Teaching Science in Primary Schools: theoretical and practical perspectives from America, Asia and Europe

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Mountain Child

The mountain child —
a fragment of the mountain —
plays in the lap of the mountain

Toddling up the mountain
he plants his feet in the mountain soil
to rise like a mountain
in the land of mountains

The whole mountain
lives inside the mountain child
And in the lap of the mountain
lives the scurrying mountain child

The mountain child sees
a plane flying over the mountain
And he asks his father —
What is that bird?

Nirmala Putul (Translated by Lucy Rosenstein)[1]

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[1] Original poem: https://www.poetrytranslation.org/poems/mountain-child/original.

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Part II
Experience reports and researches on science teaching for children

Foreword

Giuliano Reis

When I was kindly invited to write this the introduction to this book, I immediately accepted. Science and young children in primary schools is such a great combination — and one that is hardly difficulty to validate in real life – that could I not pass up such an opportunity.

When the word "science" comes to mind — and whether it is accompanied by other nouns, like "citizen", "literacy", "education" or "curriculum" — it immediately elicits the thought of two of its fundamental pillars: curiosity and creativity. I am convinced (as many of my readers would be too, I hope) that science would not exist without our innate desire to learn and our capacity to envision something beyond what we already know. A good example of what I want to say is my granddaughter.

Two years ago, my wife and I became grandparents to beautiful Sofia. Although we are "experienced" parents (if there's such a thing) — both of our daughters are young adults now — the physical, emotional, and cognitive development of Sofia never ceases to amaze us. As one friendly neighbor once said, it is as if we could see her "little neurons incessantly firing up". (He was absolutely right.)

During this time with Sofia, she constantly reminds us of how much of the early childhood years of humans are marked by the observation and imitation of what other people do and say around us. For example, if Sofia gets hold of a toothbrush, she will bring it to her mouth in an attempt to brush her teeth even though no one has ever taught her to do so. Likewise, her vocabulary is entirely based on what she has heard other people say in the house, on TV or at daycare:

“please”, “wake-up”, “more”, “get up”, “sorry”, “shoes”, “socks”, “get up”, “water”, “lap”, “my finger”, “be careful”, “no sound”, “my hair”, etc.

This is not to say that Sofia does not go on her own unscripted explorations of the environment: she has eaten sand, licked dirt, grabbed rocks, snow and cigarette butts off the street, stepped on water puddles, rolled on the dirty floors of shopping malls and museums, and even shoved her nose with fibers she pulled out from one of her stuffed animals. (No matter how much we tell her she cannot do some of those things, she often insists on having it her way. She has a strong personality, like many other toddlers her age.)

In coping others or by arbitrarily (so it seems to us) reacting to the existence of beings, objects and sensations within her immediate reach, Sofia is discovering the world using the only tools she has: her body and her senses (e.g. Reis, 2015). That is what human children do. That is how we come to know our limitations and capabilities from an early age. In other words, humans are born budding scientists.

If only there was a way to keep that natural “science-y” curiosity and imagination alive as children turn into adults, we probably would have to worry less about pseudoscience or the likes of the negationist movement. Even the scientific literacy performance in the PISA international test would be considered less relevant to nations. Science (or at least its unique way of seeking to understand phenomena) would be a more common factor in people’s daily decision-making — from financing to climate change to social media use. (It goes without saying that the nature of science is permeated with the ethical and moral imperfections of its doers – a.k.a. scientists – but that is out of the scope of my argument here).

It is this aspiration that cuts across all the chapters in this book, thus bringing them together: they speak to ways one could keep young children engaged in science, no matter where they are. In addition, they are founded on the belief that primary schools are ideal places to nurture young students' passion for this type of knowledge. Missing the chance to build on something that is already there (our inborn curiosity and imagination) is a disservice to those young minds as well as our societies. More so: it would be illogical to wait until children are older to start furthering their interest in science as a human endeavour. Why wait?

Finally, I invite readers to feel free to consider adjusting the ideas and experiences reported here to their own realities — they are not infallible recipes of success. Above all, the practical and theoretical narratives in this book are meant to inspire change, to encourage (if not provoke) one to see how primary school science can be made more relevant. Enjoy.

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Introduction

Alessandra A. Viveiro, Maria Cristina de Senzi Zancul & Pedro Neves da Rocha

This eBook gathers together texts, produced by academic authors and researchers from different countries – Brazil, Portugal, Japan, Colombia, Germany, United States, Argentina and Spain –, which deal with an extremely relevant topic in our days, that is, teaching science to children. The importance of scientific education has been largely recognized, since scientific knowledge is fundamental in defining individual and collective choices and actions, which influence the quality of life of all beings on our planet.

Those who work or live with children know that they show great curiosity and fondness in science-related topics from a very early age. But this interest must be maintained throughout life and, more than that, it must be expanded and converted into knowledge and practices that contribute to the construction of a more egalitarian society and to the protection of the environment.

The challenges for this kind of science teaching to be effective are not few, as it is necessary, firstly, to guarantee universal access to schooling and to stay in school, with special attention to girls, and children with special needs, to offer teachers training that can subsidize work with science content, equip schools with spaces and materials to carry out different activities. These challenges and many others need to be faced, especially through public policies that meet the demands of each society, each country, within its needs and specificities.

We consider scientific education a right for all individuals and advocate that it be offered systematically, by all education systems, in all nations, beginning already at the early years of schooling.

The texts organized here refer to contexts and realities in the authors' countries. However, the reflections and proposals contemplated by them, whether due to similarities with other realities, or by individuals that reflect specific issues, can lead to analyzes of the possibilities and challenges of teaching science to children in different places.

This eBook is divided into two parts. In the first, there are works that deal with more general themes of science teaching for the first years of school, related to the programs and curricula of science teaching, in each one of the countries. In the second part, the texts address more specific issues, such as inclusive education, incorporation of the nature of science in teaching, scientific literacy, innovative learning environments, learning communities, contextualized.

Preceding the thematic chapters, we present an introductory text, written by Pedro Neves da Rocha, which aims to inform readers about the terminologies of the different national education systems covered in this eBook. To achieve this goal, the International Standard Classification of Education (ISCED) was used, which states common criteria and stratifies levels of formal education around the world.

The chapter that opens the first Part, written by Ana Valente Rodrigues, Patrícia Christine Silva and Isabel P. Martins, provides a historical overview of science teaching in the early years in Portugal. The authors defend science education as a universal right that must be provided to children from a very early age. They also consider that the propositions presented, although they refer to the context of their country, can be adapted to other contexts.

In chapter 2, Daniela Schmeinck describes the bases and assumptions for teaching natural sciences and social sciences in primary schools in Germany. According to the author, the country follows an integrated thematic approach that aims to prepare children to act, in the present and in the future, in a world marked by complex and interdependent problems and issues.

From the United States, Valarie L. Akerson, Tulana Ariyaratne, Claire Cesljarev and Nader El Ahmadie, in chapter 3, also provide a brief presentation of the most recent early years science curriculum in their country, from the 1990s onwards. From that history, the authors indicate the need for policies to encourage the effective inclusion of science in curricula, in addition to defending the need for investment in primary teacher training in sciences.

Chapter 4, prepared by Hisashi Otsuji, addresses the context of Japan, internationally recognized for its strong scientific education. The author presents modern and contemporary Western influences on Japanese education since the third quarter of the 19th century, highlighting the diffusion of classical trends like Pestalozzi and Fröbel, passing through the influences after World War II, a context in which international influences mixed with traditional cultural values.

Maria Cristina de Senzi Zancul and Alessandra A. Viveiro, from Brazil, in chapter 5, present some proposals that can be incorporated into elementary school teachers training, to encourage science education for children. The authors argue that the Freirean framework can support a problem-posing scientific education that stimulates dialogical communication and the construction of autonomy.

Opening Part II, chapter 6 was written by Leonir Lorenzetti, also focused on Brazil, and deals with the influence of the Science-Technology-Society (STS) Approach and the perspective of Scientific and Technological Literacy (STL) in the country, committed to the formation for citizenship. In the contemporary context, the ability to understand the world around us, in addition to establishing connections between everyday life and systematic knowledge, is essential, and can be stimulated from an early age based on the two perspectives presented.

Still in the Latin American context, Diana Carolina Castro Castillo and Rosa Nidia Tuay Sigua, from Colombia, in chapter 7, address the issue of inclusive education. More specifically, the authors approach science teaching to blind people, using strategies based on modeling, that is, the representation of concepts and phenomena based on other models.

From Argentina, Jhon Deivi Acosta Paz, Alejandro Pujalte and Agustín Adúriz-Bravo, in chapter 8, investigated the conceptions that primary school students had regarding scientists and scientific work, based on drawings produced by children – which carried distorted images. On the other hand, through intentional educational work, these images could be deconstructed, thus showing that it is possible to overcome such conceptions through science teaching.

Chapter 9, written by Bento Cavadas, Marisa Correia and Elisabete Linhares, deals with a specific case in Portugal: Innovative Teaching Environments (ILE), aimed at initial training of science teachers. The authors present a study with undergraduate students participating in the program entitled CreativeLab_Sci&Math, who considered that the ILE promoted positive impacts on their training, through the diversification of strategies, resources, methodologies and perspectives.

To close this eBook, chapter 10 presents a case in Spain. The authors Adrian Martínez Beato, Granada Muñoz and M. Ángeles de las Heras Pérez present the concept of Learning Communities. Dealing specifically with science teaching, the chapter addresses the way in which experimental activities are carried out in a primary school in the city of Sevilla, involving students, teachers and volunteers from the community, from an investigative and interactive perspective.

Correspondence between the basic education levels in national systems according to the International Standard Classification of Education: a brief guide for the readers

Pedro Neves da Rocha

This introductory text presents a brief explanation of the International Standard Classification of Education (ISCED), elaborated by the United Nations Educational, Scientific and Cultural Organization (UNESCO), Europe Union and the Organization for Economic Cooperation and Development (OECD), to establish criteria for comparison between formal education national systems. Levels 1 to 3, referring to Basic Education, and level 0, related to Early Childhood Education, are specifically addressed for the following countries: Argentina, Brazil, Colombia, Germany, Japan, Portugal, Spain, and the United States of America – which are focused in the various chapters of this book. In addition, we present a glossary with some terms used in these countries, in order to better situate the readers of this book.

Keywords: ISCED, Basic Education, Levels of Education

INTRODUCTION

This eBook focuses on sharing educational experiences related to science teaching, at formal education, in different countries: Argentina, Brazil, and Colombia, in Latin America; Germany and Spain, in Europe; Japan, in Asia; and United States of America. Thus, this introductory text has the objective of familiarizing the reader with the different denominations and scopes of the educational systems dealt with in this book, in addition to possible correlations, similarities and divergences between them. We will focus in particular on the primary level of Basic Education, the scope of the chapters in this eBook, in addition to the secondary level – since this also encompasses Basic Education, and therefore we deem it necessary to distinguish between the two.

We emphasize that we do not intend to discuss specificities of the essence of these systems, determined by their history, sociocultural and material conditions. Investigating the essence of each national educational system is a task that requires rigor and depth – and each chapter makes this move with primacy, for its context. In a much simpler way, we only intend to stick to the structural aspects that govern the systems, mainly so that the exchange of investigations intended in this book is facilitated.

For this purpose, we will rely mainly on the International Standard Classification of Education (ISCED). This comparison system was created in partnership by the United Nations Educational, Scientific and Cultural Organization (UNESCO), Europe Union and the Organization for Economic Cooperation and Development (OECD). Such a system encompasses both formal and non-formal educational programs, national or subnational. Its motivation is to create the possibility of international comparison between statistics and national educational indicators.

ISCED was created in the 1970s, revised in 1997 and has a third version published in 2011. ISCED is divided into 2 focuses: Program (ISCED-P), which classifies the educational system, and Attainment (ISCED-A), which classifies the education degree of each individual. Subsequently, ISCED 2011 provided details for the different educational fields (ISCED-F) within each level (for example, general/academic, vocational/professional), in the different national (and subnational) proposals, in 2013. ISCED-A and ISCED-F will not be covered in details in this text. However, further details can be found in the complete publication[2].

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[2] http://uis.unesco.org/en/files/international-standard-classification-education-isced-2011-en-pdf. Access in: Oct. 6th, 2022.

A BRIEF EXPLANATION OF THE LEVELS ACCORDING TO ISCED

Currently, ISCED considers 9 levels of education, numbered from 0 to 8, in an increasing degree of complexity and specialization:

- ISCED 0: Early childhood education
- ISCED 1: Primary education
- ISCED 2: Lower secondary education
- ISCED 3: Upper secondary education
- ISCED 4: Post-secondary non-tertiary education
- ISCED 5: Short-cycle tertiary education
- ISCED 6: Bacherlor's or equivalent level
- ISCED 7: Master's or equivalent level
- ISCED 8: Doctoral or equivalent level

To determine the level of each educational proposition, different main and subsidiary criteria are used. Among the criteria, the following can be used: the educational properties of the program, as well as its content (level of complexity and/or focus); institutional context; existence or not of entry requirements; students' typical age; program duration (isolated or cumulative). In addition, the following can be observed: composition and qualification of the pedagogic staff; existence or not of regulatory curriculum; if it is part of compulsory education or not. The classification also takes into account the accumulation and sequencing between levels, recognizing the multiple paths that can be followed in the educational trajectory of a subject in each educational system.

Among these levels, ISCED 0 – Early Childhood Education corresponds to serves children from 0 to 6 years old. It is focused on the care and support for babies and children, in addition to stimulating the beginning of their cognitive, physical and socio-emotional development. Another objective of this level is usually to insert the child in social environment, outside of the family. However, this level is normally not part of compulsory education (but there are cases where it already has at least one year of compulsory education, as in Argentina and Colombia).

There is a diversity of terms for education aimed at this age group, as a reflection of different propositions, objectives and forms of institutionalization. A well-known term is *Kindergarten*, originated in Froebel's pedagogical approach. In Germany, where this approach is originated, and in the USA, the German term is commonly used. Both in Brazil and Portugal, a Portuguese translation is used: *Jardim de Infância*. The reference to the period prior to compulsory school education is also presented in terms such as *Pré-Escola, Educación Preescolar; Preschool*. Historically, institutions dedicated to the care of babies and children also emerged as a demand/right of working mothers, or even in health care for babies and young children. Therefore, there are terms more related to this type of institution, such as *Creche*, *Berçário*, *Daycare*, *Nursery*. In Japan, the names *Yoichien* and *Hoikuen* are used for earlier and later stages of Early Childhood Education.

Next, ISCED 1, ISCED 2 and ISCED 3 levels correspond to what we generally understand as Basic Education. It has a more general approach in relation to its contents (although it can be split into specializations in more advanced school years, in terms of general or vocational education). In addition, levels 1 and 2 are usually compulsory, as it is recognized as a universal right.

Compulsory education in the vast majority of countries begins at level 1, also called Primary Education. As this is the first formal level, there are no entry requirements for this one, other than the minimum age (typically between 5 and 7 years old). In general, its objectives are the introduction to the teaching of reading, writing and fundamental mathematical knowledge. Regarding the areas of knowledge, the primary level tends to be generalist, but multidisciplinary or interdisciplinary. In addition, it has one main class teacher, but in certain cases they count with the collaboration of specialist teachers in certain areas. The duration of this stage is 4 to 7 years, and the global average is usually 6 years.

As a sequence to level 1, educational programs at level 2 are called *Lower Secondary Education*. As it is sequential, attending the level 1 is a requirement to enter level 2. Furthermore, this level is aligned with the contents and disciplines covered in level 1, with a greater degree of complexity and specialization. This increase in complexity is reflected in the teaching staff, which is now composed of several specialists for areas or subjects. The duration proposed is the result of the accumulation between levels 1 and 2. Thus, level 2 can last between 8 and 11 years (more commonly 9 years) counting from the beginning of level 1. Normally, students of expected school age finish level 2 at 14, 15 or 16 years old. Finally, the increase in complexity is also reflected in a possible specialization between general and vocational education. In addition, this branching results in different possibilities of completion at level 2 (insufficient, partial or sufficient), and may or may not guarantee direct access to level 3. It should be noted that there is no interdependence between the general-vocational division and the guarantee whether or not to access the next level. That is, there are general programs that give or not access, as well as vocational programs that give or not access to higher levels.

The distinction between levels 1 and 2 is much more diverse, in between countries. In certain cases, Lower Secondary is much closer to the dynamics of Primary Education, as a direct continuation of it, with a generalist and basic proposition. In other cases, it is closer to Upper Secondary Education, with a greater degree of specialization/division by areas. More than that, both levels can be divided into smaller, graded cycles. This approximation or distance is reflected in the terms used in different countries. In Brazil, levels 1 and 2 are called *Ensino Fundamental I* and *Ensino Fundamental II*, respectively. In Portugal, the set of levels is called *Educação Básica*, and is divided into 3 cycles. The first is classified at the ISCED 1 level, while the last 2 are aligned with ISCED 2. In Argentina, *Primário* is composed by the stages *Educación General Básica I* and *Educación General Básica II*, while Lower Secondary is called *Educación General Básica III* ou *Educación Secundaria Básica*. In Germany, the accumulation of levels 1 and 2 is called *Grundschule*. In Japan, the set of levels 1 and 2 comprises the compulsory period, and is called *Gimukyoiku-gakko*.

ISCED level 1 also has denominations reflecting a more generalist character. In general, for level 1, the terms *Primary School*, *Elementary School, Primarbereich, Primário, Educación Primaria, Shogakko* are also used. ISECD level 2 also originates from the term Secondary in some cases, indicating a distance from Level 1: *Sekundarbereich I*, *Educación Secundaria Obligatoria* (in Spain, marking the end of the compulsory period), *Educación Secundaria Básica*, *Chugakko, High School.*

In this way, we arrive at ISCED level 3, entitled Upper Secondary Education education. Typically, programs at this level are designed to complete secondary education and can prepare students for entering the tertiary level, or for entering the workforce, or both. This level has in many cases a greater diversity of educational paths (general or vocational, which may have different currents and options), in comparison with level 2. Depending on the trajectory, completion in level 3 programs may or may not guarantee access to levels 5, 6 or 7 (components of tertiary education), or 4 (non-tertiary post-secondary). Their duration is also accounted cumulatively with the duration of levels 1 and 2. They are normally completed 12 or 13 years after entering level 1, corresponding to the age of 17 or 18 for students in the typical age.

In Argentina, Brazil and Colombia, level 3 is called, respectively, *Educación Secundaria Superior* or *Polimodal*; *Ensino Médio;* and *Educación Media* or *Bachillerato*. In these countries, this level has a more general standard, as well as in the USA and Japan, called *High School* and *Koto-gakko*, respectively. Germany, Portugal and Spain, on the other hand, offer a variety of paths (sometimes already started in Secondary Education), which are no longer compulsory. Thus, there are more generalist schools, focused on continuing tertiary education (*Gymnasium*, *Curso Humanístico-Científico*, *Bachillerato*) and courses more aimed at entering the workforce (*Curso Profissional*, *Curso Tecnológico*, *Formación Profesional, Formación Tecnica, Berufsschulen; Fachoberschulen*).

