equal rights for women and men in all spheres of life. In particular, Article 33 of the Constitution states that "men and women shall have equal rights (...) regarding education, employment and promotion, and shall have the right to equal compensation for work of similar value, to social security, to hold office, and to receive public honours and decorations"[38].

2.7. PISA REPORT

The Programme for International Student Assessment (PISA)[39] is an ongoing triennial

[36] Group on Women and Science '*Women and Science*', 2000. *Examen de la situación en Lituania*, [online]. Helsinki. Availible at: <http://cordis.europa.eu/pub/improving/docs/women_national_report_lithuania.pdf>.
[37] Helsinki Group of Women and Science, 2001. Availible at: <http://cordis.europa.eu/pub/improving/docs/women_national_report_poland.pdf>.
[38] Directorate General for Internal Policies, 2011. *The Policy on Gender Equality in Poland*. Available online: <http://www.europarl.europa.eu/document/activities/cont/201107/20110725ATT24649/20110725ATT24649EN.pdf>.
[39] OECD. Availible at: <http://www.oecd.org/pisa>. [Accessed on: 12 September 2017].

survey that assesses the extent to which 15 years olds students near the end of compulsory education have acquired key knowledge and skills that are essential for full participation in modern societies.

PISA data refers to students from the age of 15 and then outside the target group of the SciLit project. Furthermore, those data are useful in helping to provide a more complete picture of the analysis done so far. The assessment does not just ascertain whether students can reproduce knowledge; it also examines how well students can extrapolate from what they have learned and apply that knowledge in unfamiliar settings, both in and outside of school. This approach reflects the fact that modern economies reward individuals not for what they know, but for what they can do with what they know.

These data offer insights for education policy and practice, and help monitor trends in students' acquisition of knowledge and skills across countries and in different demographic subgroups within each country. The findings allow policy makers around the world to measure students' knowledge and skills in their own countries in comparison with those in other countries. It sets policy targets against measurable goals achieved by other education systems, and learn from policies and practices applied elsewhere. Relevant data from PISA reports have been found for Italy, Spain, Estonia and Poland.

In Italy students in score 481 points in science, on average. This mean that performance in Italy lies below the OECD average and it is comparable with that of students in Croatia, Hungary and the Russian Federation. Italy's 15-year-old students score more than 50 points below students Estonia, Japan and Singapore, and between 10 and 40 points below students in Austria, France, Germany Portugal, Slovenia, Switzerland. Here only the 3% of students are not required to attend any science lessons. Moreover, school principals in Italy reported that the science department is well-equipped and staffed, compared with most school principals in OECD countries. For instance, the 81% of principals in Italy reported that the material for hands-on activities in science is in good shape a similar percentage as on average across OECD countries[40].

In Spain performance in mathematics, reading and science remains anchored just below the OECD average, despite a 35% increase in spending on education since 2003 and numerous reform efforts at national and regional levels[41].

In Estonia students are first in Europe and third in the world after Singapore and Japan with an average result of 534 points (OECD average is 493). More than 90% of Estonian students have at least basic level knowledge in all science subjects, which are biology, geography, physics and chemistry. Among the European countries, Estonia has the smallest number of students whose skills are below basic level. There are

[40] Programme for International Student Assessment, 2015. *Results from Pisa, Country Note Italy,* [online]. Available at: <https://www.oecd.org/pisa/PISA2015-Students-Well-being-Country-note-Italy-Italian.pdf>. [Accessed: 12 July 2017].
[41] Programme for International Student Assessment, 2015. *Results from Pisa, Country Note Italy,* [online]. Available at: <https://www.oecd.org/pisa/keyfindings/PISA-2012-results-spain.pdf>. [Accessed: 14 September 2017].
[42] Programme for International student Assessment, 2015. *Results from Pisa, Country Note Estonia*, [online]. Available at: <https://www.hm.ee/sites/default/files/pisa_2016_booklet_eng.pdf>. [Accessed: 05 September 2017]

no differences between boys and girls when it comes to knowledge in sciences[42].

Spain also performs below average in reading: 488 score points, ranking between 27 and 35. Mean reading performance remains unchanged since 2000 (it decreased from 493 to 488 points, not a significant change). Germany, Liechtenstein, Poland and Switzerland performed lower than Spain in 2000 and higher in 2012. Israel, Latvia and Portugal performed lower than Spain in 2000 and as well as Spain in 2012. Spain performs just below average in science: 496 points, ranking between 26 and 33. Science performance remained stable since 2006, improving slightly, but not significantly, from 488 to 496 points.

In Poland recent reforms have led to rapid improvements in educational performance. This country remains above the OECD average in PISA 2012, with improving scores in mathematics, reading and science. The impact of socio-economic background on students' performance in mathematics in Poland is around the OECD average. Enrolment in early childhood education is below the OECD average, with increases for older children, from around 52% of 3-year-olds to 86% of 6-year-olds (compared to the OECD average of 74% of 3-year-olds and 97% of 6-year-olds)[43].

Poland achieved above-average scores in mathematics, reading and science in PISA 2012. Performance in reading, mathematics and science has been rising across PISA cycles. The impact of students' socio-economic status on mathematics scores (16.6%) is around the OECD average (14.8%). Literacy and numeracy proficiency among adults (16-65-year olds) is below the average of OECD countries participating in the 2013 OECD Survey of Adult Skills, while younger adults (16-24-year olds) perform at around the OECD average in numeracy and above the OECD average in literacy.

2.8. CONCLUSIONS

To quote J. Osborne and J. Dillon, authors of the report "Science Education in Europe: Critical Reflections": "Science is an important component of our European cultural heritage. It provides the most important explanations we have of the material world. In addition, some understanding of the practices and processes of science is essential to engage with many of the issues confronting contemporary society"[44].

In this State of the Art it has been observed how improving science education has been a relevant objective of several European countries since the end of the 1990s, and how many projects and programmes have been created since then[45].

Their main task has been to promote the study of science and also to support a positive image of it improving public knowledge on

[43] OECD, 2015. *Education Policy Outlook*, [online]. Poland. Availible at: <www.oecd.org/education/policyoutlook.htm>.
[44] Osborne, J., Dillon, J., 2008. *Science Education in Europe: Critical Reflections,* [online]. London: Nuffield Foundation. Available at: <http://www.nuffieldfoundation.org/sites/default/files/Sci_Ed_in_Europe_Report_Final.pdf>.
[45] Education, Audiovisual and Culture Executive Agency (EACEA), 2011. *Science Education in Europe National Policies practices and research.* European Commission.

this subject. In this direction, many measures, starting in the earliest school years, have been adopted trying to improve students interest in science education. Among these measures are: implementing curriculum reforms, creating partnerships between schools and companies, scientists and research centres and initializing projects focusing on continuing professional development.

As a result of this research it can be observed how SciLit partner countries present a similar legal, policy framework and curricula in terms of science education in pre-primary and primary school. They all adopt both national and regional policies for the implementation of the regional system, they all present national guidelines for teacher training and their countries' universities offer curricula containing scientific subjects for future teachers. About women participation in science education the data are not positive. Science education seems still to be gender specific despite the measures adopted at European and at national level to encourage women to participate in scientific activities.

The strategies adopted for improving aspects of education can vary significantly. They may be general strategic programmes including all steps of education and training (from early childhood to adult education) to projects focusing on a specific stage of education or on particular areas of learning. Although several results have been already reached, there is still a long way to go. European and national levels need to continue working through an active cooperation on common policies addressed to the improvement of strategies and to the building on new practices of science teaching.

THIRD PART

PROPOSAL FOR THE IMPROVEMENT OF EARLY CHILDHOOD SCIENCE EDUCATION

3. PROPOSAL FOR THE IMPROVEMENT OF EARLY CHILDHOOD SCIENCE EDUCATION

3.1. HISTORICAL OVERVIEW

The overall objective of these parts is to think over the evolution of the concepts of *scientific literacy* of the society since the mid-twentieth century to the present day. In this period, the meaning of the expression has undergone certain changes, that can be divided into three periods: a first stage characterized by the elaboration of benchmarks, a second period centered in the Nature of the Scientific Research (NSR) and, finally, a third stage devoted to the so-called Vision of the Nature of Science (VNOS).

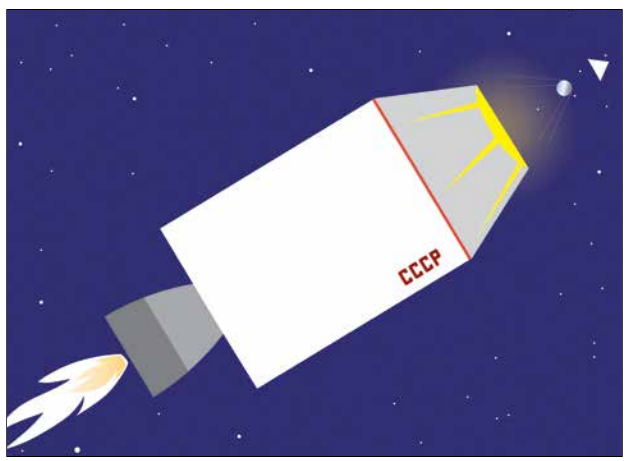
On the same footing as the science learning and according to the guidelines of the European H2020, we should also consider the removal of existing barriers that generate discrimination against women in scientific careers.

Up to 1957 (date of the launch of the Sputnik) what we might call the romantic period takes place. Thanks to the influence of important researchers such as Thomas Huxley, Charles Lyell, Michael Faraday and John Tindall, middle classes began to be interested in a scientific view of the world. It was so more for the benefits on the formation of the students´ mainly through the beauty of this vision, the creativity of its practice and the inherent independence of thought and critical thinking than for any practical reason. Because of these considerations, science makes its way into the official teaching programs.

Thus, we approach the date of 1957 with a world mired in the Cold War, still amazed by scientific discoveries and technological developments directly related to the Second World War, with a self-confident western block. Among other things, this confidence was reflected in the certainty that the education system of this side of the Iron Curtain was better than any other, therefore not in need of any modification.

In this atmosphere, to everyone astonishment, on October 4th, 1957 the Soviet Union launched the first man-made space satellite in history. This provoked (especially in the United States) a tremendous shock, fulminating the sense of security and scientific and technical superiority to which we have referred.

The Sputnik was a serious threat that had to be neutralized. To do so, a series of research and development programs of a very high cost had to be launched. But, being the USA a democratic country, as was the case, the founding of such a state budget should necessarily be supported by the citizens, especially if the effort was to last for a long period of at least fifteen years.



Sputnik´s illustration.

Furthermore, in a democratic society increasingly based on new technologies (transgenic crops, animal cloning, choosing the types of energies to be used, etc.) it is essential to count on citizens knowing what these technologies imply, so they can take informed choices among different political programs with different approaches. This resulted in a new concept of scientific literacy which should reach all citizens, in the same way as had happened with the literal literacy some centuries before.

As is mandatory in any social change directed from the state, the focus was concentrated on teaching at the early stages and, consequently, in the training of their professors and in the research on teaching methods.

As nobody in that historic moment had a clear idea of what knowledge was required in order to be considered scientifically literate, lists of scientific contents were elaborated, different for each discipline and, in some cases, for each country. It is the period of benchmarks, whose failure is evident now.

In our opinion, the concept was never well defined, and as pointed out by Bybee in his 1997 work, the term scientific literacy should be regarded as a slogan, only useful to express the importance of science education.

Given the difficulty of defining scientific literacy through a list of contents, a new proposal emerged: the belief that science is known when you know how it is made, how scientists construct it. This idea is due to the Nobel Prize winner George Charpak who, in 1995, started the program *La main a la Pâte*, inspired by the *Hands On program* started by Leon Lederman, also a Nobel prize winner, in 1991[1].

Wikipedia.

Leon Lederman (left) and George Charpak (right).

With the failure of the identification of knowledge of scientific matters with scientific literacy, the idea that you really know what science is when you know how scientists do science, began to emerge. And that marked the end of the benchmarks period and the starting of the nature of scientific research based on *inquiry*.

But this new way, when developed, turned out to be as confusing as the previous one. This was due to the fact that each discipline had its own peculiarities. Astronomy did not include experimentation, theoretical physics was done, in some cases, through *thought experiments* and some of the great discoveries were due to serendipity.

A few years after the starting of the inquiry

[1] Lederman, J.S. y Lederman, N.G., 2004. *Early elementary students' and teachers understandings of Nature of Science and scientific inquiry: Lessons learned from Project ICAN. Paper presented at the annual meeting of the National Association for Research in Science Teaching (NARST).* Vancouver: Columbia Británica Lederman.

period, deeper analyses of the nature of scientific knowledge took place, among which we cite the one due to John Durant, who in 1993 in his *What is Scientific Literacy* defines three distinct levels:

1. The lower one, which refers to the set of knowledge accumulated through history (commonly known as contents).

2. A middle level, which describes the way scientists work doing science (until recently erroneously called scientific method) and

3. The higher one, which studies the structure and characteristics of the scientific knowledge, is directly related to knowledge representation.