SYNTHESIS AND COMPARATIVE GLOSSARY

In the following table 1, we present some terms for the different programs contained in ISCED levels 0 to 3. We emphasize that due to the diversity of trajectories, mainly in levels 2 and 3, there are many different terms corresponding to each one of them. In addition, we also point out that many terms are not currently officially used in the legislation of these countries. However, because they are historical names, used in previous systems, they are still part of everyday language in those countries. Different modalities, such as education for students outside the typical age or home education also have specific names.

Table 1

Educational terms glossary

	Terms			
ISCED LEVEL	Argentina	Brazil	Colombia	Germany
0	Educación inicial	Educação Infantil; Creche; Jardim de Infância; Pré-escola	Educación inicial; Educación preescolar	Kindergarten, Kindertagesstäte, Kindertagespflege
1	Educación Primaria; Educación General Básica I e II	Ensino Fundamental/Anos Iniciais; Primário	Educación Primaria; Educación Básica Primaria	Primarbereich
2	Educación General Básica III Educación Secundaria Básica	Ensino Fundamental/Anos Finais	Educación Secundaria; Educación Básica Secundaria	Sekundarbereich I
3	Educación Secundaria Superior; Polimodal	Ensino Médio; Colégio	Educación media; Bachillerato	Sekundarbereich II; Gymnasium; Berufsschulen; Fachoberschulen
	Japan	Portugal	Spain	U.S.A.
0	Yochien; Hoikuen	Jardim de Infância; Educação de Infância	Educación Infantil	Kindergarten; Daycare; Preschool
1	Shogakko	Ensino Básico/1º ciclo	Educación Primária	Elementary School; Primary School
2	Chugakko	Ensino Básico/2º e 3º ciclos	Educación Secundaria Obligatoria	Middle School; Junior High School
3	Koto-gakko	Ensino Secundário; Curso Científico-Humanístico; Curso Profissional; Curso Tecnológico	Educación Secudaria; Bachillerato; Formación Profesional; Formación tecnica	Senior High School

Note. Own authorship.

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PART I

General issues on science teaching in primary school

Chapter 1

Portugal

Science education in the early years: paths and challenges in Portugal

Ana Valente Rodrigues, Patrícia Christine Silva & Isabel P. Martins

This chapter presents a portrait of what science teaching in the early years of schooling has been in Portugal, considering its recent history, constraints, achievements, ongoing innovative projects, and challenges to the promotion of science education for all, from a young age, and contemplating different contexts of lifelong learning. Some of the challenges identified for science teaching in the primary school education (6-10 years old) are to ensure that: i) natural sciences have their own identity in the curriculum; ii) the natural sciences having a more equitable workload compared to other subjects, also in terms of their relevance in internal and external evaluation; iii) essential learning, in terms of knowledge, skills, and attitudes, are explicit in the curriculum of natural sciences; iv) curricular guidelines for experimental science teaching are explicit; v) schools have specific spaces, equipment, and resources for the development of practical group activities at this age level. It is also urgent to ensure the quality of the supply of analogue and digital educational resources to support the teaching and learning of science at this level of education, focusing on their development based on research. Another major challenge is the pre-service and in-service teacher training, who need to include more expressively the area of Didactics of Science for the early years of schooling. There is also the need to involve teachers in research in education in general and in science education in particular, either in their practices, in projects, or in their participation in scientific events. The examples of projects presented in this chapter may constitute one of the possible answers or inspire the creation of new solutions to some of these challenges that are imposed on education, training, and research. Although the Portuguese national context has been the focus in this text, the considerations, reflections, and proposals outlined may be used and/or adapted in other contexts.

Keywords: Science education in primary education, Primary school teacher education, Science curriculum

INTRODUCTION

Currently, there is a consensus on the importance of science education from the earliest years of schooling, not only to develop an interest in science and technology careers, but fundamentally to promote basic scientific literacy for everyone, so as to enable conscious, responsible and communal citizenship, which is essential to achieve the 17 Sustainable Development Goals (SDG) in the 2030 Agenda.

It is in this sense that this chapter aims to 'paint a picture' of science teaching during the early years, in Portugal, considering its recent history, constraints, achievements, ongoing innovative projects and challenges to the promotion of science education for all, from the earliest years, and considering different contexts for lifelong learning.

1. THE SCIENCES IN THE EARLY YEARS OF SCHOOLING IN PORTUGAL: A HISTORICAL OVERVIEW

This section aims to provide an integrated description of the evolution of science education in the early years of schooling, the history of pre-service and in-service teachers education at this education level, and research in science education for the early years of schooling, as well as some of the most impactful initiatives that promoted scientific literacy in Portugal at this level.

1.1 From the mid- 19th century until the mid-20th century

In Portugal, the role of primary school teacher only became a profession when it was institutionalised with the creation of Normal Schools in the 1860s[3]. Candidates had to be 18 years old and have completed primary school as well as attend two years of education. At this time, primary education was not yet compulsory, and only became so in the second decade of the 20th century (1911 – three years; 1919 – five years; 1929 – four years). In the 1930s, Normal Schools

[3] Diário de Lisboa no. 295, 26 December 1860 - Regulations for the Primary Normal School in the District of Lisbon provides the legal framework to start training primary school teachers in Portugal.

were replaced by Primary Teacher Education Schools. Those applying to become primary school teachers were required to have nine years of schooling (general education) and two years of specific education at Primary Teacher Education Schools. The study plans did not include specific Didactic subjects, only subjects such as ‘General Pedagogy’ or ‘Methodology’.

1.2 Second half of the 20th century

In 1960[4], compulsory schooling for everyone in Portugal became four years; in 1964, it became six years; and, in 1986, with Basic Educational System Legislation, it became nine years.

It was only at the end of the 1960s[5] that primary education programmes first included a subject featuring the natural sciences, termed ‘Geographic-Natural Sciences’. In the middle half of the 1970s[6], the subject was renamed ‘Physical and social environment’. In 1991[7], the new curricular program for the primary education[8] (six to ten years old) is published and the same subject was renamed “Study of Environment” and continued to cover the social and natural

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[4] Decree-law no. 42994 of 28 May 1960 makes schooling compulsory for everyone until the fourth grade of primary school (https://dre.tretas.org/dre/240108/decreto-lei-42994-de-28-de-maio), although it had already been compulsory since 1956, albeit only for males.

[5] Ordinance no. 23485 of 16 July 1968 – approval of new programmes for the elementary cycle of primary education (https://dre.tretas.org/dre/250891/portaria-23485-de-16-de-julho). Ordinance No. 24044 of 25 April 1969 contains the elementary cycle Programme (https://dre.tretas.org/dre/314556/portaria-24044-de-25-de-abril).

[6] Ordinance no. 572 of 31 October 1979 – Approval of programmes for primary education, including the physical and social Environment. At this point, the same programme had already been proposed (1975/76), but it was in the experimental/validation period, and had not yet been extended to the whole country.

[7] Ordinance no. 139 of 16 August 1990 approves the new curricular programme for the first cycle of basic education, in accordance with Decree-Law no. 286 of 29 August 1989. This Decree-Law already mentions the subject of “Study of Environment”, but the new programme is only published for the first time in July 1991.

[8] Since 1991 primary education in Portugal has four years of schooling and is called the 1st cycle of Basic Education.

sciences. This Curricular Program has only recently been repealed[9], but the subject of "Study of Environment" remains.

It was only at end of the 1980s[10] that pre-service teacher education became widespread in higher education institutions, with a duration of three years, as a bachelor's degree. So, in 1989, the legal framework for pre-service and in-service teacher education is enacted[11], defining the professional profile of early childhood educators and teachers of primary and secondary education regarding fields of specific scientific competence, pedagogical-didactic competence, and adequate personal and social education, from an integrated perspective. The related regulations also reflect the importance placed on in-service teacher education, which are considered inseparable from pre-service teacher education. Finally, the principle that research and innovation are a permanent component in the education and professional activity of early childhood educators and teachers at all levels is also enshrined as a fundamental vector.

In 1992, the legal regime for in-service teacher education of pre-school, primary and secondary education was established[12]. In 1994, the Scientific-Pedagogical Council for In-service Teacher Education (CCPFC) was created[13], to accredit and certify in-service education sessions/programs.

At the University of Aveiro, the first Portuguese University to provide pre-service education for Early Childhood Educators and Primary School Teachers, the Bachelor's in Primary Education[14] began in the 1987/88 academic

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[9] Ordinance no. 6605-A of 6 July 2021 - https://files.dre.pt/2s/2021/07/129000001/0000200003.pdf
[10] Despite the fact that, at the end of the 1970s, Higher Education Schools had already been legally 'created' at Polytechnic Institutes and University Integrated Teacher Training Centres, and these had come to replace Primary Teacher Training Schools.
[11] Decree-Law no. 344 of 11 October 1989 (https://dre.pt/dre/detalhe/decreto-lei/344-1989-548826).
[12] Decree-Law no. 249 of 9 November 1992 (https://dre.tretas.org/dre/46396/decreto-lei-249-92-de-9-de-novembro).
[13] Decree-Law no. 273 of 28 October 1994 (http://www.ccpfc.uminho.pt/uploads/DL%20274.94.pdf).
[14] The Bachelor's Degree in Early Childhood Education was also started.

year. The study plans still did not include specific didactic subjects for different areas of knowledge, only subjects such as 'Specific Primary Education Methodology I and II'. In 1992, the University of Aveiro began to make some innovative proposals for the time, sub-dividing these subjects into modules concerning specific methodologies, namely a module on the teaching of science at these levels of education. An optional subject named Education for the Environment was also created, which related environmental topics and the teaching of science for these years of schooling.

These are the beginnings of science education during the first years of schooling in Portugal, in tandem with the emergence of research groups in this area within several higher education institutions with pre-service teacher education at this education level and accompanied the work of authors in the United Kingdom, France, and the United States, among others. It can be said that research on science education during the early years in Portugal began in the 1990s. An important landmark is Professor Wynne Harlen's conference 'How does research help the teaching and learning of science in the primary school?' given in 1993 at the IV National Conference of Science Education at the University of Aveiro[15].

Another important milestone is the financing of the first (to the best of our knowledge) research project on primary science education, namely the project 'Science/Technology in primary education: an innovative perspective[16] subsidised by the JNICT coordinated by António Cachapuz (1991-1993).

In December 1993, under the guidance of António Cachapuz, Fatima Paixão defended her Master's thesis entitled 'The challenges of curricular reform

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[15] For more detailed information on the history of these meetings, see the article from the AIA-CTS Bulletin '*A educação em ciências nos encontros nacionais em portugal - um resumo singelo de um longo percurso' [Science education at national conferences in Portugal - a simple summary of a long journey] by Martins and Paixão 2020, available at https://aia-cts.web.ua.pt/wp-content/uploads/2020/06/AIA-CTS_Boletim12especial.pdf.*

[16] Project PCTS/P/ECT/15/90.

and the teacher education for primary school teachers of natural sciences: pedagogical practice as an indicator of necessary changes', at the University of Aveiro. In September 1996, under the supervision of Maria Odete Valente, Joaquim Sá defended his doctoral thesis on 'Strategies for the development of scientific thought in primary school students', at the University of Minho. Also, to the best of our knowledge, the first book written by Portuguese authors specifically about science education in the first years of schooling in Portugal was 'Revise the practices in the primary education via the natural sciences' (Sá, 1994).

In 1997[17], the pre-service teacher education at all levels became a degree certification, and in the case of primary school teachers and early childhood educators, the degree takes four years[18]. It is in these study plans that the Didactic disciplines of Science explicitly appear for the first time. Additionally, in this year, the Organic Law from the National Institute for the Accreditation of Teacher Education[19] (INAFOP) and in 1999[20], the accreditation system of pre-service education degrees for early childhood educators and teachers of elementary, middle school and secondary education was created.

It was also at the end of the 1990s that the *Ciência Viva* - National agency for scientific and technological culture appeared, an initiative from Ministry of science and technology Professor Mariano Gago, which would be a remarkable incentive for the promotion of scientific culture, namely, with regard to science education in primary schools. Every year, between 1997 and 2008, the *Ciência Viva* Forum was held[21] where schools at a national level presented projects developed

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[17] Law no. 115 of 19 September 1997 - Establishes that the initial training of early childhood educators and teachers of basic and secondary education is obtained with a higher education degree (https://dre.pt/dre/detalhe/lei/115-1997-653145)

[18] At the same time, the 'training supplements' have been created for practicing teachers to be able to remain with a bachelor's degree.

[19] Decree-Law no. 290 of 17 September 1998 (https://dre.tretas.org/dre/96093/decreto-lei-290-98-de-17-de-setembro).

[20] Article 8, Decree-Law no. 194 of 7 June 1999 (https://dre.pt/dre/detalhe/decreto-lei/194-1999-309481).

[21] https://arquivo.cienciaviva.pt/index.php/forum-ciencia-viva

during the school year, financed by the *Ciência Viva*. It was during these Forums that many foreign researchers visited Portugal, learned about the path taken and made recommendations. A network of interactive science museums was also initiated, known as *Ciência Viva* Centres. Currently there are 21 centres in operation[22] and *Ciência Viva* Clubs have also been created in primary and secondary schools, with 237 in operation throughout the country.

In summary, science education in primary schools in Portugal appears formally in the 1968 curriculum, although not autonomous from the social sciences. However, its approach in classrooms was limited to what was proposed in the school textbook. The teachers did not have any education for the teaching of this subject. It appears in the study plan of pre-service teacher education for this education level and as an area of research interest only in the 1990s. It can therefore be assumed that it is a very recent area of education and research, with just a little more than two decades, and in a non-uniform way throughout the nation.

1.3 21st Century

In 2001, the general profile of professional performance for early childhood educators and teachers of primary and secondary education[23] as well as the specific profile of professional performance for primary school teachers[24] is approved.

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[22] https://www.cienciaviva.pt/centroscv/rede/

[23] Decree-Law no. 240 of 30 August 2001 - general profile of professional performance for early childhood educators and primary and secondary school teachers (https://dre.pt/dre/detalhe/decreto-lei/240-2001-631837).

[24] Decree-Law no. 241 of 30 August 2001 - specific profiles of professional performance for the childhood educator and the teacher in the 1st cycle of primary education (https://dre.tretas.org/dre/144653/decreto-lei-241-2001-de-30-de-agosto).

It is also in 2001 that the National Curriculum for Primary Education - Essential Skills was created[25]. With regard to science education in primary school, this document defines essential skills in the following areas: Environmental Studies, Natural and Physical Sciences, and Technological Education. It was repealed in 2011[26]. In 2009, legislation is created, which considers 12 years of education in Portugal to be compulsory[27], becoming enforceable in the 2012/2013 academic year.

In 2003 at the University of Aveiro, the first academic Master in Primary Science Education was created in Portugal, and as one of the results, there were several dissertations in the field, in which relevant and innovative topics were addressed.

In 2004-2006, the research project 'Scientific Culture and Science Education in the Early Years of Schooling' was developed (programmatic funding from FCT/MCES) in which the 'Science Garden' was conceived and installed; an innovative, non-formal educational space based on a formal teacher education space, in this case, within the Department of Education and Psychology at the University of Aveiro. Therefore, assuming the importance of pre-service teacher education, which integrates contexts of formal and non-formal science education.

In 2006 there is defined the minimum weekly time for each primary education curricular subjects[28]: eight hours in the Portuguese Language, seven hours of Mathematics, five hours of Environmental Studies, half of which is in experimental science teaching and five hours of Expressions and other areas. This

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[25] https://alvarovelho.net/attachments/article/39/LivroCompetenciasEssenciais.pdf
[26] Ordinance no. 17169 of 23 December 2011 (https://dre.pt/dre/detalhe/despacho/17169-2011-1011055).
[27] Law no. 85 of 27 August 2009 (https://dre.pt/dre/legislacao-consolidada/lei/2009-34513275) .
[28] Ordinance no. 19575 of 25 September 2006 (https://dre.pt/dre/detalhe/despacho/19575-2006-1872457).

is the first time that compulsory experimental primary science education had been applied.

Also in 2006, a unique initiative was launched at the level of in-service education for primary school teachers in Portugal, the Educational Programme for the Experimental Teaching of Sciences (PFEEC)[29]. During the four academic years in which it existed, it involved 18 Higher Education Institutions responsible for the pre-service education of primary school teachers, thousands of in-service primary school teacher and their pupils as well as equipping schools with the material resources necessary to implement the experiences proposed in educational program. A technical-scientific Commission was created, coordinated by Isabel P. Martins, who was responsible for developing and coordinating the in-service teacher education programme at the national level, as well as for producing nine teaching guides to support teachers' practices. An evaluation study on the impact of this programme indicates that it contributed to the professional development of the teachers involved, namely with regard to the appropriation of methodologies, strategies and activities related to the experimental teaching of science, as well as to the development of their students' learning, in particular, in terms of scientific capabilities. The study also revealed the influence of the PFEEC at the level of school textbooks for these education levels, as well as at the level of Curricular Unit (CU) syllabi in the area of science education of the pre-service primary school teachers' degrees (Martins et al., 2012).

In 2007, as a result of the Bologna process, the minimum requirements for teaching in primary education becomes a Master's and the pre-service education of primary school teachers follows a sequential model organised in two cycles of studies (two-step model): Degree in Basic Education with a duration of 3 years

[29] Ordinance no. 2143 of 9 February 2007 (https://dre.tretas.org/dre/206320/despacho-2143-2007-de-9-de-fevereiro) Ordinance no. 701 of 9 January 2009 (https://dre.tretas.org/dre/244354/despacho-701-2009-de-9-de-janeiro).

(Bologna 1st Cycle) and a Master's with a duration of 1/1.5 years (Bologna 2nd Cycle). In 2014, the duration of the Master's will be 1.5 or 2 years, depending on whether it qualifies, respectively, solely for primary education or cumulatively for pre-school and primary education. In these new study plans for pre-service teacher education, there is a CU of disciplinary content for sciences and a CU of Didactics of Science for this level of instruction. However, since the physical and natural sciences in the primary school curriculum are still part of the CU of Environmental Studies, in the study plans, the didactics of science also encompasses the teaching of natural and social sciences, having, compared to other methodologies, much less expressiveness in terms of ECTS/number of hours in the degree.