The three levels altogether constitute what is now defined as the *Nature of Science*.

As can readily be seen, the first level corresponds to the definition of the benchmarks, the second to the way in which science is done and the third one, which was new, is what is defined as the *View of Nature of Science* (VNOS).

Although one could think that the definition of VNOS inherited from the previous stages of scientific literacy the defect of being inaccurately defined, in this case it is mainly due to its being an active research field and under constant review, taking part in it, on the same footing, scientists and teachers (mainly those with early stages students).

It is clear that to understand what VNOS is we must have some knowledge of scientific contents in order to know what we are talking about. Those contents should be determined by the teachers, according to the age of their students and their cultural status.

The View of Nature of Science is, as Durant states, a knowledge of higher level. It deals with the ways in which science is built, how scientific knowledge is generated, the internal structure of science in data, laws and theories, and how those theories substitute one another over the history.

We could say that the *View of the Nature of Science* relates to scientific contents as linguistics is related to language speaking. Linguistics handles the different languages, grammatical structures, relations between them and the transformations undergone as the object of its study.

At the present time the teaching of science has become a cross-disciplinary research field, on which converge, beside the classical areas, the ideas of knowledge representation and knowledge management. From the first one it takes mental representation methods, which perfectly fit the Piaget and Vygotsky models and social views of Kuhn's[2]; from the second, explicit and tacit knowledge concepts are taken, in coincidence with the Dreyfus brothers study of expert levels of knowledge.

Within this new point of view, the scientific contents or explicit knowledge is to be found in textbooks, reports and memories. Implicit or tacit knowledge, on the other hand, lives only in the minds of

[2] Kuhn, T. S., 1962. *The Structure of Scientific Revolutions*. Chicago: The University of Chicago.

professionals, being impossible to represent it in reports, notes or to be easily explained.

As research goes on in the field of science teaching, it becomes more and more clear that the View of the Nature of Science is a tacit or implicit knowledge, being mandatory to the teachers to master it in order to transmit it to their students. Helping the school masters to achieve this level of knowledge is the main goal of the present project[3].

3.2. NATURE OF SCIENCE AND ITS CONNECTION WITH EDUCATION: A CASE STUDY IN POLAND

On February 21-23, 2017, scientific training called *The Nature of Science and its Connection with Education* was organized at the Kujawy and Pomerania In-Service Teacher Education Centre in Bydgoszcz, Poland (KPCEN Bydgoszcz). The participants were 30 female teachers from kindergartens and early years of primary school education, interested in the topic. They were the first to respond to an invitation to the training that was sent to all kindergartens and primary schools in Bydgoszcz and eight counties of the Kujawy and Pomerania province, which is the main area of teacher development activity for KPCEN Bydgoszcz.

At the beginning of the training, the participants were asked to complete the questionnaire *Views of Nature of Science*. Each participating teacher signed her questionnaire with a nickname or a symbol. At the end of the training, on the final day, all the participants completed the same questionnaire again and signed it with the same nickname/ symbol that was used on the entry questionnaire.

This procedure enabled the comparison of the questionnaire results at the *entry* and *exit* for the same people as well as the examination of the increase in the participants' knowledge or the shift in their views of science. The topic of *Archeology in the Classroom* was investigated in the same way. The teacher training activities lasted two days and included 10 teaching hours. During the workshops the teachers were extremely engaged in doing the suggested experiments, which they analysed from the scientific perspective, searched for explanations, independently inquired: *Why is it happening like that?*

The analysis of questionnaire results was conducted through comparing the richness

Teacher training regarding *What is the world made of* in Bydgoszcz.

[3] McComas, W. F.; Clough, M. P.; Almazroa, H., 1998. The role and character of the Nature of Science in science education. In W. F. McComas (Ed.), *The Nature of Science in science education: Rationales and strategies,* Vol. 3, p. 39. Dordrecht, the Netherlands: Kluwer Academic Publishers.

and length of the responses given by the participants before the workshops started and at their completion.

There was a relatively large increase in the richness of responses to these questions which focused on issues particularly emphasized during the workshop activities. This demonstrates that the classes were interesting and stimulated the participants to think about the links of science with education.

Detailed results of the questionnaires

I. TITLE OF THE QUESTIONNAIRE:

Views of Nature of Science (VNOS)

AIM OF THE QUESTIONNAIRE:

Study of the increase in the participants' knowledge related to general views on science

CHARACTERISTICS OF THE RESEARCH PARTICIPANTS:

- The Questionnaire "Views of Nature of Science"[4] was administered among the participants of the workshop "The Nature of Science and its connections with education" twice –at the entry and exit.
- The participants chose their nicknames, which they used in both questionnaires –thus enabling the comparison of the responses.
- 23 pairs of questionnaires were obtained (*entry* + *exit*) –this is the basis of the comparative analysis of the results.
- 9 *entry* questionnaires had no *exit* equivalents.
- 3 exit questionnaires had no entry equivalents.

VIEWS OF NATURE OF SCIENCE –
THE QUESTIONS:

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

2. What is an experiment?

3. Does the development of scientific knowledge require experiments?

   - If yes, explain why. Give an example to defend your position.

   - If no, explain why. Give an example to defend your position.

4. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence, or types of evidence, do you think scientists used to determine what an atom looks like?

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?

[4] Lederman, N.G. et al., 2002. *Journal of Research in Science Teaching.* Vol. 39, Nº 6, pp. 497-521.

- If you believe that scientific theories do not change, explain why. Defend your answer with examples.

- If you believe that scientific theories do change:

  (a) Explain why theories change.

  (b) Explain why we bother to learn scientific theories. Defend your answer with examples.

7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence do you think scientists used to determine what a species is?

8. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

   - If yes, then at which stages of the investigations do you believe that scientists use their imagination and creativity: planning and design; data collection; after data collection?

Please explain why scientists use imagination and creativity. Provide examples if appropriate.

- If you believe that scientists do not use imagination and creativity, please explain why.

9. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

10. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

    - If you believe that science reflects social and cultural values, explain why and how.

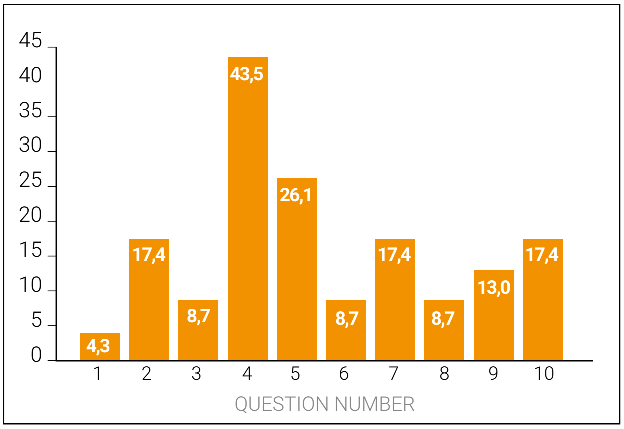
Defend your answer with examples.

- If you believe that science is universal, explain why and how. Defend your answer with examples.

The greatest increase in the length of the response was observed in question 4. The 43,5 % of the participants enriched their responses.

VIEWS OF NATURE OF SCIENCE QUESTIONNAIRE RESULTS

Percentage of workshop participants who displayed increase or enrichment of their responses to each of the questions of VNOS



Question 4: **Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence, or types of evidence, do you think scientists used to determine what an atom looks like?**

Sample answers:

ENTRY	EXIT
No response	Attracting and repelling particles "+" and "-"
Because they got to know the structure of the atom thanks to modern technology.	- Theories of quantum mechanics - Radioactive research - Computer research
I have no idea.	They studied different objects by establishing their properties in different conditions.

A relatively large increase in the length of the responses was also observed in question 5. 26,1% of the participants enriched the content of their responses.

Question 5: **Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.**

Sample answers:

ENTRY	EXIT
No response	A scientific theory is a hypothesis that has been confirmed and has been supported by many studies. If a scientific theory is universally recognized, it can become a scientific law.
Yes, there is.	A theory is what we think. A scientific law – what we prove, e. g. by an experiment.
There isn't. I think that each theory is guided by some laws.	A scientific theory can become a scientific law. We have a theory about objects attracting each other; we create an experiment. We have this theory supported by an example and it becomes a scientific law.

The results of the questionnaire *Views of Nature of Science* and the participants' opinions expressed during the workshops show that teachers:

- Recognized the training, the conducted experiments, as a rich source of scientific knowledge
- During the classes, analyzed the results of the experiments **more carefully and deeply** than in their previous work with children in this field
- By experimenting, became more interested in the scientific basis of the studied phenomenon
- Have been inspired to seek their own solutions in the field of effective scientific education of young learners
- Approached the scientific knowledge very concretely, practically
- Spoke in simple language about "difficult" scientific knowledge
- Awakened their cognitive curiosity while performing the proposed experiments
- Felt joy when discovering the results of the experiments
- Have a great need for science-based training.

II. TITLE OF THE QUESTIONNAIRE:

Archaeology in the classroom

AIM OF THE QUESTIONNAIRE:

Study of the increase in the knowledge of the participants of the archaeology workshop.

Teacher training in *Archaeology in the classroom* in Bydgoszcz.

CHARACTERISTICS OF THE RESEARCH PARTICIPANTS:

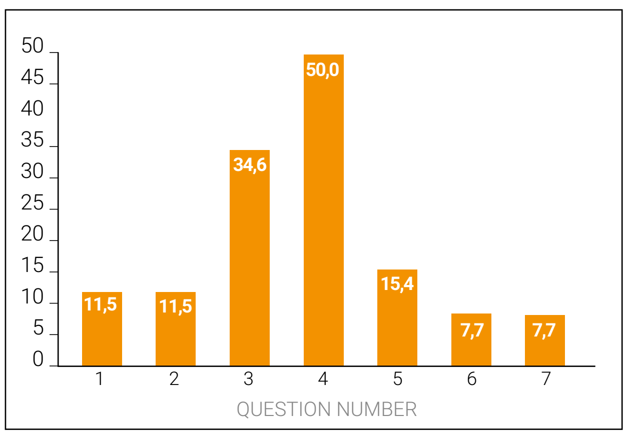
- The Questionnaire *Archaeology in the classroom* was administered among the participants of the workshop *The Nature of Science and its connections with education* twice –at the entry and exit.
- The participants chose their nicknames, which they used in both questionnaires –thus enabling the comparison of the responses.
- 26 pairs of questionnaires were obtained (entry + exit) –this is the basis of the comparative analysis of the results.
- 7 entry questionnaires had no exit equivalents.
- 3 exit questionnaires had no entry equivalents.

ARCHAEOLOGY IN THE CLASSROOM
THE QUESTIONS:

1. What is, from your point of view, archaeology? What does it deal with?
2. Is there any relationship between archaeology and other disciplines?
3. What is the main source of information in archaeology?
4. Would you know what the basic techniques used by archaeologists are?
5. Do you think that archaeology can employ scientific theories? Why?
6. Identify some areas where you can find an archaeologist working.
7. To explain the origin of modern man, some archaeologists believe that the evolution towards homo sapiens occurred in various parts of the planet at the same time; others argue that the homo sapiens emerged in Africa; others believe the three continents evolved at a time but there must have been some genetic exchange. How is it possible that such different conclusions are produced if all these scientists are studying the same data sets?

ARCHAEOLOGY IN THE CLASSROOM QUESTIONNAIRE RESULTS

Percentage of workshop participants who displayed increase or enrichment of their responses to each of the questions ARCHAEOLOGY IN THE CLASSROOM



The greatest increase in the length of the response was observed in question 4. 50% of the participants enriched their responses.

Question 4: **Would you know what the basic techniques used by archaeologists are?**

Sample answers:

ENTRY	EXIT
No	He/ she makes: sketches, photos, maps with notes based on found things, lab work.
Unfortunately, I don't know any	Observations, records, work with materials foundtheir properties in different conditions.
No response	- Analysis of maps - Analysis of artifacts - Analysis of excavations - Observations - Notes, sketches

A relatively large increase in the length of the responses was also observed in question 3. 34,6% of the participants enriched their responses.

Question 3: **What is the main source of information of Archaeology?**

Sample answers:

ENTRY	EXIT
Objects found	- Analysis of material remains - The use of geophysical methods - Observation and survey of the site - Cartography - Engineering (buildings, machinery)
Exhibits, objects found	Search and study - archaeological sites, excavations, artifacts - objects, things that, based on an analysis, build an image of social life of people in a given period.
Discovery	- Stationary objects, e. g. buildings - Objects - Artifacts

The results of the questionnaire ***Archaeology in the classroom*** and the participants' opinions expressed during the workshops show that teachers:

- Before the training, were not interested (or only superficially and generally) in the issues of archeology.
- They took active part in the proposed activities with interest and engagement.
- Highly evaluated the training materials.
- Have discovered that an archaeologist does not just dig out finds from the ground.
- Broadened their knowledge of the work of the archaeologist.
- Emphasized the fact that seemingly difficult aspects of the work of the archaeologist can be expressed in simple language, clear and understandable for children.
- Want to transfer the knowledge gained during the workshops to their work.
- Despite the short duration of the archaeological workshop, they got extremely inspired to search for knowledge on topics related to archeology.
- Expressed the need to continue participating in this type of training.