In 2008, it became compulsory to take tests to gauge pupils' learning at the end of the primary education (4th year of schooling), but only in the subject areas of Mathematics and the Portuguese Language. The overvaluation of these subjects in terms of educational policies has repercussions on teacher practices, who end up dedicating even less time to approaching other subjects, such as the Natural Sciences. It also has consequences in terms of the relative value given by parents and the rest of the community to the subjects.

Also in 2007, the Agency for Evaluation and Accreditation of Education[30] (A3ES) was created, becoming the entity responsible, among other things, for the evaluation and accreditation of the HEI study cycles, which includes teacher education degrees.

In terms of in-service teacher education, in 2014 there will be a greater selection of education programs, according to the intervention strategies defined by the Ministry and stricter evaluation criteria for education programs (CCPFC, 2014) and the new legal regime is decreed for in-service teacher education and

[30] Decree-Law no. 369 of 5 November 2007 (https://dre.tretas.org/dre/222337/decreto-lei-369-2007-de-5-de-novembro).

the respective coordination, administration and support system is defined[31]. The process of accreditation for in-service education entities, of the teacher educators and education programs continues to be the responsibility of the CCPFC, under the terms of its own regulations. However, mechanisms are introduced to monitor teacher education, namely the Directorate-General for School Administration, and the General Inspectorate of Education and Science (IGEC), responsible for controlling and inspectioning of in-service education activities.

Also, in regard to educational policies and their influence, in 2013 and 2014, the curricular goals of the Natural Sciences were defined, but only for the 5th, 6th, 7th, 8th and 9th years of school. In the primary school curricular program, only the goals defined in the 1991 Environmental Studies remain in effect.

Only beginning in 2016, the assessment tests, which have since been conducted in the 2nd grade, begin to integrate Environmental Studies content, going on to have mixed tests for the Portuguese Language-Environmental Studies and Mathematics-Environmental Studies. Even so, the Environmental Studies always appears in an 'undervalued' way and as it encompasses both the social and natural sciences, the contents of the latter are not very expressive. Furthermore, the assessment of learning related to practical experimental activities is residual.

In 2017, the Profile of Students Leaving Compulsory Schooling was created[32], a reference document that establishes the matrix of principles, values and skill areas that must be followed in the development of the curriculum. In this document, the importance of skills such as 'scientific, technical and

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[31] Decree-Law no. 22 of 11 February 2014 (http://www.ccpfc.uminho.pt/Uploads/RegJuridico/2014/DL%2022.2014.pdf).

[32] Ordinance no. 6478 of 9 July 2017 (https://dre.pt/dre/detalhe/despacho/6478-2017-107752620) and Decree-Law no. 55 of 6 July 2018 (https://dre.pt/dre/detalhe/decreto-lei/55-2018-115652962)

technological knowledge' is explicit. However, the Teacher Profile continues to be that from 2001.

In Portugal until 2015, there was no national association in the area of science education that included the early years of schooling, an aspect that was overcome with the creation of the Portuguese Association of Science Education[33] (APEduC) in August of that year. There was also no specific scientific journal for publications within the scope of research in teaching science, so in 2020 the first issue of APEduC Magazine/Journal is released: Research and Practices in Science, Mathematics and Technology Education[34], which according to Martins and Paixão (2020) '...came to provide a new impetus towards research and towards the involvement of the many existing research groups and, to be certain, the consolidation and internationalisation of ENEC - Portugal' (pp. 138-139).

In 2018, the Essential Learning for Primary and Secondary Education and the Curricular Management Instrument are defined - curricular autonomy and flexibility[35]. In 2021, the previous curricular[36] documents (programmes and goals) are repealed, and only: a) the Profile of Students at the end of Compulsory Schooling; b) Essential Learning; c) the National Strategy for Citizenship Education; d) the professional profiles/skill benchmarks (when applicable) are in effect. Therefore, currently (2021) at the level of specific curricular guidelines for primary education, what is in effect is the essential learning for Environmental Studies.

In relation to the repealed Programme, the EA does not present substantial differences in terms of the proposed contents. The learning presented still lacks a sequential and progressive organization of subjects over the years. A brief

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[33] http://apeduc.ipcb.pt
[34] https://apeducrevista.utad.pt
[35] Decree-Law no. 55 of 6 July 2018 (https://dre.pt/dre/detalhe/decreto-lei/55-2018-115652962)
[36] Ordinance no. 6605-A of 6 September 2021(https://dre.pt/dre/detalhe/despacho/6605-a-2021-166512681).

analysis of the Environmental Studies EA allows us to observe that less than 50% of learning is explicitly related to the natural sciences. From these, one can clearly see the predominance of biological science content over the physical sciences.

If we take as a reference the learning recommended in TIMSS 2019 for the 4th year of schooling and, by comparison, the essential learning defined for Environmental Studies, we can see that about half of the learning evaluated in the TIMSS is not covered in the EA (Silva, Rodrigues & Vicente, 2021).

In terms of distribution of the minimum weekly workload for different subjects provided in the Primary School Curricular Management Instrument (Table 1), it appears that there is a 40% decrease in the number of hours per week for the area of Environmental Studies in relation to the ones proposed in 2006.

Table 1

Weekly workload of components in the primary school curriculum in 2006 and 2018

Compulsory subjects/components of the primary school curriculum	Weekly Workload (h)		
	2006	**2018**	
		1st and 2nd years	3rd and 4th years
Portuguese	8	7	
Mathematics	7	7	
Environmental Studies (biology, physics, chemistry, geology, geography, history, technology)	**5**	**3**	
Artistic Education (visual arts, dramatic expression/theatre, dance and music) Physical Education	5	5	
Study support and Complementary Offer	---	3	1
English	---	---	2
Total weekly hours	25		

Summing up, in Portugal, science education in the early years is still a quite recent teaching, education and consolidated research area. Despite increased research in this field, there continues to be a devaluation of the natural science curriculum in primary education, which also has repercussions at the ECTS level and the respective weekly workload of didactic CUs from individual study plans for pre-service teacher education at this level.

In addition, 81% of primary school teachers who are currently in the field, whether in the context of public or private institutions, are over 40 years old (DGEC & DSEE, 2020), and half of them over 50 years old, which means that their pre-service education was at least 20 years ago. In terms of an academic degree, 82.4% of primary school teachers, teaching in Portugal have a degree or equivalent and 10.5%, a Bachelor's degree or other and the remaining 7.1% a Master's or PhD (DGEC & DSEE, 2020). This means that the primary school teachers trained in the post-Bologna degrees, who are currently practicing in the profession, are in the 7.1% mentioned above.

Based on this context, in the following section, we intend to briefly identify and discuss the experimental teaching practices prevalent in Portuguese primary schools, as well as the results of Portuguese students' performance in national and international external assessment tests.

2. SCIENCE TEACHING IN THE EARLY YEARS OF SCHOOLING IN PORTUGAL: TEACHERS' PRACTICES AND STUDENT PERFORMANCE

There are several studies (e.g. Bretes & Correia, 2018; Correia & Bretes, 2009; Rodrigues, Oliveira, Bem-Haja & Silva, 2019; Silva, Rodrigues & Vicente, 2020) who have been dedicating themselves to the identification of science teaching practices in the early years of schooling in Portugal, displaying overall, that they are not in line with national and international demands for science education at this education level. In the same sense, despite the increase in practical and experimental activities in Portuguese primary schools, the results of the annual reports are referenced on 'Curriculum Management: experimental teaching of science' performed by the Inspectorate General of Education and Science[37] since 2015, based, namely, on the observation of science classes in the primary schools, and the analysis of documents and interviews.

An analysis of these studies allows us to verify that the practice of teaching science in the early years of Portuguese primary schools are predominately: scarce and not very frequent, occur monthly or semi-annually; distant/disconnected from children's daily lives; focused on knowledge and its memorisation to the detriment of developing other scientific skills; based on teacher demonstrations, oral explanation of contents that hardly inspire teaching that stimulates the active role of children in the learning process; supported by the school textbook, which continues to be the resource of choice for teachers.

As mentioned in the previous section, currently, the teaching staff in the primary education is very old, and many had already completed their pre-service education two decades ago. The offer and frequency of in-service education, with the exception of the PFEEC, in the specific area of experimental science teaching is also reduced (IGEC, 2019). This type of in-service teacher education, usually by its nature, requires practice in the context of the classroom and the availability of teachers to perform it are not always there. They usually choose 'to attend in-service teacher education program based on traditional models that, although not very relevant to their professional practice, require less dedication and provide the formal certification necessary for career progression' (Reis, Galvão & Batista, 2018, p. 257).

In Portugal, gaps in pre-service and in-service teacher education are one of the constraints to the practice of teaching science. Another relevant aspect, and closely related to teacher education is the conception about science and science

[37] Paragraph 2, sub-paragraph c) from Regulatory Decree no. 15 of 27 January 2012 (https://dre.pt/dre/detalhe/decreto-regulamentar/15-2012-543879).

teaching. Some studies reveal that Portuguese primary school teachers, despite recognising the importance of science education, reveal a naïve image of science, which makes it difficult to adapt their practices to the proposals of teaching science geared toward scientific literacy (Bretes & Correia, 2018; Correia & Freire, 2009; Gonçalves, Valadas & Freire, 2011; Mira & Linhares, 2020; Torres & Vasconcelos, 2015).

Other factors mentioned in studies (e.g. Rodrigues, Oliveira, Bem-Haja & Silva, 2019), which present themselves as obstacles to a more systematic and more practical teaching of science, are: lack of space, equipment and adequate resources for the experimental sciences teaching in primary schools, the lack of time to fulfil the whole program of the disciplines, the difficulties in managing children's behaviours during the implementation of experimental activities, the size of classes; the work associated with the preparation of these types of activities.

In summary, many teachers feel insecure in their approach to certain content and, in particular, to implement experimental activities, which necessarily have repercussions on the nature of their students' learning. The performance results of Portuguese students in both external national (2nd year of school assessment tests) and international (TIMSS) assessment tests corroborate this idea.

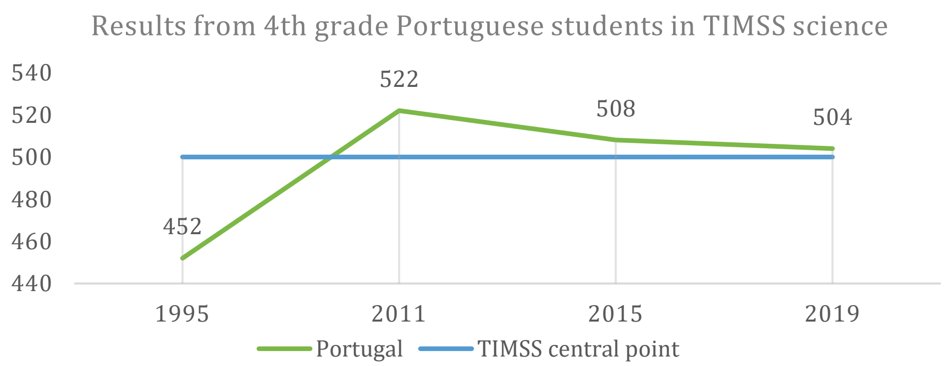
The external national assessment of the science learning performance of primary school pupils as mentioned above, only started in 2016, and includes only children attending the 2nd year of schooling. It aims only to measure learning developed on the following scale: they were able to respond to the expected; were able to respond to what was expected, but could still improve; reveal difficulty; were unable to respond to the expected or did not respond. The overall analysis of performance results for the years 2016/2017, 2017/2018 and

2018/2019[38] shows that about half of the primary school students (45% more) showed difficulty, could not answer as expected or did not answer the questions about science.

TIMSS is the international study that evaluates, namely, science learning for 4th grade primary school pupils. Portugal participated in four editions: 1995, 2011, 2015 and 2019 (Figure 1). If there was an increase of 70 points from 1995 to 2011, in the next three editions, Portugal showed an appreciable decrease performing in the area of science, displaying a trend contrary to most countries, a drop that brings it closer to the central point of the TIMSS scale (500 points), although it is still higher.

Figure 1

TIMSS Science Results for 4th grade Portuguese students



By analysing the results of both the national and international external evaluations with the performance of Portuguese primary school pupils, it can be deduced that they fall short of what is desirable. Despite the limitations that tests of this nature present, the scenario described points to the need of increasing contexts for the promotion of scientific literacy from the earliest years of

[38] In 2019/2020 and 2020/2021, national assessment tests were not held due to the COVID-19 pandemic situation.

schooling, in order to either prepare young people to follow socio-scientific issues as citizens, or at the level of developing a greater appetite for choosing careers related to Science and Technology.

3. INNOVATION IN SCIENCE EDUCATION DURING THE EARLIEST YEARS OF SCHOOLING: SOME EXAMPLES OF CURRENT PROJECTS IN PORTUGAL

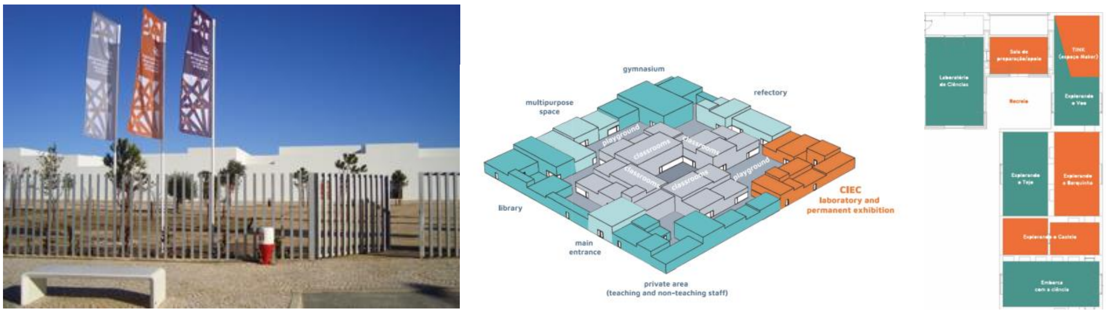
In response to the shortcomings mentioned, namely: lack of spaces and adequate didactic resources for science teaching in the primary education, gaps in pre-service and in-service teacher education, undervaluation of natural sciences in the primary education curriculum, innovative projects have been developed in Portugal for science education at this level of instruction. In the following sections, three of these projects are briefly presented, in which the authors of this chapter are involved, namely: the Integrated Science Education Centre – *Ciência Viva* School of Vila Nova da Barquinha (CIEC-ECV); the Experimental Science Teaching Programme (PEEC) and the Digital Educational Resources Project for Science in Primary Education (RED_Ciências).

3.1 Integrated Science Education Centre - C*iência Viva* School of Vila Nova da Barquinha

The Integrated Science Education Centre – Escola *Ciência Viva* de Vila Nova da Barquinha is a pioneering and unique project in Portugal, the product of research by the University of Aveiro (Rodrigues, 2011, 2016) and developed by a multi-disciplinary team (researchers, teachers, architects, politicians, local community...) and at the initiative of the local Municipal authority. It is a science centre that is an integral part of a public primary school and was designed in an original way simultaneously with the school itself (Figure 2).

Figure 2

CIEC entry; CIEC and school plan; CIEC plan



It is, therefore, a non-formal educational space, which is found inside a formal educational space, and it necessarily creates the need to reinvent the relationship between these two educational spaces at the level of proposals for the exploration of scientific subjects, in particular with the 12 classes of primary school pupils who attend this school (approximately 280 students).

It is a made up of a non-profit association in operation since 2013 and is open to other schools and the general public, not only when school is in session, but also after school, weekends and during vacation. CIEC direction has been the responsibility of the University of Aveiro, which coordinates a team of six monitors and a technical research scholarship.

The CIEC has a more internal level of intervention, put into operation through the 'Experiment+Science Programme´ with the implementation of practical weekly science activities (90 min) in the laboratory, for the 12 classes of primary education during school hours, in an assisted manner alongside teachers holding the class and in an integrated way with the existing interactive modules in the permanent exhibition (Figure 3); and with the implementation of weekly activities (45min) for children at the local Kindergartens and with a monthly visit for each of these groups to the CIEC.

Figure 3

Activities within the scope of Experiment+Science

The CIEC also assumes the implementation of 13 thematic workshops in the context of curricular enrichment activities that have an annual global theme, this year in 2021-2022, it is ‘Sustainable Barquinha through art and science’.

Given the innovative nature of this project, and taking into account what has already been described in terms of the Environmental Studies curriculum for primary education, it was necessary to develop a proposal for curricular organisation based on the CIEC's interactive exhibition room themes and determining activities from the PFEEC guidelines. This proposal resulted from investigative work by one of the school’s teachers (Costa, 2016) in the context of a Master's degree.

The proposals for Kindergarten are based on the brochure ‘Awakening to Science - Activities for 3 to 6 year-olds’ (Martins et al., 2009).

At the level of CIEC's intervention with other schools and the general public, there are study visits, visits by other groups or individuals, families or individuals, initiatives such as science cafes, short stories and science, science dinners, science and art trails, vacation with science, ... In addition, from the CIEC design phase, there was a concern to implement in-service teacher education programs/sessions for the teachers who would go to that school, so the promotion of in-service teacher education programs is also one of CIEC's missions. At pre-service teacher education level, there are several pupils who have been doing their internship at this school and developing their research projects immersed in this context. Therefore, the CIEC, which was a product of research, is also an object of research.

From the most recent study on the perceptions of students, teachers and parents about the CIEC project (Rodrigues, Oliveira & Souza, 2021), it highlights the fact that students recognise the importance of performing practical science activities in the Laboratory from pre-school and primary education: more than half of the students stated that the practical activities performed in the CIEC Laboratory, throughout pre-school and primary education, contributed to learning about science, to promoting an interest in science and so they can continue to learn about science in subsequent years. More than one third of the secondary school students attending the 'Science and Technology' course stated that the choice for this course was influenced by the performance of practical activities in the CIEC Laboratory at primary education. Insofar as the CIEC permanent exhibition, most students also confirm the contribution of exploring the modules to learn more, enjoy and continue to learn about science in subsequent years, as well as the desire to learn about other science centres.

In terms of learning assessment results (2018/2019), the average scores in the internal assessment of students at the VNB school cluster were higher than the regional average (CIM-MT) in primary and secondary education. With the national assessment of science learnings, primary school students of VNB also had results that were higher than the regional and national average.

The results from this study as well as other ones point to the success of this project and the need to extend the experience to other contexts. Although there are initiatives to promote some of these events/activities at the regional level, it is still insufficient.

The consolidated experience of almost a decade of CIEC operation, and the reflections and evidence of investigative work, allow us to evolve towards a more ambitious proposal of Science Education in the earliest years in Portugal. This is how the Experimental Science Education Programme (PEEC) emerged, which is presented in the next section, and has as its ambition, intervention at a national level.

3.2 Experimental Science Education Program for Primary Education (PEEC)

The Experimental Science Education Program (PEEC) for primary education is a research project[39] that began in 2019, using design-based research methodology with the intention to start from the more systematised evaluation of the CIEC 'Experiment+Science' Program for primary education, and propose, validate and evaluate a reformulation to this programme, which will be termed PEEC.