To summarize, the above analysis of questionnaire studies on *Views of Nature of Science* and *Archaeology in the classroom*, teachers of kindergartens and early school education acknowledge that:

- Their scientific knowledge is not on a high level.
- They need to change the above-mentioned fact.
- They are open to new approaches to shaping children's scientific interests.
- Talking to children about scientific issues should not be avoided just because they are very young.
- After the training, they looked differently at the experience of discussing experiments with children.

Since September 2017, employees of the Kujawy and Pomerania In-Service Teacher Education Centre in Bydgoszcz have extended the teacher training and development offer for kindergarten and early childhood education teachers with modules related to the scientific approach to learning about the surrounding world.

3.3. Methodological proposal: beyond the NOS

In the historical perspective we have just described, the final link in the methodological chain of science teaching is based on the knowledge of the Nature of Science. The underlying philosophy of this construct, NOS, is the postulate that science has its own structure, a structure that the student must discover in order to understand the behaviour of nature. To our understanding, this is an erroneous approach, confusing reality and mental representation. **NOS tells us the structure of science is no more than the structure of the mental representations that human beings develop to allow them to assimilate the behaviour of a limited aspect of nature.**

These representations coincide what Piaget calls **schemas,** the main components of which, in the case of science, are magnitudes, laws, and models or theories[5].

Knowledge of the Nature of Science is replaced in our view of learning by **the need for the student to become conscious of the nature of human knowledge and how this is constructed.**

Jean Piaget, psychologist and biologist.

According to this view, the development of learning from the point of view of the cognitive process of knowledge construction, should be considered a process of question-led research (Inquiry). In this process, the student becomes the researcher, so that they discover and use the innate mental structures on which the representation of our knowledge of the real world is based: conceptualisation and the discovery of laws. These *two mental operations* are developed simultaneously in all human beings who acquire a mother tongue, based on these concepts[6].

The first models of knowledge were developed, of course, in ancient Greece. They are based on the mental representation of concepts, which Plato called *ideas* and Aristotle *universals.* Although both describe the reason for their presence in our minds (innate for Plato and the fruit of experience according to Aristotle) neither of them devised a mechanism by which this knowledge is verified or substituted. In the present day, the only model

[5] Piaget, J., 1972. *The Principles of Genetic Epistemology*. New York: Basic Books.
[6] Pinker, S., 1999. *Words and rules*. Massachusetts: Massachusetts Institute of Technology.

for the evolution of human knowledge is, as we have said, that proposed by Piaget, based on very simplified representations of reality and structured into *concepts, laws,* and *models or theories*[7].

These representations are consolidated, developed, and modified through assimilation processes (acquisition of competencies) and accomodation (varying the concepts, models, or theories, that make up the representation). The Piagetian model of knowledge construction is equivalent, if not identical, to that used later by Kuhn for the evolution of scientific knowledge, applied to scientific societies (see, for example, The Structure of Scientific Revolutions).

Thomas Kuhn. Physicist, historian and philosopher.

In addition, this model is that used in artificial intelligence, where the computer tries to mimic the human mind; this is the inverse model to that introduced in the Cognitive Revolution (modelling the brain as a computer), and which is still predominant in cognitive psychology. Teachers must be conscious of the fact that the evolution of science is a social process, with very marked coincidence with the processes described by Vygotsky, which also include the Piagetian operations of assimilation and accommodation (applied to societies of people)[8].

Leo Vygostky, psychologist.

In our opinion, an important process in our research is the appearance in the students of a certain resistance to new models (if these have not been constructed by the students themselves) when these limit or invalidate previous models, in a similar way to the social behaviour Kuhn describes when normal science is replaced by a more advanced vision.

As we can deduce from these considerations, at the base of our pyramid of the representation of reality are concepts. In the case of science, the only difference with other types of representations is the fact that only measurable concepts (*magnitudes*) are considered to be constituent elements of that knowledge. This requirement allows us to use mathematical formalism to deal with the measured values and make quantitative predictions.

[7] Piaget. In: Wikipedia. Availible at: <https://en.wikipedia.org/wiki/Piaget%27s_theory_of_cognitive_development>.
[8] Vygotsky, L., 1979. *Mind in Society: The Development of Higher Psychological Processes*. USA: Harvard University Press.

The basis of all scientific representations includes the five fundamental, or primary, magnitudes, as verified through dimensional analysis: space, time, matter, energy, and information, with this last parameter having been introduced by Shannon in the middle of the 20th century as a fundamental magnitude in Information Theory. This new magnitude has been extended to all areas of knowledge, fundamentally computer science and robotics (which are impossible to understand without this concept). It is also essential in biology, in order to understand the scope and encryption of the genetic code. But we will look at this subject in subsequent projects.

Applying the methodology to the project *What is the world made of*

When a student come into our classroom, as we have said, they already know how to conceptualise and elaborate laws perfectly. For that reason we can put them in situations where they can utilise these mental capacities[9].

We start by observing a *natural phenomenon*, such as the process by which clothes get dry when they are hung out, or the inverse, where the glass in a cold window fogs up. We then analyse the phenomena involved and choose one to study in our classroom.

The first step in our research consists of *doing experiments*, manipulating reality by reproducing the natural phenomenon we have selected in our classes. To do this we used the *technology* found in the classroom itself: scissors, glue, paperclips, glasses, and so on. For this project we chose experiments relating to intermolecular forces, experiments on change of state, surface tension, and the like. Specifically, we look at the forces of cohesion and adhesion, which make a drop of water stay between our forefinger and thumb, and the elastic behaviour when we separate them.

Cohesion and adhesion forces in water.

The second step consists of describing what happens in the experiment, concentrating only on the important elements. The description should lead us to discover new processes and find a name for these, as it is the case of cohesion and adhesion, based on the tendency of a liquid to stick the skin of the fingers and stretch the drop of water, which resists breaking. We christen these phenomena (we **conceptualise** them) with the names of adhesion and cohesion. We must explain to our students that, for an experiment to be useful, the results must be the same wherever the experiment is conducted and whoever carries out the experiment.

The third step consists on looking in a little more detail at the process itself. To do this we

[9] López Sancho, J.M., 2003. *La Naturaleza del conocimiento*. Madrid: Central Catequística Salesiana.

use the pathway of questions: Why does water stick to the skin of our fingers? Does it only stick to fingers, or to any object? How does the drop stretch without breaking? These questions can lead us to other experiments that give us an answer, or to a process of reflection in which we can clarify this point.

Next, we talk to our students about the best way to describe the behaviour of nature in accordance with the philosophy of Leucippus, and discover the laws that govern this behaviour, in other words, the fixed guidelines that are always fulfilled in nature. To do this we can use various kinds of gloves to see if the liquid adheres to any type of material; we can also use other liquids, like cooking oil or soft drinks, to see if every liquid behaves in the same general way.

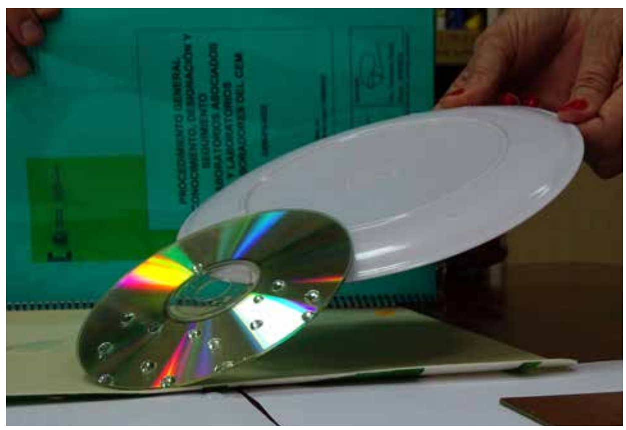
Once we have reached the conclusion that all the liquids we have used exhibit elastic behaviour and stick to solid surfaces, we can define the laws: all liquids exhibit cohesion and adhesion.

Surface tension.

We have arrived at these laws by *induction* (i.e., assuming that any liquid behaves in the same way as the liquids we have used). With our students, we can also discuss the possibility that somebody, somewhere, discovers some liquid that does not adhere to a surface. If this situation arose (which is always possible), we would need to change our laws immediately.

This, then, focuses us on the fundamental question - why does water obey these laws? Surely the answer lies in the nature of water. In order to addresss this issue, we have to know what water is made of.

If we want to discover what water is made of, we must subject it to extreme situations, such as the processes in which it appears and disappears from our sight. The condensation of water vapour on a cold surface (a drinks can) or the evaporation of water from the surface of a table after it has been wiped with a damp cloth, can give us the answer.



Adhesion forces in the CD surface.

In this way we arrive at the **construction of models,** which can include things that we are unable to detect with our senses, either because they are too small (like molecules or atoms) or because we are not sensitive to their magnitudes, such as the ultrasound used by a remote control or the infrared or the ultraviolet radiation that is generally known as black light.

Through our creativity, we can assume that water is in the air in the form of very small particles that we cannot see, but when these join together in large quantities on the cold surface of the can, they form droplets.

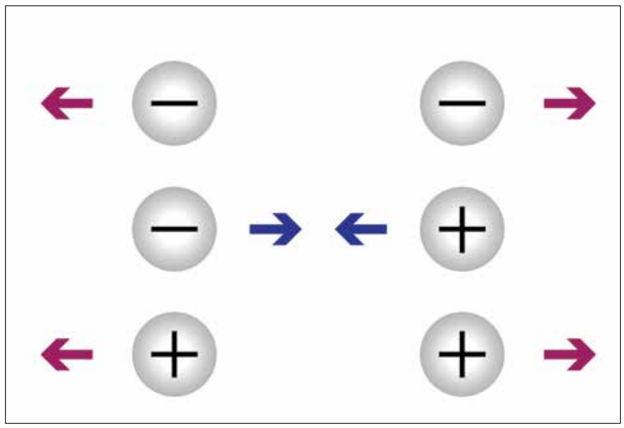
And if water is made of molecules, we can assume (by induction) that other things, like ice and other solids, are made of molecules too. In this way we are able to develop a hypothesis that we can express in the following way: all materials are made up of very small particles that are invisible to the naked eye, which we call molecules.

When these are very spread out from one another they form gases. If they are in contact, but not stuck to one another, like marbles in a bag, they form the liquid state. When they are “stuck” to others, which prevents them moving, we say that they are in a solid state. And we can use the mentioned marbles to construct an *analogical model*.

Next, we have to test our model, using it to try and explain the processes of cohesion and adhesion we observed in our experiments and described in our laws: why do water molecules join together, producing cohesion? Why do water molecules stick to those in the skin and other substances?

In order to explain the observed macrocospic behaviour we must introduce new forces between molecules, which cause them to join to each other. When the molecules that join together are the same, we call the forces cohesion. If they are different, we call them adhesion.

Continuing with our example where we follow a research path based on questions, to help us to discover the nature of scientific knowledge (concepts, laws, and models), we must turn to a different scientific field: electricity. Thanks to new experiments we discover that intermolecular forces are due to the distribution of charge between the molecules, and that these obey the general laws of electricity: charges of the same sign repel and different signs attract.



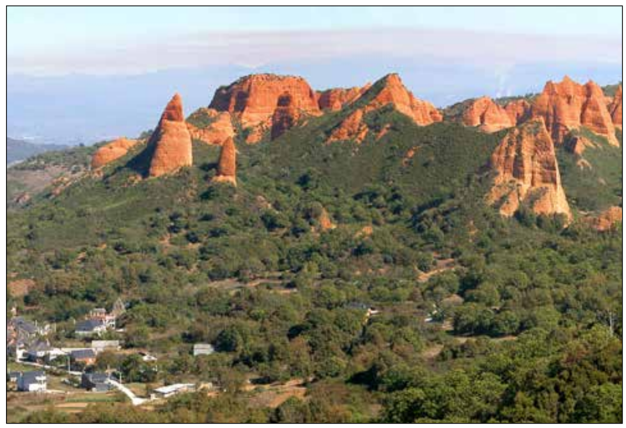
The electricity laws.

Once the students have followed the experimental pathway described, based on questioning, they summarise the route they have taken, focusing on the way they have developed their mental representations. Along the pathway they have formed new concepts, new laws that they were not aware of, and have also resorted to pre-learned knowledge (electricity) to explain and give the reasoning for the laws discovered. The students have integrated NOS and NOSI in a process of metacognition, the explicit knowledge of which will be very useful throughout their lives.