The PEEC consists of three components[40]: curriculum, activities and evaluation. In the curricular component of the PEEC, it is proposed to develop a curricular science proposal in primary education, which is assumed to be an independent subject. To this end, an analysis of five primary science education curricula (Singapore, England, United States of America, Australia and Canada) was conducted according to criteria related to results from the TIMSS and PISA. The analysis and crossing of content from the curricula, in comparison with the Portuguese curriculum, resulted in the construction of a curricular proposal that takes into account various topics of Biological, Physical and Earth Sciences for each year of primary education. For each topic was defined a set of knowledge, skills, attitudes and values, including knowledge about history and the nature of science.

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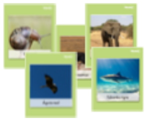
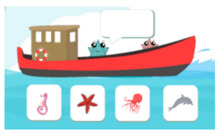
[39] This work is financed by National Funds through the FCT - Foundation for Science and Technology - and co-financed by the ESF - European Social Fund - through the Regional Operational Programme Centre, I.P., under the doctoral fellowship with the reference SFRH/BD/143370/2019

[40] https://youtu.be/drkfBIG6X10

The PEEC activities have educational resources for about 120 activities, thus contributing to the development of various ways listed in the curriculum proposal to learn. The activity proposals for each problem question are supported by an Inquiry-based science education perspective, aiming at the active involvement of students. As such, in addition to a brief description of how the session can be organised, a set of resources will also be made available, as some examples can be seen in the following table (Table 2):

Table 2

PEEC teaching resources

Contextualisation videos	Episodes with an average duration of 40 seconds portray an everyday situation related to the problem issue to be explored	
Registration sheets	Individual and/or group records in editable A4 and A3 format	
Analogue games	Card games, board...	
Recorded conversations	Videos for conversation with experts (scientists, dentists, doctors...) and the community in general.	
Infographics	Dynamic and visual videos with the explanation of phenomena, theoretical ones, among others...	
Digital evaluation games	Games for mobile devices with immediate feedback system	
Information leaflets	Posters and information leaflets in dynamic digital format, so they can be printed on topics to be explored.	

For the PEEC assessment, recording devices are provided for each problem question. For the purposes of diagnostic assessment, both formative and summative, digital games inspired by serious games were created to assess knowledge, skills, attitudes and values. Assuming that not all schools have the equipment to implement these games, we also designed evaluation tests in which the same understanding of games are evaluated with the possibility to edit them.

In the 2020/2021 academic year, 70 activities were developed and evaluated, with the participation of 12 primary school classes. The preliminary results point to the improvement of students' learning at the level of scientific skills, as well as to the relevance of resources developed for this purpose. In this 2021/2022 academic year, the PEEC activities are being implemented again, some reformulated and others that had not yet been tested, with the prospect of implementing around 100 activities and validating the respective resources. After validation and redesign of PEEC resources, they will be available online for free on a website and on the YouTube channel[41].

The PEEC was developed in conjunction with the project, Digital Educational Resources, to support science education in primary education, which is presented in the next sub-section, so it also includes activities proposed in it.

3.3 Digital educational resources to support science education in primary education

In December 2019, the Digital Educational Resources (DER) project for the primary education began with the general coordination of the General Directorate of Education[42]. This project is based on in-service teacher education program implemented in the past, namely the PFEEC (2006-2010). The science

[41] https://www.youtube.com/channel/UCSXhOUcrGpAcxDBqCloLz8w
[42] POCH-04-5267-FSE-000124

component is coordinated by the University of Aveiro (DEP/CIDTFF) and also has the Nova University of Lisbon (iNOVAMediaLab) as a partner for the multimedia component. Its overall purpose is to design/adapt, produce, validate, implement and evaluate digital educational resources to support the practice of experimental science teaching for primary school teachers and to promote student learning at school and outside of school.

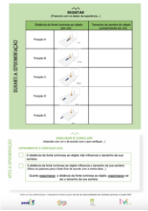
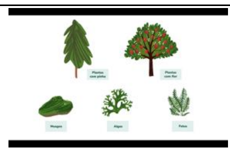
The Science Digital Educational Resources are organised on a site with a teacher's area and a student area. There is content developed to approach eight different topics determined in the "Study of Environment" subject, namely, i) Dissolution[43], ii) Light, shadows and images; iii) Sustainability; iv) Electricity; v) Floating in liquids; vi) Physical state changes of materials; vii) Plants; and viii) Human body. Each one of these topics is available in the teacher's area:

- The conceptual framework, with the essential concepts on the topic for the teacher (scientific knowledge of disciplinary content);
- The curricular framework, with the list of expected learning concepts in the implementation of activities, in terms of: knowledge, skills, attitudes and values. The Essential Learning expected on the topic and on the areas of skills and values for the student profile at the end of compulsory schooling.
- The didactic exploration proposal for each problem question that encompasses the components described and illustrated in Table 3:

[43] Funding under the scope of Centre 2020 - Portugal 2020 - Inter-municipal Community of Médio Tejo (CIM.MT) - *Support Resources to Change the Practice of Experimental Science Teaching* (RAMPEEC), enrolled and approved in the application, PEDIME Médio Tejo - Phase 1, put into operation through a protocol between CIM.MT, the General Directorate of the Ministry of Education in Portugal and the University of Aveiro.

Table 3

Components of the proposal for didactic exploration of each topic from RED_Ciências

Components	Description	Illustrative example
Description of teaching exploration	Suggestion of how teaching exploration can be organised	
Student's records	Editable documents, whether at the level of activity planning, or at the level of data and conclusions (class, group or individual format)	
Learning assessment activities	Documents in editable quiz format (e.g. diagnostic or formative	
Evaluation registry devices	Editable documents for monitoring student's learning (e.g. rubrics, graded scales)	
Contextualisation cartoons	Documents with a problem situation related to the topic in question.	
Digital games	Digital games with an immediate feedback system (e.g. Sustainability in play; The human body from the outside in)	
Analogue games	Editable games for printing (e.g. deck of cards, plants in play; water footprint range)	
Infographics	Short videos with information and explanations on a certain topic (e.g. The water cycle; The path of electricity; The constitution of plants)	
Posters	They consist of non-editable documents with information from a particular topic (e.g. aspects of family life from different parts of the Planet; Skin: constitution, functions and care)	

Videomaker	Construction of artefacts in a STEAM perspective (e.g. periscope; kaleidoscope; submarine)	
Video tips	They consist of displaying tips to help teachers prepare experimental activities (e.g. selecting or constructing objects/materials alternative to laboratory)	
Lesson videos	They portray a real class with children in the laboratory about the problem question under study	

The project activities are being validated by primary school teachers who volunteered for this purpose and who are developing them with their classes, based on the resources available on the website. Before, during and after the development of activities, teachers collect data that allow them to evaluate the existence of mobilising the expected learning, the adequacy and usefulness of the proposals, among other aspects.

The official and widespread availability of all of these resources is planned for the first quarter of 2022.

4. CHALLENGES TO SCIENTIFIC EDUCATION, TRAINING AND RESEARCH IN THE EARLY YEARS OF SCHOOLING IN PORTUGAL

One of the biggest challenges to science education, but also to education in general in Portugal, is the existence of a social pact for education so that the educational policy guidelines are not at the mercy of political parties depending on their rise to power, but are based primarily on research in education taking into account the reality of Portuguese schools. As we can see from the description made in the previous sections, the change of governments sometimes has serious implications on the importance given to science education in the early years of schooling, which has impacts on both, its presence in the curriculum and on the basic weekly workload. This has repercussions in terms of the desirable practice of more regular and systematised experimental teaching.

In the authors' opinion, primary education should integrate the various areas of knowledge, which mean that each subject should have its own identity and definition of specific essential learning. Therefore, one of the challenges in Portugal is that the natural sciences can have their own identity in the primary education curriculum, as in many other countries (e.g. Ireland, England, Canada, United States, Spain, Australia...). Furthermore, the curriculum should integrate essential learning in a sequential and progressive manner in each year and throughout the four years of schooling. It is also essential to determine more equitably, the knowledge, skills, attitudes and values, and to make more explicit curricular guidelines/directives for the development of practical experimental activities.

Another important challenge for the validation of natural sciences in the primary education in Portugal is to give them a fairer position in assessment tests (external evaluation at a national level) compared to other areas of the curriculum and, in addition, the incorporation of more issues that allow for the evaluation of skills, attitudes and values, in addition to canonical knowledge. This last aspect is equally important in terms of internal evaluation which is still very much focused on assessing knowledge through written tests.

The fact that primary schools do not have their own place for performing experimental activities (e.g. laboratory) with equipment and resources suitable for this education level and in sufficient quantity for group work, is also a limitation for performing activities of this nature and often contributes to the prevalence of demonstration-type activities by the teacher. It is essential that the construction of new primary school buildings include a laboratory space with specific characteristics for this education level.

Usage of the school textbook as one of the main strategies used by teachers to address science topics is also a constraint, and therefore, it will be a challenge to innovate in this area. The school textbooks for Environmental Studies continue to present a low level of conceptual requirement for practical work and, therefore, do little to promote the scientific process. There is still a validation of the result in relation to the process itself. Mostly, simple facts and concepts are mobilised and stimulus to the development of skills is neglected (Ferreira & Saraiva, 2021). On the other hand, the fact that they determine content from the natural and social sciences, but mostly in a disintegrated fashion, means that there are periods of time in which the natural sciences are not even addressed, and many of the 'experimental activities' are relegated to the end of the school year. In this digital age, it is essential to rethink the concept of 'School Textbook' whose traditional format is largely outdated and unadjusted to the reality of our students. It is imperative to respond to the need for quality educational resources to support the practices of our teachers, in particular for science education. Indeed, the development of analogue and digital educational resources to support the teaching and learning of science in the early years of schooling is an urgent challenge. The COVID-19 pandemic exacerbated this need and showed how the school was not prepared to keep up with the digital age. Not only at the level of material resources, which are clearly insufficient and/or are obsolete, but also in terms of the digital and pedagogical-didactic competences of teachers.

Therefore, one of the great challenges is undoubtedly the pre-service and in-service teacher education. With regard to scientific education in the early years of schooling, it is essential that, in the education degree study plans, the teaching of science should have a greater expressiveness and pre-service teachers can implement practical experimental activities and projects in classes that integrate different community partners (e.g. companies, scientists...), as recommended to perform in the future with their students. The use of active teaching and learning methodologies that integrate formal and non-formal educational contexts during the teacher education process is essential for them to feel safe in the development with their students. Another crucial aspect in teacher education is the initiation to research in education, so that they can reflect and innovate upon their practice throughout their careers. Accompanying and integrating research groups will be a very important educational path.

Although relatively recent, research in science education in the early years of schooling in Portugal, has had very significant growth. At this level, one of the challenges is to get research to teachers who are in the field. However, researchers, mostly teaching higher education, are increasingly encouraged as a way of padding their Curriculum Vitae to publish the results of their studies in indexed journals that are mostly in English and not very accessible to teachers. On the other hand, primary school teachers have a daily schedule of five school hours, which brings constraints to their participation in congresses and other scientific events.

These are some of the challenges by which we consider it relevant to reflect and intervene in favour of better science education. The examples of projects presented in the previous section may be comprised as one of the possible answers or as inspiration for the creation of new solutions to some of these challenges that are imposed on education, training and research in science in the early years in Portugal.

Although the Portuguese national context has been our focus of attention in this text, the considerations, reflections and proposals presented here may be used and/or adapted in other contexts. The problems in education are global, although the manner in which their approach is created may seem to appear local. What varies are the responses that each community and each country finds or adopts to solve them. Education in Science is everyone's right for more involved and better citizenship. Children have the right to be involved from an early age.

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Chapter 2

Germany

Understanding the big picture – teaching primary science and social sciences in German primary school

Daniela Schmeinck

This chapter describes the teaching of primary science and social sciences in German primary schools and its underlying concepts and principles. Unlike many other countries, Germany follows the concept of an integrated subject approach. Thus, learning and teaching primary science and social sciences aims to prepare children for their current and future life in a world characterized by complex issues and tasks e.g., mobility, digitality, globalization, sustainability, and climate change. To enable appropriate teaching, primary school teacher need to select topics for the lesson that are both, comprehensible for the children so that they can understand the complexity and interdependence e.g., of the environment, society, and economy. On the other side, however, compatibility with the concepts used within specific disciplines is indispensable to enable long-term and compatible learning. Last but not least, good teaching and learning must allow children to relate as much as possible to their general and individual life experiences.

Keywords: Primary science and social sciences, Key problems of society, Integrated subject approach

"If you want to build a ship, don't drum up people to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea."

Antoine de Saint Exupéry

KEY PROBLEMS OF SOCIETY AND REQUIREMENTS OF CONTEMPORARILY EDUCATION

In 1992, Klafki reflected upon contemporary primary school education and the mandate of primary science and social sciences (in German:

Sachunterricht). He highlighted six epochal characteristic key problems of society which by today are still current and highly up-to-date:

- the question of war and peace;
- the environmental question/the ecological question;
- the rapid growth of the world population;
- the socially produced inequality;
- the threats and opportunities of the new technical control, information and communication media;
- the subjectiveness of the individual and the phenomenon of the me-you relationship against the background of the tension between individual aspirations for happiness, interpersonal responsibility, and the recognition of the other (Klafki, 1992).

While according to Klafki (1992), these key problems apply as target perspectives for the whole of society and thus for more than just primary school education. Nevertheless, he emphasised that especially the primary science and social science lessons in the primary school curriculum play an important role. Through this and by the use of suitably chosen examples an important basis for the future can and, indeed, should be established at that age (Klafki, 1992).

The various key problems described by Klafki as well as the challenges identified by the United Nations (2015) Sustainable Development Goals (SDGs) (UN General Assembly, 2015) cannot be explained or even solved by a one-dimensional, subject-specific approach. Nor can they be taught through traditional didactics. The complexity of the underlying issues requires a holistic and interdisciplinary approach and contemporary pedagogies. For instance, the question of war and peace is not only a politically orientated question. It is a question of cultural norms, natural resources, historical developments, economic interests, and political goals. Issues about climate change, the environment and sustainable development are not easily solved. Especially without a multi-perspective consideration and appropriate pedagogies that consider the political and economic interests in addition to the laws of nature and technical opportunity, and importantly, the learner and the teacher (Schmeinck & Kidman, 2022).

Yet, how can this apparent balancing act be successfully done in teaching practice? And how do subjects and content have to be set up to meet the high requirements of contemporarily education?

PRIMARY SCIENCE AND SOCIAL SCIENCES GERMAN PRIMARY SCHOOLS

In Germany, primary science and social sciences (in German: Sachunterricht) is the most widely used subject designation for the discipline of general studies classes in primary schools and special education schools. The subject pursues the challenging task of supporting elementary school students in understanding their natural, cultural, social and technical environment in a factual and objective way. Based on this, the children are to make their environment accessible in an educationally meaningful way. They are to be enabled to orient themselves in it, to participate and to act (GDSU, 2013).

The purpose of teaching primary science and social sciences is not to accumulate factual knowledge or to practice practical skills such as map reading or riding a bike, but to provide the foundation for lifelong education. Taught appropriately, the subject can thus make a decisive contribution to children's real understanding of the world.

The content areas of the primary science and social sciences as a holistic discipline thereby touch on areas for which various natural and social science disciplines provide expert knowledge and methodically proven procedure. Thus, whereas on the one hand the broad range of the contents of the subject offer "a variety of opportunities to link up with primary school children's experiences and interests. On the other hand, in view of the numerous and sometimes competing demands made on the primary school, the question arises of where the emphasis in the content of general knowledge teaching lies" (GDSU, 2003, p. 9)

In order to fulfil both the connectivity towards the subject disciplines of secondary schools as well as the life experiences and interests of the children, the Perspective Framework for primary science and social sciences (in German: Perspektivrahmen Sachunterricht) distinguishes the following five different perspectives within both the thematic areas as well as the ways of thinking, working and acting:

- the social sciences perspective (politics – economy – social issues);
- the nature science perspective (animate and inanimate nature);
- the geographical perspective (spaces – natural basis – living conditions);
- the historical perspective (time – change);
- the technological perspective (technology – work) (GDSU, 2013, p. 14).

However, these five perspectives must not be regarded as separate and independent of one another. The simple addition of the different perspectives in the form of separate, perspective-related contents does not meet the multi-perspective approach required in the Perspective Framework. Likewise, one cannot assume that the world of things itself is ordered according to the scheme of scientific disciplines (Luhmann 1985/2004, p. 12).

In order to fulfil the living worlds of children and thus their complex lifeworld issues, the various perspectives need to be meaningfully interconnected within the subject's lessons. Multi-perspectivity inter-related with a meaningful interconnectedness, therefore, is the constitutive characteristic of the subject primary science and social science (Sachunterricht) in German primary schools. Teachers need carefully to choose those examples and contents for their teaching that allow useful links between the children's life experiences and interests and the learning opportunities offered by the subject areas. The present and future significance of the potential content is thereby just as important as the exemplary meaning for the subject and the individual learning preconditions of the children. (Schmeinck, 2017)

SELECTED DIDACTIC CONCEPTS AND EDUCATIONAL PRINCIPLES

Contemporary, "good“ teaching of primary science and social sciences is characterized by various didactic concepts and educational principles, which are briefly described by way of example in the following paragraphs. Although presented separately below, the different concepts and principles can and should be understood as intertwined.

Lifeworld and science orientation (in German: Lebenswelt- und Wissenschaftsorientierung)

The lifeworld orientation in teaching primary science and social sciences focuses on the children's perspective. The children’s world thereby represents a model of everyday knowledge, influenced by the learners’ social environment (Kahlert, 2004). Lifeworld orientation describes the children’s lifeworld from a constructivist perspective as a personal, strongly subjective, and not a universally valid world.

Lifeworld orientation in teaching primary science and social sciences does not aim at basic understanding of things and structures, but rather describes accessibility to things. Primary science and social sciences teaching should offer the possibilities to extend the accessibility and the limited field of experience of the children. In doing so, the connection to the subjective world of the children should be the starting point of learning (Kahlert, 2021).

The term science orientation in combination with teaching primary science and social sciences was originally established during the educational discussion of the 1970s. The term in these days described the change in primary science and social sciences teaching from a local-historical to a science-oriented approach. Today, the goal of a modern (science-oriented) subject teaching is not the "imparting of systematically organized knowledge [...] in order to provide as much (inert) knowledge as possible for further learning.” (Möller, 2006, p. 110-111)"

The goal of modern, science-oriented teaching is that learners:

- feel interest and pleasure in thinking about phenomena in nature and technology and are interested in exploring scientific and technical questions and problems;
- develop confidence in being able to figure things out and understand them;
- develop willingness and enjoyment to engage in exploratory thinking and to accept challenges in thinking;
- develop skills to communicate about scientific and technical issues;
- begin to build an understanding of science and scientific work (nature of science) and learn appropriate procedures (e.g., undertaking experiments);
- acquire a basic conceptual knowledge that they can use to predict and explain phenomena (Möller, 2006, p. 111).