Example of methodological delimitation: *Archaeology in the classroom*

The part of *Archaeology in the classroom* focuses, as its name suggests, on archaeology, the study of ancient societies based fundamentally on the analysis of their material remains. Archaeology belongs, therefore, to the field of social and human sciences. The nature of this subject makes it eminently interdisciplinary, for it is necessary to collaborate with many scientific disciplines and use different technologies. In effect, geology, geography, mathematics, biology, engineering, and so on, are currently developed contiguously to archaeology.

This makes archaeology an ideal discipline for working on in the classroom. Consistent with this idea, the main goal of the initial training was that the teachers clearly understood, above all, that the study of ancient societies and, in particular, archaeological research, offer many possibilities for teaching science in the early stages of education. In this sense, we could say that the driving force behind the project is the usefulness of archaeology, both as a tool for teaching social and human sciences in the classroom and its potential for teaching scientific reasoning. This is revealed through the study of several closely interrelated aspects: for example, culture and its materiality as a distinctive element of the human being; the interaction between the environment and society and the relationship this action has with environmental problems and landscape formation; or, for example, relating to the above, the role of landscape analysis and the evolution of spaces over time, as a way of understanding processes of change in societies (in other words, the importance of understanding spatial relationships to comprehend societies); or the understanding that the diversity of societies in time and space necessarily leads to a respectful acceptance of that diversity; and indeed, an appreciation of our cultural heritage. The landscapes, the archaeological deposits, the remains exhibited and safeguarded in museums, these are the tangible and visible past, our memory; and archaeology has an enormous responsibility to its knowledge, its protection, and its conservation.



Archaeological landscape. Las Medulas, Spain.

When proposing the guiding axis for the training project, articulating the content for this, and designing activities for structuring and carrying out the classroom work with the children, **archaeological method** was selected as the focus. The question of “methodology” seems at first excessively reductionist but, in the end, we decided to follow this methodological path, given that this, together with the interdisciplinary nature of archaeology, allowed us to better adapt our proposal to the school curriculum of the various educational stages (from infant education up to the final years of primary). Additionally, it promotes the development of transversal activities involving several subjects (mathematics, language, visual art education, etc.). Moreover, we consider this pathway to offer innumerable possibilities for developing basic cognitive skills for reseach. On the other hand, it allows the content to be better-adapted to the educational diversity represented by the project partners (Lithuania, Estonia, Poland, Italy, and Spain).

The initial training sessions were divided into 6 thematic blocks. Each of these 6 blocks was aimed at the understanding of a basic concept for scientific reasoning in archaeology and, therefore, understanding the environment of schoolchildren: these concepts are *material culture* or *archaeological record* (second block: Foundations of archaeology), *site* and *landscape* (third block: Archaeological methods I); *time* and *stratigraphy* (fourth block: Archaeological methods II); *context* (fifth block: The archaeology lab) and, finally, *heritage* (sixth block: Why is the past important?). These five blocks should be preceded by a first block (Initial evaluation), where teachers fill out a questionnaire structured around the VNOS questions. The questionnaire is completed with an activity, the DART test ("Draw an archaeologist"), which has shown gr eat potential to address false myths and preconceived ideas, both in the teacher training and the classroom, with children of very different ages.

Test DART: drawing an archaeologist.

As you will see in the specific guide dedicated to *Archaeology in the classroom*, these blocks were modified during the development of the project, to adapt the training content so that it worked in the classroom; therefore the structure of the guide does not strictly follow the initial pathway established. The reason for these changes is so that once the teachers have acquired this basic training, they are able to work in the classroom and guide activities according to their particular interests. In any case, the new structure and the result, which is the guide presented here, respect those grand "concepts", fundamental for understanding our immediate environment, its historical depth, and the value of past research.

When putting this project into practice, after the initial evaluation, the different blocks allowed us to guide teachers down a learning pathway where they discovered the transversal nature of archaeology and its content. These days, archaeology is defined as the recovery, description, and systematic study of the material culture of the past, as a way to gain access to the societies that built it.

We insist on the need to delimit the term *past* here: archaeology does not involve the study of rocks or dinosaurs, which fall under geology or palaeontology. Archaeology begins when the first tools, recognisable as such, appeared, and runs right up to the present: from the study of the first hunter-gatherer societies to, for example, the much more recent Spanish Civil War. Based on these concepts, the training is articulated through the study of *time* and *change*, illustrated, for example, by simple stratigraphic sequences.

The idea of *context* has acquired a particular importance, making it possible to coherently link the above with the value of heritage and the need to care for it, because it is testimony to our past and a lasting source of wealth.

These concepts have also allowed us to introduce a fundamental aspect: how research (in this case historical and archaeological research) creates social value and produces sustainable resources. In short, these aspects, listed briefly here, and which will be developed in the guide dedicated to archaeology, have allowed us to specify and convey the fact that all these useful aspects are areas of archaeology, making this subject worth teaching in the classroom.

It is fundamental that this content is addressed in the classroom starting in Early Childhood Education, adapted to the different cognitive stages, as confirmed throughout the development of this Erasmus+ project and reflected in the *Archaeology in the classroom* guide.

Science in the European Heritage context

It is universally acknowledged that the cultural heritage of the past is the only way to understand the reality of the present. And understanding reality is the only guarantee of enjoying freedom of thought, inherent in the critical spirit essential in any democracy.

These ideas were expressed by Aldous Huxley in his work *Brave New World*[10]. In it he warns us against undesirable totalitarian political systems, only possible after prohibiting the study of cultural heritage, in other words, history.

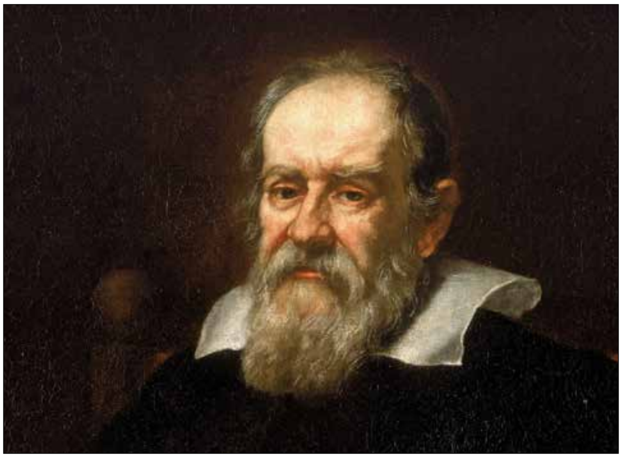
In the oft-repeated words of Paul Preston, *those who cannot remember the past are condemned to repeat its mistakes.*

In this project science has been presented as a way in which people understand a part of reality, which can be described using the limited number of concepts we can measure, weigh, or count, in other words, through magnitudes.

But this activity can not be understood without considering it an important part of the history of humanity in the broadest sense; scientific breakthroughs have profoundly modified societies, and the attitudes of societies have caused impressive steps forward in terms of scientific knowledge.

Scientific research cannot be studied outside the context formed by historical paradigms (with their values and beliefs) in which the researchers were immersed, nor without taking into account the technologies available to the researchers (such as Galileo's telescope), or the mathematical limitations of each period.

[10] Huxley, A., 2005. *Brave New World.* Nueva York: HarperCollins Publishers.



Galileo Galilei Portrait.

For all these reasons, it is evident that it is impossible to maintain this perverse division, which C.P. Snow, an English physicist and novelist, denounced, very appropriately in this context, as the existence of the two cultures[11].

The great historical epochs, from the Stone, Bronze and Iron Ages, to the modern Information Age, have been characterised by their prevailing technology, making a mockery of the persistent omission of science when talking about historical heritage. Arthur Koestler makes it clear in the preface to *The Sleepwalkers*[12]*: In the index to the six hundred odd pages of Arnold Toynbee's "A Study of History", abridged version, the names of Copernicus, Galileo, Descartes and Newton do not occur.*

But humanists are not the only ones at fault. The majority of the stories about specialised science, including Kuhn's The Structure of Scientific Revolutions, focus on groups of researchers without taking into account the influence that society, with its beliefs and superstitions, had on their way of thinking, and their finding and developing of research objectives.

Within this new concept of heritage, teaching in the early stages of education in the EU should, in our opinion, take into account three objectives. It should:

a) Situate the citizens in their place in history, within the context of European cultural heritage.

b) Provide them with sufficient knowledge to be able to take the decisions of a democratic society.

c) Prepare them to undertake productive work in a world of rapid and unpredictable scientific and technological changes, which enables them to have a dignified and enriching life.

With regard to the first point, in our particular context, in Europe, science and philosophy have advanced strongly together. The most important Ancient Grecians could be said to have been as much scientists as philosophers.

Parmenides, Thales of Miletus, Pythagoras, Leucippus, Socrates, Plato, Aristotle, Ptolemy and Archimedes, among many others, tackled important problems, both from the perspective of knowledge on specific matters and the nature of that knowledge itself. Later, indeed very soon after, art became united with science, technology, and engineering.

[11] Snow, Ch. P. Enero 2013. *The Two Cultures*. The New Statesman.
[12] Koestler, A., 1959. *The Sleepwalkers,* Hutchinson.

Dome of Santa Maria de las Flores, by Brunelleschi.

The vault of the Pantheon was recreated, after the engineering efforts involved in ribbed vaults, in the Brunelleschi in Florence, Saint Peter's in Rome, and Saint Paul's in London. With the help of mathematics, **Europe came up with common solutions to common problems,** and these had a common aesthetic, presenting, from that moment on, a common face to travellers from the East, who were confronted by a scene dominated by, firstly, the Romanesque and, later, the Gothic.

From the 12th century onwards, there was great interest in Greek knowledge, in many cases stemming from Arab translations of manuscripts miraculously saved from the library of Alexandria. Translated into Latin at the Toledo School and spread throughout Europe along the pilgrimage routes, these would soon provoke a cultural revolution, the Renaissance, which ended up shaping a European cultural heritage that would never disappear.

In this project we present scientific discoveries as just another part of the culture developed by humanity (in this particular case in Europe) and that is, indisputably, part of the European Heritage.

For this reason, one of the recommendations that we allow ourselves to present to the European authorities is that the subjects on European Heritage include the models and theories developed by scientists; we do not want to fall, in this day and age, into the same trap into which Toynbee fell a little under a century ago and which we commemorate in 2018: *The aim of the European Year of Cultural Heritage is to encourage more people to discover and engage with Europe's cultural heritage, and to reinforce a sense of belonging to a common European space. Our heritage: where the past meets the future*[13].

[13] Europa, 2018. *Año Europeo del Patrimonio Cultural 2018*. Availible at: <https://europa.eu/cultural-heritage/about_es>.

FOURTH PART

POLICY RECOMMENDATIONS FOR IMPROVING SCIENTIFIC LEARNING IN EARLY AGE EDUCATION

4. POLICY RECOMMENDATIONS FOR IMPROVING SCIENTIFIC LEARNING IN EARLY AGE EDUCATION

Our recommendations are inspired by two ideas: the first is to present science as a human construct, with the same characteristics as any other form of knowledge our species has, and that, therefore, is developed through the same methods and mental processes; the second is the need to integrate this scientific knowledge into the historical context in which it developed and which it has influenced, highlighting its importance as an essential ingredient of European Cultural Heritage.

1. Introduce the teaching of science into early stage education within the concept of European Heritage, using the milestones of European history to situate scientific discoveries in time. In our opinion, science and technology are a common creation and a true mark for EU countries. Scientific training in the first stages of education is a necessary link in the socialisation of science.

2. Introduce science education in the context of gender equality. Teachers must teach scientific activity equally to boys and girls, using historical examples and *references from famous women scientists*. It is in the early stages, around the age of 7-8, when the first differences in gender-linked trends appear. After this period our only recourse is to try and modify acquired behaviour.

3. Teach science from the perspective of how science is constructed. The fact that children know the way science is constructed influences their attitudes and approach to scientific breakthroughs, pseudosciences, and esoteric beliefs, so they reject these as non scientific.

4. Unifying the science curriculum in the first stages of education or, at least, establishing a common core of knowledge for all EU countries.

5. Teach science within the framework of new research into science education, such as the NOS and NOSI.

6. Make teachers and their students aware of the mechanism behind scientific knowledge and the way it is constructed: simplified mental representations of reality or certain aspects of this, which are always susceptible to being experimentally falsified. Conceptualisations and models are the mental operations on which scientific knowledge is based.

7. All EU countries agree on the need to teach science at school. We propose that scientific institutions become involved in updating the scientific knowledge of non-university teachers throughout their professional lives.

8. Support the creation of permanent scientific training programmes in science institutions that guarantee that teachers and the results from their classrooms are rigourous and up to date.

9. For us, it is a mistake to split science from the rest of history. The difference between scientific knowledge and all other knowledge is that science deals only with a very limited number of concepts: those that can be measured, weighed, or counted and which we refer to as magnitudes.

10. Create mixed communities of scientists and teachers, avoiding the tendency of both professions to mutually segregate (web platforms and spaces).

All the partners of this SciLit Project.