Within teaching primary science and social sciences, the lifeworld orientation and the science orientation are always equal as central orientations. In this way, the learning objects should always be considered in the field of tension between the child and the subject and prepared for learning and teaching accordingly.

Interest orientation (in German: Interessensorientierung)

Interests are of great importance in our lives. People therefore tend to pursue their interests over long periods of time (e.g., as a hobby, a specialty, etc.). The reason why we are attracted to what is interesting to us is mostly individual and has developed at some point over time. But interest can also be awakened situationally, by a special, striking, or challenging event - and often flatten out just as quickly. The object then possesses a special interest for a certain period. In both cases, we attach a special significance to the object - and this significance supports learning processes. We develop questions about the object because it "has something to do with us".

Both aspects play a role in the teaching primary science and social sciences: At first, it is a matter of arousing interest in the current subject matter. In the long run, however, a general interest in and an open-minded attitude towards phenomena are also aimed at.

Action orientation (in German: Handlungsorientierung)

Action-oriented teaching is holistic and student-active teaching. In the classroom, the products of action agreed between the teacher and the students guide the organization of the teaching process. The students' mental and manual work is thus brought into balance.

Action-oriented teaching in its ideal form has some central characteristics:

- It starts with a problematic situation of manageable complexity appropriate to the age group, which is recognizably significant for the learners.
- Students and teachers agree on a goal with which they can identify. They plan together how to get there, carry out the plan, evaluate the result achieved and the process that led to it. In between, there are interim reflections and possibly plan revisions as needed.
- This result, the action product has a recognizable "use value" for teachers and students: one can do something with it, show it to parents, a concrete change, an object or a utility, new knowledge is created. It is not about preparing for the next class assignment or the exchange value of good grades.
- The lesson is determined by achieving the agreed goal - what does not contribute to this may have to find a place in another lesson series.
- The pragmatic, emotional and cognitive dimensions of learning are considered equally important ("head - heart - hand"), as are the quality of results and the quality of process.

Education for sustainable development (in German: Bildung für nachhalteige Entwicklung)

Education for sustainable development (ESD) pursues the goal of "enabling people to recognize and evaluate the problems of the present and future, from the local to the global level, and to participate in the development and design steps that are necessary to enable present and future generations to live well." (ANU, 2020). The associated task of not only making the global dimensions of local action visible to primary school students, but also enabling them to think and act in a way that is fit for the future, is not always easy to implement in daily classroom practice, however. Nevertheless, it is now more important than ever that children already in primary school age gain insights into global interrelationships and recognize how they themselves can contribute to everyday decisions, both now and in the future. The promotion of interdisciplinary knowledge is therefore just as important against the background of education for sustainable development as the promotion of children's abilities to think ahead and act autonomously. Only when children understand the complex and global interrelationships and when they can assess the consequences and effects of their own actions can they also be motivated and empowered to participate in social decision-making processes.

Climate and environmental protection, biodiversity, raw material and energy consumption, production and consumption, globalization and many more - all these are key issues that we all must deal with. Education that makes people competent to deal with these major challenges in terms of sustainable development is therefore of crucial importance - even at primary school age.

Digitization-related learning (in German: Digitalisierungsbezogenes Lernen)

Access to digital technologies and the Internet is having a decisive impact on all levels of a child’s life: personal, family, social, and in the future, professional. In the educational context of primary schools, both analogue and digital media play a decisive role through various media-didactic (media-educational) functions. On the one hand, digital media and artifacts are used extensively in primary science and social sciences. Thus, mainly due to its specific approach, primary science and social sciences teaching can contribute to reconstructing the complex, digitally shaped reality of life in an interdisciplinary didactic way (learning about media).

On the other hand, digital media can support learning and cognitive processes in primary science and social sciences lessons in such a way that includes the development of the understanding of the subject as a science process (scientific literacy, e.g., in the form of data acquisition and communication). In this respect, digital media can be seen as "media-didactic added value" (learning with and through media). In addition, digital media are used in primary science and social sciences lessons in several ways. For example, to allow access to things, as a source of information, as a research tool, as a means of documentation, and as a means of communication.

The declaration "Medienbildung in der Schule" (media education in schools) published by the German Kultusministerkonferenz (Conference of Ministers of Education) in 2012 aimed to implement basic and continuous media education as a critical aspect of school education and to offer schools and teachers professional learning opportunities for media education in schools. Four years later, the KMK presented the strategy paper "Bildung in der digitalen Welt" (Education in a Digital World). Thereby, the fundamental goal of the KMK strategy was to provide all students entering the primary school from the year 2018/2019 onwards with the required digital competencies until the end of their compulsory education (KMK, 2016, p. 18). Thus, even primary schools are required to facilitate learners' digital competence.

Starting with primary education, federal states in Germany include the competencies required for active, self-determined participation in a digital world into their curriculums. This will not be done by a separate curriculum for one's own and new subject but will become an integral part of the subject curricula of all subjects. Each subject contains specific approaches to the competencies in the digital world. Thus, subject-specific competencies are in the same way acquired, then essential (subject-) specific characteristics of the competencies for the digital world. In this way, the development of competencies (analogous to reading and writing) is promoted in various learning opportunities and experiences (original in German; KMK, 2016, p. 11-12).

The following six areas promote learners' digital competence:

1. Research, process and store
2. Communicate and cooperate
3. Produce and present
4. Protect and act safely
5. Problem-solving and acting
6. Analyse and reflect (KMK, 2016).

The competence areas described by the KMK involve much more than basic computer-based knowledge or pure knowledge of appropriate technologies. Nevertheless, division of areas and competencies is artificial. There are numerous overlaps and cross-references between the areas and competencies. The current and future opportunities of primary school children in the digital world depend very much on how we prepare them for life in this digitized world. To help children become both technically competent and digitally literate in an increasingly globalized and digital world, and thus to support the five key areas of digital literacy, it is essential that teachers select teaching content and methods in which digital media can be integrated in a meaningful way that adds value to teaching and learning processes. Teachers should reflect on the various learning processes with the children. In this way, digital media will add value to the teaching content. In addition, the digital competence of the learners will be promoted so that they are able to use media safely, creatively and responsibly (Schmeinck, 2022).

CONCLUSION

Within the described multi-perspective approach children become enabled to learn systematically and reflectively as well as being empowered to shape their own environment. They get fundamental insides into complex situations, problematic areas and into the mutual interdependence of environment, society and economy. Additionally, the approach presented in this paper enables the connectivity towards both, the subject disciplines of secondary schools as well as the life experiences and interests of the children and thus contributes to developing the necessary requirements for present and future learning in children (Schmeinck, 2012, 2017).

To be able to teach this multi-perspective approach in an appropriate way, those teachers teaching the subject require competences in all different perspective areas as well as in the various didactic concepts, pedagogical principles, teaching methods and techniques. Therefore, teacher training institutions need to make a common effort to guarantee that all these professional prerequisites are met (Schmeinck, 2017).

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Chapter 3

U.S.A.

Science education in the Elementary Grades in the United States: teaching and learning science

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Elementary science education has been included in the national science education standards for decades in the United States. Despite this inclusion for science beginning from the kindergarten grades, science can often be found to be taught less often than other school subjects. There has been much research on strategies for best practices in elementary science teaching that emphasize science literacy and equitable science teaching, but these are not always included in the classroom. Recommendations are made to influence policy for including science in elementary schools beyond listing them in science standards, and to provide funding for professional development for elementary teachers.

Keywords: Elementary Science Reforms, Elementary Science Literacy, Science for All, STEM, Equity

INTRODUCTION

Teaching science in the elementary schools has been recommended in the United States for decades. Yet, we find that science is often given less attention and time than other subjects. For example, a recent research study found that in kindergarten classrooms roughly three percent of the day students were engaged in science lessons or for about nine minutes (Engel, et. al., 2021). Despite that unfortunate fact, there are many teachers who are science enthusiasts and strive to make science an integral part of their classrooms. In this chapter we will describe trends found US elementary science education in: standards and reforms, science literacy, equity in the classroom, and other influences on science programming in the elementary classroom.

ELEMENTARY SCIENCE FOLLOWS STANDARDS AND REFORMS

National Science education standards were introduced as early as 1989 with the book 'Science for All Americans' designed by Project 2061 at American Association for the Advancement of Science (AAAS) and included science standards for those as young as kindergarten. Seven years later, the National Science Education Standards (NSES) was published. However, critics soon found fault with the NSES, arguing that it included too many topics, resulting in a science curriculum that was "a mile wide and an inch deep" (Zucker & Noyce, 2020). The result was introducing Next Generation Science Standards (NGSS) published in 2013. As it addressed the previous science guidelines' problems, NGSS aims for in-depth understanding on fewer topics. However, the NGSS does not emphasize scientific literacy development and decision making in the science world abilities development. For example, the final NGSS document does not mention the name of a single scientist nor does it expect students to learn about key events in the history of science, such as Galileo's conflict with the church about Earth's place in the solar system or Jonas Salk's development of a polio vaccine and his decision to place it in the public domain (Zucker & Noyce, 2020). For example, Galileo's heliocentric universe vs. biblical geocentric universe provides a good lesson on observations, inferences and predictions (which is one aspect of Nature of Science, which will be discussed later in the chapter). In fact, NGSS was unable to address science education in the context of societal and personal concerns associated with the COVID-19 pandemic (Zucker & Noyce, 2020). Many believe that NGSS needs to be updated with the modern trends, technology, social, economic and political changes. However, NGSS sets the foundation to prepare students for college, careers, and citizenship from K-12 (Vieira & Tenreiro-Vieira, 2014). Science classes in elementary level should provide the opportunity for students to engage in experiences, to build scientific knowledge, to develop values/attitudes, logically argue and to make decisions according to science knowledge.

US states can choose to adopt these standards, or to modify or create their own standards. Even if an individual state chooses not to formally adopt the NGSS, their own state standards generally make recommendations for similar content objectives. This choice of NGSS adoption at the state level influences elementary science education in the United States. In the following paragraphs we describe the composition of the NGSS for elementary grades. These standards are available by website or app for a device, and so page numbers are not available.

For elementary grades, the standards are divided into grade level bands beginning with kindergarten and building on these standards with new standards at each grade level year through fifth grade. For example, in Kindergarten there are standards within "Forces and Interactions: Pushes and Pulls". Within this standard students are to demonstrate they can plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object. Within this standard there are connections to scientific and engineering practices of "planning and carrying out investigations" and nature of science including "scientific investigations use a variety of methods, as well as the disciplinary core ideas of forces and motion including strengths of pushes and pulls and changing direction, as well as interaction among objects. There are also connections to the *crosscutting concept* of cause and effect, in the realm of "simply tests can be designed to gather evidence to support or refute student ideas about causes."

These standards are built across grade levels, with third grade students being called to note that an object generally has multiple forces acting on it, as well as the patterns of an object's motion being observed and noted and recorded. By the fourth grade students are to develop a definition of energy, such as the faster an object is moving, the more energy it possesses, and energy can be moved from place to place by moving objects or through sound, light, heat or electric currents.

Topics in Kindergarten include interdependent relationships in ecosystems, animals, plants and their environment, weather and climate, engineering design. Topics in first grade include Waves: Light and Sound, Structure, Function, and Information Processing, Space Systems: Patterns and Cycles, and Engineering Design. Second grade includes Structure and Properties of Matter, Interdependent Relationships in Ecosystems (building on kindergarten), Earth's Systems: Processes that Shape the Earth, as well as Engineering Design. Third grade returns to Forces and Interactions, building on Kindergarten, Interdependent Relationships in Ecosystems, building on second grade, Inheritance and Variation of Traits: Life Cycles and Traits, Weather and Climate, building on kindergarten, and Engineering Design. Fourth grade includes Energy, which builds on kindergarten and third grade, Waves and Information, building on first grade, Structure, Function and Information Processing, building on first grade, Earth's Systems: Processes that shape the Earth (building on second grade), and Engineering Design. Fifth grade includes Structure and Properties of Matter, Matter and Energy in Organisms and Ecosystems, Earth's Systems, Space Systems: Stars and the Solar System, and Engineering Design. Each year builds on the previous year, connecting various content areas across the elementary grades, but including Engineering Design in each and every year.

ELEMENTARY SCIENCE LITERACY

A prominent goal in elementary education is to develop literacy skills in reading and writing. Teachers and parents alike have an instrumental role in shaping and modeling practices and skills that are associated with literacy. This home to school connection can be strengthened by teachers encouraging learning at home by providing literacy activities that the whole family can participate in. This practice not only helps develop literacy skills in the elementary students at home but also can strengthen the partnership between the teachers and family which has both academic and socio-emotional benefits for the elementary child.

Meyer, Ostrosky, Favazza, Mouzourou, van Luyling, and Park (2016) incorporated a home literacy program that introduced books and activities that included a "Science programme adapted from the ScienceStart!™" and a special friends program. The 16 classrooms studied were randomly assigned either the Special Friends program or the Science Program. Each program offered class book readings, cooperative learning groups with activities that came from the books and home book reading in which a new book was sent home for the family to read with the student for each week of the six-week study. The families conducted a survey and results suggested that many families enjoyed the books from the science program. While there were negative reactions to the program, the overwhelming results from the study suggest that families noticed developmental advances in language, literacy and concepts (especially science concepts) and found much enjoyment in sharing the literature and activities with their children. This indicates that a school to home connection can be a great place to foster literacy development with science related trade books as well as an avenue for teachers to build important connections with families (Meyer, et al., 2016). Teachers are generally more confident in teaching literacy than science. Therefore, intercurricular literacy and science lessons can be a support for building science lessons and assessments.

Besides science concepts that are included in elementary science classrooms, what other scientific ideas are related to scientific literacy? Nature of scientific knowledge is one such idea which can be described as the characteristics about science that make it different from other kinds of knowledge. Nature of Science (NOS) is considered an important educational goal by science education researchers (Allchin, 2020; Lederman 2007; Olson, 2018). However, it is rare to see effective NOS instruction taking place in an elementary science lesson (Akerson et al., 2019). To contribute to a student's scientific literacy it is not enough to teach solely science content knowledge but also explicit understanding of the Nature of Science. NOS had been previously explicitly included in standards documents, such as the Benchmarks for Science Literacy (AAAS, 1993; Akerson et al., 2019). Currently, in the Next Generation Science Standards (NGSS Lead States, 2013), there is no strong focus on NOS (Akerson et al., 2019), which we believe is a drawback. It has been eight years since the introduction of the NGSS standards and we are experiencing a strong need for a new set of Science Standards in the United States. Research shows that through appropriate instruction, elementary students can, and do, develop sophisticated understandings of NOS as young as 5 years old (Akerson & Donnelly, 2009). Even though there are no expectations for NOS included within the main NGSS document, there are descriptions of NOS ideas in Appendix H of the document, indicating that there is still some attention to NOS in science education instruction in the USA (Akerson et al., 2019).

Learning science does not mean understanding rocket science. Acquiring the skills and knowledge to understand scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity should be the ultimate goal of learning science (NRC, 1996). Conceptualizing NOS is a component of scientific literacy (Akerson et al., 2019). A scientifically literate person can ask, find, or determine answers to questions derived from curiosity about everyday experiences, describe and predict natural phenomena, understand articles about science in the popular press so as to engage in social conversation about the validity of the conclusions, identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed, evaluate the quality of scientific information on the basis of its source and the methods used to generate it, and pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately (NRC, 1996). These are believed to be the foundation of learning science; hence these NOS components need to be taught when the learners are young. According to Quigley (2010) young children (as young as K-2 level) are capable of conceptualizing NOS aspects to varying degrees, and it is essential that they receive explicit reflective instruction to help them reach their potentials in these understandings (Akerson et al., 2015).

For example, the atomic model that students learned 50 years ago is different from the atomic model that students learn today. There is no guarantee that the atomic model that we learn today will remain unchanged for another 50 years. However, there is general consensus that the atomic model that we learn today is more accurate than the model that students learned 50 years ago. Likewise, the model that students will learn 50 years from today will be more accurate than the model we learn today. This is an example related to the tentative nature of Science. We can understand this aspect better than many other aspects of NOS because the tentativeness of NOS is relatively easy to teach and learn. A study done on K-2 students shows the levels of improvement varied across different aspects while showing the highest improvement in tentativeness of NOS (Quigley et al., 2010). If the students are provided explicit understanding of NOS, they will understand those better. So, the students will not be confused when they learn such concepts in science (or changes in science).

Nature of Science (NOS) is considered a crucial component of scientific literacy and research has shown, that for students to sufficiently learn NOS that teachers must have good understandings of NOS and of how to teach it (Akerson et al., 2015; Abd-El-Khalick et al., 1998; Akerson et al., 2009; Lederman, 2007). Many pre-service teachers as well as some in service teachers have no solid understanding about NOS. Despite having had a course to teach them NOS content, and being in a methods course that provided them with explicit and reflective instructional strategies for teaching NOS, they (teachers) did not actually observe appropriate ideas about NOS being explicitly taught to students, and this could be a critical component for supporting the transfer of Pedagogical Content Knowledge (PCK) for NOS to the teaching of NOS (Hanuscin, 2013).

EQUITABLE LEARNING EXPERIENCES IN THE ELEMENTARY CLASSROOM

COVID-19 has created a global experiment in teaching and learning that is challenging for both teachers and students (Usak et al., 2020). Teachers have worked overtime to learn new online and virtual methods to teach their students. Virtual and distance learning was first implemented as an alternative for elementary levels in the USA. Although no one is immune to COVID-19, it has disproportionately impacted communities already affected by poverty and individuals of color (Schwartz, 2020). Researchers have found positive effects of teaching virtually. Virtual and online learning arguably promote equity by broadening student engagement, providing a rigorous approach to science instruction and supporting a community-based approach to learning (Miller et al., 2021). African American students prefer online learning better as it has less space for classroom bullying (Miller, 2021). However not all households in the USA have equal access to a computer and an internet connection at their home. One third of Hispanic households do not have access to a desktop computer or laptop computer and one fifth of African American households do not have access to home broadband internet (Atske & Perrin, 2021). We have heard stories that high school students drive to McDonald restaurant car parks to access the internet to do their school projects. Of course, being below driving age means that elementary level students with no internet cannot enjoy that privilege to complete school work at a nearby McDonald's because of their inability to drive and own a car. The equity gap can increase for students at these grade levels.

VIRTUAL/ONLINE TEACHING IN ELEMENTARY

From a study that was done in Turkey, it was found that elementary school teachers have mixed feelings about online and virtual science implementation (Ozdemir, 2021). Researchers stated that online Science, Technology, Engineering, and Mathematics (STEM) implementations are fun and interesting but implementing it is hard and the process is complicated. Also, teachers shared that their students complained about learning new technologies and it was noteworthy to spend too much time explaining the methods and technology. When a brief literature review was done, it can be found that the attitude and preferences for teaching science virtually is becoming more positive in the last few years. Given these conditions, teachers have worked overtime to learn new tools, create virtual learning opportunities, and support all their students in continuing their education in less-than-ideal circumstances (Miller et al., 2021). There are many innovative ways that elementary teachers use technology to support online science learning and some teachers have personalized their own way that they can teach science better and their students can understand better. One advantage is online learning supports student centered learning better. Also it helps students to collaborate better than in the traditional teacher centered face to face classroom. As we are experiencing many new virtual instructional strategies, virtual instruction has facilitated teachers to develop new instructional approaches that can even be further introduced into in-person instruction (Miller et al., 2021).

Recent research has shown that virtual instruction is often of lesser quality than in-person instruction in terms of rigor and student engagement (Dibner et al., 2020; Lan & Hew, 2020). This significantly affects the under-represented students in elementary science education. Virtual instruction runs the risk of exacerbating the barriers that our educational system creates for students of color, students from low-income families, and students for whom English is not their first language (Miller et al., 2021). As elementary science students are highly dependable on their parents or guardians, the unexpected low performance in online learning highlights a lack of resources and inability to access the online resources at home rather than than parent or caregiver negligence. So always the online elementary science class should be inclusive and welcoming. To maintain good social interaction, our researchers, including myself, used to ask our pre-service teachers to keep their cameras open in their online classes. One researcher noticed that one student did not open her camera at all, but one day that student turned on the camera during office hours and it was in her bathroom. The girl was sitting on the toilet telling the instructor that this was the only quiet place she had to join classes and therefore kept the camera off (Zhong et al., 2021). We do not know what difficulties and hardship they experience in the environment from which students log into online school, again making it critical to work to make science classrooms inclusive and welcoming.

Similarly, Hu and Lu (2020) found that teachers reported a low level of experience in online teaching. This, combined with a very little time to prepare, have forced K-12 schools in the USA to search for quick and effective solutions to a new educational reality imposed by the global COVID-19 pandemic. The solutions that these schools were seeking revolved around maintaining effective teaching in this altered educational setting, seeing as both students and teachers were accustomed to interacting and working academically within the actual physical classroom. There is a level of disquiet regarding whether online classrooms would still be able to provide teaching that will still be able to study the students intellectually, help them progress to the targeted academic levels and implement a high-quality curriculum, while simultaneously not setting goals which are not feasible for the classroom teachers to achieve. The scope of this study covered two different online teaching programs, one in the state of Milwaukee, and the other in the state of Boston. The researchers sought, through a comparative analysis to highlight the differences related to how these programs are designed, and how they affect the learning experiences of the involved students. This would ultimately lead to the illustration of both the pitfalls and advantages of these two programs and would help the researchers arrive at recommendations that would serve to enhance future online learning class designs and experiences.

The study examined the cases of two students, each who was involved in one of the two differently designed programs. The first type of program was an asynchronous online class, and in this type of class, the students had access to the different materials related to the curriculum in an online manner, with the teacher serving as a guide (Zucker & Kozma, 2003; Friend & Johnston, 2005). The students and the teacher in this program design did not interact academically in a real-time manner, and no visual or auditory interaction was necessarily involved, unless images were uploaded, or recorded audio clips or videos were utilized (Bernard et al., 2004; Murphy et al., 2011). In this study, the asynchronous online teaching was conducted through a software called SeeSaw, which was used at the participant student's school; the educational methods involved physical games, videos, worksheets, crafts and other games that were present on the software itself. Parents were also involved in this program design assuming responsibility for multiple tasks including, uploading their children's work to the software and taking photos and playing the physical games with their children. The second type of program was a synchronous online class, and in this type of class, students were connected to their teacher through audio, video or both in-real time. Although still in different physical locations, the students and the teachers are required to synchronize their meeting times to overlap, which is to a large extent similar to what happens in a regular classroom (Bernard et al., 2004; Murphy et al., 2011). This program included 10 different subjects (the asynchronous one included only 4), had particular activities related to the different subjects and included special activities for the class. In addition, this program design offered different forms of interaction with other students as well as their teacher. These included classroom-wide quick sharing and one-on-one conversations. The instructors considered the first four weeks as a trial, after which they used the feedback of both students and their parents to update their online classroom approach.

When comparing the experiences and reactions of the participants, the researchers were able to recognize advantages and disadvantages in both program designs. In the asynchronous model, the student was at more liberty to explore the different offered learning topics and to do so at his own comfortable pace. Some of the offered activities had a very positive impact on the student, such as the sorting game, where the student was translating these activities into his everyday world, outside of the class setting, both willingly and at his own request. However, despite the excitement and happiness expressed by the participant, a feeling of impatience related to the activities that involved the parents, such as physical games and crafts, was conveyed by the student, as waiting for the parents made this student feel distracted and disinterested. The student also showed decreased willingness to complete the more challenging activities that were presented. With regards to the synchronous model, extended and more regularly occurring in-classroom interactions as well as a larger number of offline activities seemed to offer solutions to the extended waiting times experienced in the asynchronous learning model, as well as having less dependency on the involvement of parents. In addition, the different types of interactions between the students and their teachers and among the students themselves served to better address the individual needs of the students as well as bring forth the benefits that emerge from the different classroom interactions. The drawbacks to this model were the very large amounts of digital content as well as the extended time spent on the computer screen.

The researchers, as a conclusion of their study, suggest an integration between the two models that would bring together the different advantages of both studies and hence offer a "middle ground" that would sustain these advantages, and limit the potential drawbacks.

STEM IN ELEMENTARY SCHOOLS

With the advent of the NGSS in schools, some elementary schools are moving from science teaching to "teaching STEM." In the United States, the job market has witnessed a growth of STEM-related jobs at a rate that is triple to non-STEM ones, and these STEM jobs are playing an important role in supporting the country's economy (National Science Board, 2014; Byrnes & Wang, 2018). However, a decreased achievement in science classes, among low-income, Hispanic and Black students, compared to their Asian and White peers who are at a better socioeconomic status, has led to unequal opportunities in pursuing these careers (Byrnes & Wasik, 2009). This gap in science achievement, that is observed in kindergarten and first grade, and becomes more prominent in middle and high school, is exacerbated in the increasing inequality in income that the United States is experiencing (Greenfield et al., 2009; Saçkes et al., 2013; Morgan et al., 2016; Byrnes & Wang, 2018). Hence, this sustained and apparently increasing difference in science achievement results in decreased motivation among these low-income, Hispanic and Black students in addition to their chance in successfully pursuing STEM-related careers. The researchers consequently aimed to develop a theory that would help foster equitable learning, and provide equal achievement solutions for students of different socioeconomic statuses. For this purpose, researchers have been working toward developing and conducting tests using a model named the "opportunity-propensity model (O-P model) of achievement." To develop this model, the researchers first analyzed different pieces of literature to identify factors (predictors) that correlate with student achievement, and then conducted additional studies using controls to eliminate any of these predictors that were determined to be false-positive (Byrnes & Miller, 2007; Byrnes & Wasik, 2009; Sakes et al., 2011; Wang et al., 2013; Byrnes & Miller-Cotto, 2016; Byrnes & Wang, 2018). Then, using Hierarchical Linear Modeling (HLM) or Structural Equation Modeling (SEM), the theorists developing the O-P model would suggest relationships among these predictors.

Briefly this O-P model has divided the predictors of achievement that were constantly appearing in the literature, and sustained after controlling, into three categories. The first category are the opportunity factors, classified as features present within the learning contexts at school and home that would stimulate the acquisition of skills. These learning contexts include books, trips to museums and of course classrooms among others, and include aspects such as methods of evidence-based teaching and exposure to content. The second category are the propensity factors, which are the characteristics present within the children, that allow them to acquire the skills within these previously mentioned contexts. Those factors include motivation among the students, their self-regulation and existing knowledge that these students might possess and that would thus contribute to their acquisition of skills. The third category of factors are the antecedent factors, and those factors attempt to explain first the reason why some children are exposed to more learning opportunities than others and the reason why these children have the will and capability to benefit from these additional learning opportunities. These factors are identified for the purpose of including other variables that emerge from analyzing the literature and to be able to complete the picture of student achievement to the best possible extent, and include gender, the expectations from parents, the socioeconomic status and race/ethnicity.

Through this study, the researchers aimed to first, to utilize a combination of predictors of science achievement, both new and previously established, to test various O-P models. These models offer a different comprehension of how the three categories of predictors (opportunity, propensity and antecedent) are related when predicting the outcome of student science achievement. Secondly, in a national study looking at variations in the early science skill development, researchers aimed to study and justify the presence of differences related to gender, ethnicity/race and socioeconomic status, in the early science skills of a national sample.

The study was entitled ECLS-K:2011, and was a follow up to a study originally conducted from 1998 to 2007. The researchers justify the importance for conducting this study by the implementation of several governmental policies and the occurrence of demographic shifts, both important events that have taken place since the 1990s. These events, according to the researchers, are necessary to take into consideration, seeing as how they might have the potential to impose effects on various "key developmental outcomes". The study sample included 14,624 children, in varying percentages between White, African American, Asian, Hispanic and other racial groups. These participant children had attended kindergarten for the first time in the year 2011, and were evaluated using a science assessment at the end of both kindergarten and first grade levels. The variables included in the examination that this study conducted were new, and were not part of the examinations done in previous O-P related studies. These variables met the theoretical definition and therefore fell under the three broad categories of variables: antecedent factors, opportunity factors and propensity factors. The antecedent factors were selected based on their ability to answer why some children possess a greater level of self-regulation, executive function skills and prerequisite science skills and what caused some children to attend schools where opportunities to learn science that were more favorable were provided. The opportunity factors were selected based on their indication of certain characteristics present in the school context that fostered or adhered the ability to acquire science skills, while the propensity factors, per their definition, indicated characteristics present among children, that made them possess the ability and will to benefit from opportunities of learning presented to them. The outcome or dependent variable of this study was the scientific achievement of these students at the end of the first grade, and was predicted as a result of the influence of the three variable categories (Curran & Kitchin, 2019).

Through the results of their study, the researchers first emphasized on the importance of the concept of mediation when considering the outcome which was science achievement. Mediation was an important factor to consider, whether taking into consideration the O-P model that only had a no mediation (direct) path or that that only had mediation; in addition, omitting mediation paths, even in a model that fit the data excellently, would render the model misleading. Second, the researchers emerged with conclusions related to the existing theories of learning and motivation. The first conclusion was that the theory for achievement should integrate various constructs of the theories that are considered competitors to it such as the motivation theory. Although the various theories do provide an accurate emphasis on the roles that certain constructs play, individually, they are incomplete or incomprehensive. The second conclusion was that there were various factors that were not previously considered with regards to their role in predicting achievement. The third conclusion was that there were several predictors that were uncovered by the study, which had not been linked to early science achievement. This adds to previous theories that linked math achievement, solely, or in combination with reading achievement, to science achievement, noting that these previous theories revolved around children at the middle or high school level. In addition, the researchers concluded that children entering a classroom should be at equal levels of enthusiasm for the subject, and be presented the entire content in a unified approach that targets the whole group. Hence, it is of extreme importance to pay extra attention to the preparation provided to children at the kindergarten level. These children should encounter identical experiences, regardless of their socioeconomic status, with the aim of adequately preparing them for the science instruction that they will encounter in the upcoming grade levels. Furthermore, the national scale at which the study was conducted made the results even more significant to the level of kindergarten education. The reason behind this was that the study included a sample, representative of the national schooling population for this age level, and was not limited to the characteristics of a particular school or schooling system. Moreover, the study came to a conclusion that a lot of factors need to be taken into consideration and integrated, to be able to illustrate a complete image, that explains the expected achievement for the students. These factors include the ratings of self-regulation by the teachers, ratings by the parents pertaining to what level their children were able to express the characteristics of being an engaged learner, in addition to prior achievement. The study also suggested that there seems to be a national trend in the approach taken by teachers in class, where this very similar approach in presenting the required material from textbooks, might be playing a role in influencing the achievement of certain students. In addition, the findings that the study uncovered seem to be extending further than the level of just kindergarten and first grade, where these factors that were found to play a role in affecting student science achievement, seem to have an impact on other grade levels as well.

The researchers recommend the utilization of some "high-impact teaching strategies", that were derived from findings in cognitive psychology that have been well-established, and recommended by the Institute of Educational Sciences

(Pashler et al., 2007; Byrnes & Wang, 2018). These strategies involve presenting the students with material that slightly exceeds their level regardless of the level at which they stand, when entering the classroom for the first time at the beginning of the fall semester. The researchers also highlight that there are still other factors that need to be addressed, as 34% of the variability in student science achievement that relates to factors or predictors has not yet been unraveled (Wang & Degol, 2016).

OTHER FACTORS THAT INFLUENCE ELEMENTARY SCIENCE TEACHING

Other approaches for teaching elementary science in the United States include problem-based learning, inquiry teaching, use of discourse strategies to promote student learning, and appropriate teacher knowledge and background.

In their study, Johnson et al., (2019) set out to collaboratively engage kindergarten students with Project-Based Inquiry (PBI) Global. Students engaged with their five senses to explore the various artifacts. The goal of the study was to understand how teachers can use digital tools and inquiry to promote cultural understandings. Aligned with United Nation sustainable development goals, the Project Based Learning (PBL) approach "(a) ask a compelling question, (b) gather and analyze sources, (c) creatively synthesize claims and evi-dences, (d) critically evaluate and revise, and (e) share, publish, and act." In one instance, students were able to use their sense of smell and taste to compare hot chili pepper sauce from Korea with the American staple, Franks Red Hot sauce. Conclusions were that students were able to take ownership of their cultural explorations while learning science concepts.

Samarapungavan, Patrick, and Mantzicopoulos (2011) studied Kindergarten science learning and motivation as they relate to participating in an inquiry-based science program. The year-long implementation of inquiry-based science in Kindergarten was part of a larger study called the Scientific Literacy Project. This project uses activities that fostered children to understand that science is a set of cultural practices, which as we have seen in a previous section, is related to Nature of Science. Through a variety of measures both researcher-created and standardized assessments were used to understand students' uptake of learning science concepts through inquiry. A portfolio rubric was used to evaluate this. The results suggest that teachers felt they did not have time to teach science, and that low levels of science literacy in teachers can foster misconceptions in inquiry teaching. Also, the inquiry-based classroom prompted a lot more teacher questioning and ultimately was more effective in developing student understandings of science concepts.

Harris, Crabbe, and Harris (2017) found that Kindergarten teachers can use discourse strategies such as questioning, scaffolding and clarification questions to support kindergarten students' learning science and scientific inquiry. Particularly because kindergarten students cannot usually read and write, it is important to foster discourse strategies to support their learning.

Fauth, Decristan, Decker, Buttner, Hardy, Klieme, and Kuntner (2019) conducted a study of 54 Classrooms comprising 1070 third grade students to determine factors that can be attributed to teachers that relate to student science learning. Results show that teacher competence (measured with pedagogical content knowledge, self-efficacy, and teaching enthusiasm) was positively related to students' interest in science. Teacher self-efficacy was positively related to their students' achievements, with teachers with higher science teaching self-efficacy having students with higher science achievements. Three dimensions of teaching quality (cognitive activation, supportive climate, and classroom management), which refer to the actual teacher-student-interactions in the classroom, mediated these relationships. These results help illuminate the mechanisms behind the effects of teachers on student outcomes. Teachers need content knowledge, pedagogical content knowledge, and high science self-efficacy, to be enthusiastic, and to develop a supportive climate with appropriate classroom management, all the while, activating their students' cognition.

DISCUSSION AND RECOMMENDATIONS

While elementary science education has been a part of the recommendations for science teaching for decades, and has been part of the standards, including the current NGSS standards, we still have elementary science being taught less than other school subjects (e.g. Engle, 2021). This is despite the fact that there is much research on strategies for elementary science teaching, such as a focus on scientific literacy, equitable science teaching–including PBL and other hands-on strategies, and an emphasis on STEM. We are of the mind that an emphasis on STEM could either support elementary science teaching, or bury it, as it could be presumed that if a teacher is teaching mathematics s/he could be teaching "STEM" and therefore also science. Or if done appropriately, the emphasis on STEM could influence the inclusion of science in elementary classrooms as teachers strive to incorporate all disciplines.

How can we ensure science is taught in the United States throughout the elementary grades, using equitable, evidence-based practices that emphasize scientific literacy? It has not been sufficient to simply include such goals in the standards. It has also not been sufficient to require elementary teachers to take science courses as well as science methods courses. In some way it appears necessary to influence policy not only for science standards but also policies addressing mandated time devoted to teaching and learning science in the US elementary classroom. Certainly professional development programs can help to provide support for teachers to include science in their elementary curricula. Funding for these programs should be made available to university faculty to provide evidence-based programs, with funding for teachers to engage in best practices. Professional development plus policy that does more than include standards for elementary science education can go a long way to ensure science is being taught and learned in a way that promotes scientific literacy for all young science learners.

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Chapter 4

Japan

The origin of primary science education in Japan: a case of an East Asian country

Hisashi Otsuji

In this chapter, readers encounter the introduction and transition of primary science education in Japan. Some practical educators and their hidden backgrounds are emphasized, in addition to a review of events related to science education. Since the modern education system was introduced in the 1870s, the children-centered methodology of Pestalozzi and Fröbel was significant. Currently, according to international comparative surveys, Japanese students' performance in science is remarkable. However, the influence of social backgrounds such as World War II, democratic education after the war, and cultural backgrounds such as the view of nature and Mahayana Buddhism has not been seriously examined. As modern education began, there were foreign influences, legislation was put in place, and views of nature and nationalism were affected. In the modernization process, the people changed their values and responded flexibly. The effects of war cannot be ignored. It is our responsibility to review our values and history, looking to the future.

Keywords: Pestalozzi, Nature, Mahayana Buddhism

INFLUENCE OF PESTALOZZI

In the Edo period, in Terakoya or clan schools, there was almost no way to teach besides reading or reciting Confucian books and copying model-texts by brush. After the end of the Edo shogunate, in the Meiji Restoration, one of the main policies by the Grand Council (Dajokan) was to adopt the Western education system and unify the system in central sovereignty. That was the proclamation of the Education System Order (Gakusei) in 1872 when the Gregorian calendar was also introduced.

In the 1870s, the last samurai, Hideo Takamine[44] (1854–1910), was sent to Oswego Normal School[45] in the United States and brought Pestalozzian thoughts and methods back to Japan. Pestalozzi (1746–1827), in the face of war-torn orphans, founded and practiced the child-centered educational method influenced by Jean-Jacques Rousseau (1712–1778). He aimed for the harmonious development of abilities through children's voluntary activities, emphasizing their individuality and intuition. His ideas and methods were brought to the east coast of the United States at that time and spread by Hermann Krüsi-Dunham (1817–1903) and Edward A. Sheldon (1823–1897); in what was known as the "Oswego Movement." Takamine was not the first person to introduce Pestalozzi's methodology into Japan, but he later served as the principal of Tokyo Higher Normal School and came to be called the Father of Normal School in Japan. In the early days when the methodology of reading textbooks was mainstream, Takamine brought about a new philosophy that was later inherited by the child-centered principle in the Taisho Free Education Movement (1920s–1930s).

Two educators in Europe who learned from Pestalozzi also influenced Japanese education. One is Friedrich W. A. Fröbel (1782–1852), known as the ancestor of early childhood education, and the other is Johann F. Herbart (1776–1841).

THE BEGINNING OF KINDERGARTEN EDUCATION

When the first kindergarten in Japan was established in 1876 at Tokyo Women's Normal School (currently the Ochanomizu University), there were

[44] Hideo Takamine had been besieged in Aizu-jo Castle in 1868, surrendered, and studied at Keio University after the battle. He stayed at Krusi's house.
[45] Now the State University of New York at Oswego.

only three teachers, two assistants and a director. One teacher, Clara Matsuno[46] (1853–1941) was born in Berlin and studied at a nursery teacher training school founded by Fröbel before coming to Japan. She came to Japan to marry and was asked to work there as the headteacher, delivering training on the Fröbel Gifts (Table 1). Fuyu Toyoda (1845–1941), who lost her husband and brother in the turmoil of the Meiji Restoration, learned from the younger headteacher. She had worked as a language teacher at the Woman's Normal School and moved to the attached kindergarten. Fuyu had no children but she had experience raising children. When she was 12, her mother died after her brother's birth, and she brought up the baby with her sister. The following year of the establishment of the kindergarten, when Clara was on long-term leave due to childbirth, Fuyu and Hama Kondo[47] (1839–1912) worked hard with 150 children.

Table 1

Fröbel's Gifts and Activities (Occupations)

Number	Gifts	Number	Occupations
1	Yarn Balls	11	Perforating
2	Sphere, Cylinder and Cube	12	Sewing
3	The Divided Cube	13	Drawing
4	Rectangular Prisms	14	Knitting & Weaving
5	Cubes & Triangular Prisms	15	Paper Folding
6	Cubes & Rectangular Prisms	16	Paper Cutting
7	Square & Triangles Planks	17	Peas-Work
8	Sticks	18	Card-Board Work
9	Rings	19	Playing in the Sandpit
10	Peas or Pebbles	20	Modeling with Clay

Note. Adapted from *Yochien Jiten (Encyclopedia of Kindergarten)*. (1994). pp.492-497.

[46] Clara Louise Zitelmann met Hazama Matsuno, who learned at the forest academy in Berlin. Their marriage was the first international marriage between a Japanese man and a German lady.
[47] Hama Kondo established her own kindergarten later.

The director, Shinzo Seki[48] (1843–1879), had been a Buddhist monk, and he also worked as an intelligence officer in a Christian church in his late twenties. He enrolled in an English school, was baptized, went to Europe, and enrolled in the Anglican Preparatory School. However, in 1873, when Christianity was legally permitted in Japan, he returned to Japan, resigned as an intelligence officer, and quit the monk. He started over as an English teacher, got married, and appealed to the Ministry of Education about founding kindergarten. He started to work as a translator for Clara and then became the director of the kindergarten. He translated Fröbel's ideas and directed kindergarten education in Japan (Kuniyoshi, 2011).

There were twenty Fröbel gifts and activities (occupations) in Japan at that time, including building blocks and origami (Table 1). They have simple but refined rules that are easy for young children to recognize, and it is possible to create work based on the rules while predicting the product in their minds. Origami makes children's hands dexterous and allows them to practice concentrating on things, which is part of a foundation for science education.

Maemura (2015) describes early childhood education as follows:

> Clara's basic idea, of course, reflected Fröbelism. It respected the development and individuality of the child and preached the use of gifts based on the child's play which focused on their interests. Regarding childcare during the introduction of kindergarten education in Japan, criticism such as "translation-like" and formalistic has been repeated. I do not deny this kind of criticism. However, even at that time, Fuyu and other teachers likened the growth of infants to the growth of trees. They learned the foundations of Fröbelist childcare, such as emphasis on intuition, respect for individuality, development of imagination, development of creativity, and the effect of interaction. Moreover, they interpreted the original idea and expressed it in their own words. (omit) Of course, at that time, it was impossible to learn the details of Fröbel's educational philosophy, but Fröbel's naturalism was rather more acceptable to Japanese than Westerners. (Maemura, 2015, p. 122)

[48] His tomb was made to resemble the shape of Fröbel's tomb.

Both Fröbel's view of children and the educational tools he created were based on Christian ideals. It is interesting that these ideals and influences were accepted in the early days of kindergarten education in an East Asian country where Christianity was not pervasive. Here, the fact that a Mahayana Buddhist monk was fascinated by Fröbel's view of children and kindergarten education is very interesting. I will touch on this point later.

Maemura raises another essential theme related to science education: "Nature."

Nature and some related concepts are embedded in contemporary kindergarten education, which consists of five content areas: health, human relationships, environment, language, and expression. Table 2 shows the most recent aims and contents of Environment in the Course of Study for Kindergarten in Japan (Ministry of Education, Culture, Sports, Science and Technology, 2008; 2017), which relates most to nature and science education.

In the current Course of Study for Kindergarten, nature, seasons, life, animals and plants, rules, quantities, diagrams, interest, curiosity, and discovering are just some of the keywords related to science. At this stage, children become involved in natural things and phenomena, cultivating logical thinking ability and awe for living things without realizing. Those are the significant features of primary science education in kindergarten. The affinity between children and nature is universal.

Table 2

Addressing the Environment in Kindergarten Education

Aims and Contents	Description
Aim	Fostering children's abilities to relate to the environment with curiosity and inquisition, and to incorporate this into their daily life.

Objectives	(1) To develop interest in and curiosity about various kinds of things and experiences around them through a sense of familiarity with their surrounding environment and contact with nature. (2) To initiate interaction with their surrounding environment, and to enjoy making and discovering new things and incorporating them into their lives. (3) To enrich children's understanding of the nature of things, the concepts of quantities, written words, etc. through observing, thinking about and dealing with surrounding things and experiences.
Content	(1) Leading a life close to nature, being aware of its grandeur, beauty and wonder. (2) Being in contact with various things in their lives and developing an interest in and curiosity about their nature and organization. (3) Being aware of changes in nature and in people's lives in accordance with the seasons. (4) Developing and incorporating an interest in things surrounding them, such as nature. (5) Acknowledging the importance of life, and appreciating and respecting it by becoming familiar with animals and plants living in the surrounding area. (6) Being familiar with various cultural things and traditions in our country and community. (7) Treating their surroundings with care. (8) Developing an interest in surrounding things and play equipment, and thinking about creative ways to make the best use of them. (9) Developing curiosity about the concepts of quantities and diagrams in everyday life. (10) Developing curiosity about simple signs and written words in everyday life. (11) Developing curiosity about the information and facilities that play an important role in their lives. (12) Being familiar with the national flag and all its functions inside and outside the kindergarten.
Dealing with the Content	It is necessary to note the following points with regard to dealing with content: (1) Teachers should place importance on processes enabling children to learn to think for themselves, by maintaining a relationship with their surrounding environment during play, and then developing curiosity about their surroundings. This will facilitate an interest in the significance and workings of their surroundings and enable them to recognize rules and codes. In particular, teachers should nurture in children the desire to think for themselves, by encouraging them to listen to other children's ideas and to enjoy generating new ideas. (2) Teachers should devise processes whereby children can deepen their relationship with nature, given that the foundation for rich emotions, curiosity, the ability to think and expressiveness is cultivated through direct contact with the grandeur, beauty and wonder of nature, something which is very important to experience during early childhood.

	(3) Children should be encouraged to develop a willingness to voluntarily interact with nature through sharing their feelings about things and experiences, and animals and plants living in the surrounding area. This should be done in such a way that these various relationships enable children to foster a sense of attachment and awe toward these things, as well as a respect for life, a spirit of social responsibility, and an inquisitive mind. (4) When getting to know the culture and traditions, children should be encouraged to develop a sense of connection with society and a sense of international understanding, through the traditional events of our country such as New Year and festivals, national anthems, nursery rhymes, warabe uta and traditional play, and activities to come into contact with different cultures. (5) Children should be encouraged to place importance on their experiences based on the necessities of their own lives, so that interest, curiosity, and an understanding of the concepts of quantities and the written word can be fostered.

NATURE AND CHILDREN IN SCIENCE EDUCATION

The concept of "nature" has been regarded as an essential characteristic of Japanese science education, not only in kindergarten but also at the compulsory level. Since it began with an imitation of the West, it was initially a collection of subdomains, such as physics, chemistry, and natural history. However, in 1886, "Elementary School Order (Shoggako)" and "Elementary School Subject and its Degree (Shoggako no Gakka oyobi Sono Teido)" were issued, and the new subject, called "Rika", emerged as an integrated school subject. Its aim is clearly expressed in the 1891 Outline of the Course of Study for Elementary Schools (Shogakko Kyosoku Taiko):

> Article 8: The gist of RIKA is to refine the observation of ordinary natural things and phenomena, to understand the outline of their mutual and related relationships, and to cultivate the mind of loving nature.

The phrase "loving nature" in this statement is a characteristic of Japanese science education, and three backgrounds have been emphasized. One is the influence of the Romanticism from Europe. It is similar to the idea of Natural History that was directly brought from Germany.

The second background is inspired by imperialism or nationalism against sudden Westernization. Among the bureaucrats of the Meiji era, there was a conflict between a group trying to promote Westernization and a group emphasizing the traditional ways. During "Europeanization", the Japanese government only incorporated the achievements of science and technology from the West but not to ideology or politics (Itakura, 1968; 2009). For example, the "Imperial Rescript on Education", which had an impact until World War II, was issued in 1890. Itakura mentions that the statement matched the feudal order and Confucian morals.

The third theory, focusing on the deliberation committee (Muraoka, Takamine, etc.), advocates the underlying view of nature among Japanese. Han-ichi Muraoka[49] was the first Japanese person to obtain a PhD, studying at Strasbourg University with Wilhelm C Röntgen (1845–1923). After studying abroad, the members who were familiar with the latest Western science and educational philosophy and methods fully recognized the importance of the process of science, including observing natural phenomena, and translated the idea into educational goals (Ogawa, 1989).

Although there are a few interpretations, "Loving Nature" was adopted as a long-standing science education goal and fits the Japanese view of nature.

PESTALOZZIAN IDEAS AND METHODS ARE STILL ALIVE

Muraoka was a leading physicist, but he also had educational achievements. Another purpose of his studying in Europe was to investigate teacher training in Normal Schools, and he was the first to introduce Herbart's four-step theory for lessons. Herbart's disciples applied it to the five-step theory, and it was introduced in Japan at the time. Even now, it is said that a 45- or 50-

[49] Muraoka attended the first Novel Prize Award Ceremony for his colleague Röntgen.

minute science class should be composed of at least three stages: introduction, deployment, and summarization. This division is taken for granted, but few Japanese teachers know its roots in Herbart via Muraoka.

Takamine brought the following basic principles from the Oswego Normal school, as summarized by his teacher, Edward A. Sheldon (Sheldon, 1862, pp. 14–15):

1. *Activity is a law of childhood. Accustom the child to do --- educate the hand.*
2. *Cultivate the faculties in their natural order --- first from the mind, then furnish it.*
3. *Begin with the senses, and never tell a child what he can discover for himself.*
4. *Reduce every subject to its elements --- one difficulty at a time is enough for a child.*
5. *Proceed step by step. Be thorough. The measure of information is not what the teacher can give, but what the child can receive.*
6. *Let every lesson have a point; either immediate or remote.*
7. *Develop the idea --- then give the term --- cultivate language.*
8. *Proceed from the known to the unknown --- from the particular to the general --- from the concrete to the abstract --- from the simple to the more difficult.*
9. *First synthesis, then analysis --- not the order of the subject, but the order of nature.*

Some of the items had already been claimed by Comenius (item 8), and some were later seen in Dewey (item 2, 3, 5). All are inherited by prospective teachers during their teacher training in Japan now. What Takamine brought is still alive.

An American educator, Marion M. Scott (1843–1922), brought the Pestalozzian way of teaching to Japan before Takamine. According to the record, he started lecture style, communication style using concrete materials, and the Monitorial System (Bell–Lancaster method), which depended on students' developmental stages. Japanese education researchers have seemed to overlook students' thinking abilities in communication and have accepted it as a question-and-answer (Q and A) method that asks students only for knowledge. Now that the student-centered way of learning is again in vogue, Scott's struggle should be focused on again as a research theme.

THE INFLUENCE OF WAR

The 1870s was also the decade when the Liberty and Civil Right Movement took place. It led to the subsequent establishment of the Constitution (1889) and the National Diet (1890). With this kind of underlying movement, general education and teacher training became widespread (the increase of the number of schools, teachers, and students). The Taisho Free Education Movement (1920s–1930s) situates in this flow.

There were several Normal Schools in the countryside where the educational movement was flourishing. Chiba University, which I attended, was one of them. It is hard to say that there was a remnant of it in the 1980s, as World War II was on the way, but I was fortunate to thoroughly acquire the practical methodology of child-centered learning, which can be traced back to Pestalozzi.

Just like the conflicting forces of Nationalism and Westernization, democracy and autocracy also sway as giant invisible pendulums, affecting education. Let us take a few examples related to war.

First, when the modern educational system started, Natural History began in the 4th Grade. It moved to Grade 5 with subsequent reforms. Though there have been topics related to science in another subject, Reading, there had always been an argument that science teaching should start in the lower grades. Suddenly, science began to start at Grade one in 1931 when the National Schools were introduced. In short, this was because World War II affected the education system. The government felt there was a need to improve the science abilities of its people.

The myth that "Science is neutral, and the values of people and society caused its misuse" has long been believed. Many people in my country are skeptical of such a simple discourse. Japan is a unique country due to experiences like being hit by atomic bombs and by the nuclear disaster after the huge earthquake though it has been said to be safe. It is natural that the results of science and technology change and affect our lives and society, but society also affects science and science education.

Here, I want to focus on how science was NOT introduced. The science subject introduced in lower grades in 1931 was called the Observation of Nature (Shizen no Kansatsu). Naomichi Shiono (1898–1969) and Genjiro Oka (1901–84), who were in charge in the Ministry of Education, did not produce the textbook for students because they were afraid that students would just read the text and remember concepts. To make science lessons more active, rather than providing textbooks for children, they left it to the teachers' guidance and activities.

Previously, Japanese textbooks were criticized for being thin relative to other nations. The methods and results were not well written, but students were correctly guided in the process of inquiry by teachers in praxis.

The second example is the impact of the Cold War on education. After World War II, the idea of producing militaristic boys was completely changed, and democracy education began. Most people thought they lost the war because of poor science and technology, so science and mathematics were emphasized after the war since they cultivate students' logical thinking abilities. The new ideas of the Pragmatism of John Dewey were introduced as "Life Unit Learning", including problem-solving. I think the shift was not impossible because teachers had experienced the child-centered way of teaching and learning in the Taisho Free Education movement.

Major changes in the curriculum manifest themselves in revisions to the curriculum guidelines (Course of Study) approximately every 10 years.

There emerged a criticism toward the child-centered way of teaching and learning. Teachers may take such an interest in their students' development that they do not progress in the curriculum. The criticism of "Crawling Empiricism" caused the significant revision of the Course of Study. It was replaced by Keito Gakushu (structured learning).

Since the mid-1950s, various textbooks have been developed in the United States. They are called alphabet soup because they use acronyms such as BSCS, CBA, and PSSC. This was spurred by the Soviet Union's launch of the first satellite, Sputnik, in 1957. In Western countries, this is called the Sputnik Shock; a large portion of the budget was invested in science education, and many science textbooks were created. Children were considered "small scientists", and it was believed that it was good to learn like a scientist.

The 1969 version of the Course of Study was revised due to the influence of the curriculum reform movement in the United States. The number of hours in science and mathematics also increased. In Japan, this is called the Modernization Movement.

It was this modernization curriculum I learned when I was in junior high school. Most tasks were given by teachers, not something around us, not out of our curiosity, not something we were wondering about. I remember we were asked, "Let's calculate the size of the molecule", and we measured and calculated the size of the molecule of oleic acid. I understood, but many of my friends showed little interest in invisible things.

Behind the curriculum reform movement, there was the Cold War between the United States and the Soviet Union. It is certain that I was educated under the influence of the war.

Table 3 shows the changes in the number of lesson hours in the Course of Study after World War II. The science and the total number of class hours of compulsory education is indicated. No details but general tendencies are observable.

Table 3

The Change of Standard Number of Yearly School Hours of Science and Total Hours in Elementary and Junior High School (for each revised Course of Studies).

Revised Year		Elementary						Junior High			
	Grade	1	2	3	4	5	6	7	8	9	Total
1947	Sci.	70	70	70	105	105-140	105-140	140	140	140	945-1015
	Total	770	840	875	980-1050	1050-1190	1050-1190	1050-1190	1050-1190	1050-1190	
1951	Sci.	20-	30%	25-	35%	25-	35%	105-175	140-175	140-175	
	Total	870	870	970	970	1050	1050	1015	1015	1015	
1958	Sci.	68	70	105	105	140	140	140	140	140	1048
	Total	816	875	945	1015	1085	1085	1120	1120	1120	
1969	Sci.	68	70	105	105	140	140	140	140	140	1048
	Total	816	875	945	1015	1085	1085	1190	1190	1155	
1977	Sci.	68	70	105	105	105	105	105	105	140	907
	Total	850	910	980	1015	1015	1015	1050	1050	1050	
1989	Sci.	-	-	105	105	105	105	105	105	105-140	735-770
	Total	850	910	980	1015	1015	1015	1050	1050	1050	
1998	Sci.	-	-	70	90	95	95	105	105	80	640
	Total	782	840	910	945	945	945	980	980	980	
2008	Sci.	-	-	90	105	105	105	105	140	140	790
	Total	850	910	945	980	980	980	1015	1015	1015	
2017	Sci.	-	-	90	105	105	105	105	140	140	790
	Total	850	910	980	1015	1015	1015	1015	1015	1015	

Note. Schools have 35 weeks per year, except Grade 1. “105” shows 3 classes per week. A class has 45 minutes in elementary and 50 minutes in junior high schools.

The total number of learning hours was at its maximum in the 1969 revision. Its 1,048 hours decreased by 13.4% to 908 hours in the following revision.

The 1989 revision eliminated science lower grade science (first and second grades of elementary school), which began in 1931 under the wartime regime. Instead, "Living Environment Studies" were started as a joint subject with social studies. The teachers who specialized in elementary science regretted the loss of students' opportunities to make inferences even in the lower grades. However, it was easily accepted by the majority of elementary school teachers who did not specialize in science. For example, in the learning of flowers, students no longer find regularity, structure, or conditions for plant growth. The top priority for the unit was to shift to the family feeling happy for flower gift.

The table shows a significant reduction of the total number of hours in the 1998 revision. The revision also introduced a cross-curricular time called "Period for Integrated Study". In some cases, a school that had been teaching 140 hours in Grade 9 saw a reduction to 80 hours in the following year (−42.9%). When the number of hours is reduced, the content is generally brought to the upper grades. Moreover, in this revision, the content was reduced by 30% as a whole. Nothing could be treated because of the enormous reduction at Grade 9. More literate students were not expected.

Although this reduction in time did not affect the international comparative survey, the decline in the academic ability of children has become a social problem, and backfilling has been progressing since 2008. At present, the student-centred teaching method is attracting attention again with the aim of "proactive, interactive, and authentic learning".

LAWS AND REGULATIONS

Science education quality assurance is regulated by the government, partly because of Japan's loss in World War II. The Science Education Promotion Act, the Order for Enforcement of Science Education Promotion Act, and the Ordinance for Enforcement of Science Education Promotion Act were all established less than ten years after the war. As a result, children became to study science in almost the same science room using the same equipment, anywhere in Japan.

Teacher quality has been regulated by law since the 1880s. In Japan, the period of practical student teacher training is as short as 2 to 3 weeks. There are many regulations for universities regarding pre-service teacher training. Recently, in addition to pre-service training, recruitment examinations, and in-service teacher training have been recognized as a part of teachers' lifelong development. However, teaching is no longer a popular profession for young people. In particular, science is a subject that needs longer preparation time for experiments than other subjects, and science teachers are required to be more motivated than usual[50].

IN CLOSING: A CASE OF THE COUNTRY WITH UNDERLYING MAHAYANA BUDDHISM IDEAS

People's values have changed drastically due to modernization. Some emerged as educators from samurai and some from monks. Some educators created and arranged a lasting goal based on the Japanese view of nature. Science education was influenced by the surrounding elements as well as events like the war. While some laws stipulate certain mandates, they also guarantee quality as

[50] Further information is available in Otsuji et al. (2016).

a standard. Overseas trends also had an impact. We need a solid perspective to determine what is essential.

Educators get energy from children and serve them by having them in front of us. One of the important concepts in Mahayana Buddhism, which is subconsciously widespread in Japanese minds, is the Bodhisattva. Bodhisattva has several meanings, one of which is that even though you have to practice yourself, you also stop your work and help others. Bodhisattva prioritizes the salvation of others over self-awakening. The ideal image of teachers drawn by prospective teachers in Japan is almost the same as this Bodhisattva's image. Standing beside students, they wish to support students' growth, aiming at improve their own teaching skills. The same is true for science teachers. They prepare a lot before class, so that the children can easily become interested, analyse the phenomenon, and enhance their awareness and discussion. To be a better science educator, it is important for us to become aware of the natural environment and ethnic, cultural, and historical characteristics related to science education, in addition to the scientific knowledge and PCK. I hope this chapter brings some new ideas to readers.

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Chapter 5

Brazil

Teacher training possibilities in science education for children

Maria Cristina de Senzi Zancul & Alessandra Aparecida Viveiro

The importance of a science education that allows people to take part consciously and informedly in decisions that involve major issues in our society has been defended in different studies. It is also argued that such an education should start from the early years of elementary school, revealing the need for teacher training that includes conceptual, procedural and behavioral content in the area of science. This chapter presents some proposals that can be incorporated into the training of elementary teachers in order to foster science education for children.

Keywords: Science education, Elementary education, Teacher training.

> *As a teacher, I should be aware that without the curiosity which moves me, which makes me restless, which drives my search, I cannot learn or teach. Exercising my curiosity correctly is a right of mine as an individual, to which corresponds the duty to fight for it, the right to curiosity. Domesticated curiosity may help me achieve mechanical memorization of the profile of this or that object, but not actual learning or full knowledge of the object.*
>
> *Paulo Freire (2002, p. 33)*

SCIENTIFIC KNOWLEDGE AND SCIENTIFIC LITERACY

The importance of scientific knowledge in contemporary society has been supported by several arguments and a large number of people acknowledge that such knowledge is key to a better understanding of the world in which we live.

For the American scientist and astronomer Carl Sagan (1997) “science is more than a body of knowledge; it is a way of thinking” (p. 28). In his book The Demon-Haunted World: Science as a Candle in the Dark he states that our civilization is highly dependent on science and technology, yet almost nobody understands them. According to the author, "this is a prescription for disaster" (Sagan, 1997, p. 28). The book was published in the 1990s, and since then this dependence has increased significantly, prompting us to reflect on the need and urgency of a science education that enables conscious and informed participation in decisions that involve major issues in our society, such as those related to the environment, food production and distribution, use of new technologies, health care, among many others. This requires teaching science from the early school years. In this text, we present proposals for teacher training in science education that we believe can foster science education for children.

For Harlen (1989), children build the first explanations about the world around them during their years of elementary education. That is why a systematic teaching and learning process of this reality is important, in order to contribute to the discussion of ideas and the development of concepts. The author argues that if schools do act in this sense, other spheres of life, such as mass media, which are concerned neither with science nor the education of individuals, may influence the development of children's learning behavior.

According to Fumagalli (1998), science should be taught from the early years of schooling for the following reasons: children have the right to learn science; schools have a social duty to disseminate scientific knowledge to all individuals; scientific knowledge possesses a social value capable of transforming the way we interact in the world.

Zancul (2007) stresses that the arguments for teaching science in early school years include the fact that scientific content is part of elaborate culture; the role that children play as social subjects with regard to different issues; the interest they show in science topics.

According to Quintanilla-Gatica et al. (2011),

> … enseñamos Ciencias Naturales en el nivel inicial, para formar ciudadanos con competencias científicas básicas, que les permitan comprender el mundo que los rodea y actuar en él, de manera que lleguen a participar de forma informada y consciente en la resolución de problemas relacionados con la ciencia que la sociedad actual presenta. (p.62)

Lorenzetti and Delizoicov (2001) support the development of scientific literacy from the beginning of schooling, even before the child knows how to read and write. For the authors, such literacy is a "process by which the language of natural sciences acquires meanings, becoming a means for individuals to expand their universe of knowledge, their culture, as citizens within society" (Lorenzetti & Delizoicov, 2001, pp. 52-53).

Other authors have also discussed the importance of scientific literacy, such as Chassot (2003), Santos (2008), Roberts (2011), Valladares (2021) and Silva and Sasseron (2021).

In an overview of the idea of scientific literacy in science education research in the last forty years, Silva and Sasseron (2021) stress the viewpoint advanced by Valladares (2021), considering that it updates the idea of necessary scientific literacy for the 21st century context.

Valladares (2021) systematizes the main views of the concept of scientific literacy developed in the last two decades and argues for scientific literacy as a potential tool for social transformation, which requires the engaged participation of different social groups. According to the author,

> … to be transformative, scientific literacy requires a commitment to an alternative notion of emancipation that avoids generating dependencies that assign, in a contradictory way, roles of superiority to science teachers and to science itself that are mostly frequent in multicultural contexts. (Valladares, 2021, p.583)

For Santos (2008), the Freirean perspective of science education constitutes a radical view of scientific literacy. According to the author,

> From Freirean educational principles, the idea unfolds that a Freirean humanistic science education perspective is a political commitment to sociopolitical action, considering conditions of oppression in society. (…) From this Freirean humanistic perspective, an approach to science education is then highlighted, which implies the introduction of socially relevant themes and socioscientific issues, the establishment of a dialogical process in classroom, and the development of sociopolitical action. Hence, a Freirean perspective of science education is presented as a radical view of scientific literacy. (Santos, 2008, p.361)

Based on the considerations of Santos (2008), we believe that the Freirean framework (Freire, 2002, 2005) can support a problematizing science education that favors dialogical communication and the construction of the individual's autonomy, for both science education in the early years of schooling and the training of elementary school teachers (Viveiro et al., 2015; Zancul et al., 2015).

TEACHER TRAINING AND PRACTICE IN EARLY SCHOOL YEARS

Despite the rationale in favor of teaching science to children and the possibilities that such teaching offers to students' development, research shows that it is fairly neglected in the first years of schooling.

According to Mizukami et al. (2002), elementary school teachers in Brazil are specialized in language arts in Portuguese, with a focus on basic literacy and mathematics, to the general exclusion of other areas, including science.

For Hamburger (2007) and Longhini (2008), there are serious gaps in relation to science content in teacher training courses, which, for the early years of schooling, results in textbook-based lessons that are hardly critical of the content taught and the teaching strategies used. In our view, if teachers adhere to the concept that teaching science means conveying ready-made knowledge, it is unlikely that they will explore scientific content in a diversified and attractive way for children.

For our children to learn science, teacher training related to this area must be widely discussed.

According to studies, the concepts of science and scientific work that prevail among teachers show, among other aspects: an understanding that science is dogmatic, closed and infallible; an idea that there is a single scientific method, characterized as a number of defined steps; a view of linear and cumulative growth of scientific knowledge, largely seen as the work of geniuses who discover things, disregarding scientific crises and revolutions; an individualistic and elitist image of science; an unquestionable belief in the ability of science to solve the problems generated by itself and by technology; a notion that overestimates the qualitative and quantitative limits of nature (Gil Pérez et al., 2001).

By not considering essential aspects of the nature of science, even when they include science-related subjects, teacher training courses contribute to the preservation of distorted conceptions, mainly by omission (Raboni, 2002; Longhini, 2008).

In Brazil, teacher training for early elementary school years happens mainly through bachelor’s degrees in education, which qualify teachers to work with content from different areas, including natural sciences. Currently, almost half of these courses are distance learning programs, according to a study by Alves et al. (2022), which makes it even more difficult for undergraduates to practice the procedures that are part of science teaching.

The education of a multi-subject teacher is a complex task, as it must address the fundamentals of teaching and the different areas of knowledge within set limits of time, availability of faculty, workload, etc. However, inadequate training in science may compromise the development of science teaching for children (Viveiro & Zancul, 2012).

We believe that a broad discussion on teacher training perspectives is required, capable of contributing to a more comprehensive understanding of the role of science education in the early years of schooling. We also believe that training should provide teachers with resources to mediate content in the area of science, enabling them to develop coherent and informed work in the classroom.

The scientific literature in the area of science education has contributed possibilities for teaching practice that can be explored in initial and continuing teacher education, some of which we will present in the following section.

TEACHER TRAINING POSSIBILITIES

Based on the work of authors in the field of science education, in this section we point out and discuss a few elements that can be incorporated into teacher training programs for science education in early elementary school. We believe that this proposal can be developed from the perspective of a problematizing education, as opposed to the banking model of education (Freire, 2002, 2005). In this sense, it is necessary to encourage dialogue, because without dialogue there is no communication and without communication there is no true education. Dialogue is able to guide, among other things, the development of curriculum frameworks more closely focused on local demands and the interests of learners in different contexts and cultures. A problematizing education should include experiences that encourage decision-making and responsibility, favoring the development of autonomy.

We argue that experience with different strategies during the training process can help teachers use them later in the classroom. Thus, we consider the following to be relevant for the curricula of these courses:

To address history of science and philosophy of science from a procedural perspective

For effective change to happen in classroom practices in the early years of schooling, teachers must first understand the current conceptions about the nature of science and scientific work, based on what is consensual among perspectives and epistemological theses of contemporary authors such as Popper, Khun, Lakatos, Toulmin, and abandon naive and mistaken views (Osborne, 1998; Gil Pérez et al., 2001).

According to Chassot (2003), history of science is the producer of scientific literacy and the basis for understanding philosophy of science. In agreement with the author, we understand that studying aspects of philosophy of science alongside the historical approach is key to understanding the nature of science. It is interesting to discuss and problematize what science is, what its study objects are, and how everyday knowledge relates to scientific knowledge. Thus, it is important to consider the existence of alternative, popular kinds of knowledge and explore their uses in different social practices, analyzing the way in which institutionalized science deals with such knowledge. Boaventura de Sousa Santos (2007) proposes to contrast the monoculture of modern science with an ecology of multiple and heterogeneous kinds of knowledge, including modern science, in a sustainable and dynamic interaction between them.

Exploring history of science can contribute to understanding that scientific knowledge reflects much of the way the world is or was viewed at a given moment by a group of people, since the facts and results of experiments are closely related to the explanatory models of each period. It is possible to use the history of scientific “discoveries” or the biography of researchers to discuss, for example, how scientists make deductions.

By following the historical process of the development of a theory, its problems, the mistakes made and their implications, and the social and economic relations involved, we can also explore, in an interesting way, the uncertainties of science and its transience. Furthermore, in historical accounts we can appreciate the collective character of scientific activity and issues that involve the mutual influences between science and culture.

Moreover, as pointed out by Gil Pérez et al. (2001), exploring the history of science makes it possible to deconstruct the idea of the existence of a "Scientific Method" while clearly revealing that research methods do indeed exist. According to the authors, "if there is something fruitful to highlight in the history of the construction of scientific knowledge it is precisely the methodological pluralism" (Gil Pérez et al., 2001, p.136).

To use experimental activities in an investigative approach

For Gil Pérez et al. (2001), an important aspect related to understanding the nature of science involves "refusing an empiricism that conceives knowledge as resulting from inductive inference based on 'pure data'" (p. 136). It must be clear that data only make sense when interpreted according to a theoretical system. Every investigation is accompanied and guided by points of reference.

We advocate the use of experimental activities in an investigative approach for believing that they can contribute to the understanding of the dynamics of scientific activity.

A teacher who, during his or her training, did not engage in activities that involve investigative experiments or approaches to problem situations, for example, will hardly feel confident to conduct work of this nature with his or her students (Zancul, 2008).

Thus, we believe that it is possible to offer teachers in training the possibility of experiencing a set of procedures more akin to ways of working that are consistent with the production of scientific knowledge, discussing the results obtained in the experiments, regardless of what they were, analyzing the evidence found, interpreting relationships from the results, investigating possible causes when the findings differ from the expectations. Like Calor and Santos (2004), we understand that it is important

> …to presume that scientific research does not end with the results obtained, but is developed from working hypotheses, is one of the ways to make science teaching less apathetic and more associated with scientific practice. (p. 61)

In addition, we believe that it is necessary to go beyond the manipulative dimensions of procedures, making use of more investigative and cognitive experiments, exploring factual, conceptual, procedural and behavioral contents in a coordinated manner (Gonçalves & Marques, 2006).

To use field study as a learning and teaching strategy

Field study involves replacing the classroom with another environment which offers conditions to study the relationships between the living things it harbors, including humans, thus making it possible to explore natural, social, historical and cultural aspects (Fernandes, 2007). A non-formal space can favor the observation of phenomena and engagement in situations that are different from those normally experienced, providing the development of investigative practices that integrate knowledge from different areas and contributing to a comprehensive view of reality.

For Viveiro and Diniz (2009), "the greater the diversity of the environment chosen for study, the greater the range of content that can be addressed, thus enriching the context of lessons" (p.6).

Prominent among non-formal institutional spaces are museums and science centers, whose main goal is to promote scientific culture based on communication between the field of science production and the community (Delicado, 2004). However, the way in which such spaces communicate science and technology to their audiences has a direct impact on the type of education they will favor. Although there are a few different proposals, a model still prevails that presents science as a neutral, ahistorical body of knowledge, disconnected from social, political or cultural issues (Meyer & Meyer, 2014). On the other hand, when these spaces provide dialogical communication, they can favor a broader understanding of the nature of science. It is important to explore spaces that go beyond the mere exposition of facts and demonstration of scientific phenomena by offering interactive proposals that encourage reflection and appreciate other forms of knowledge (of everyday life, of traditional populations, indigenous, etc.). In any case, it is up to those who plan visits to these spaces to complement what is offered by the different institutions.

Other environments besides institutional spaces can be used for field study. A given reality can be studied with a simple walk in the school surroundings or an outing to a more distant site, such as a permanent preservation area.

Field study can also motivate students and bring people together, strengthening relationships that will continue in the classroom.

In teacher education, experiences in extracurricular environments favor the understanding of phenomena as well as the possibilities and challenges offered by these strategies for teaching in elementary education.

To use a science-technology-society-environment (STSE) approach, considering its multiple interactions

Working within a STSE perspective presupposes considering environmental, economic, quality of life and industrial aspects of technology in relation to nature, as well as the fallibility of science, which involves democratic discussions about values and opinions (Sutil et al., 2008).

Nevertheless, Santos and Mortimer (2001) point out that many educational proposals involving science, technology and society (STS) have largely emphasized technical and biological aspects to the detriment of political and ethical dimensions. For the authors, a science education that aims to be neutral is ideologically biased. Scientific information about the subject being studied is essential but not enough if we want to go beyond the mere transmission of scientific facts.

Thus, when thinking about debating the STSE relationship, we must go beyond the naive position of reducing this task to the inclusion of new concepts that better explain the scientific principles related to technological issues and explore the many contradictions resulting from the internal interactions of the social system and its relations with the surrounding environment (Viveiro et al., 2009).

It is important to explore the wide range of interrelationships between the production of knowledge and its applications in society. We can, for example, use everyday events to analyze the consequences of applying scientific knowledge to issues that affect health and the environment. Newspapers and magazines daily feature news and stories on subjects such as the use of stem cells, cloning, GM foods, radiation emitted by electronic equipment, pollution, etc. It is possible to explore news in the media to debate, among other aspects, the different facets of the development of new technologies or to analyze the ethical issues present in these themes. "Among these themes, those that discuss the so-called scientific controversies may contribute to encourage relevant reflection and questioning" (Pieroni & Zancul, 2021, p.12).

To explore and encourage reference to different bibliographic sources

There is a vast production of science books on various different subjects, many of them written by specialists in their respective areas. There are great books on ecology, environmental education, nuclear energy, sexuality, science atlases and dictionaries, biographies of scientists written in a style suitable to be understood by children and youngsters, among others, accessible even in digital format, available online. Science dissemination articles, presented in more accessible language than academic papers, are also good sources of reference. Such resources can be used in different kinds of activities aimed at understanding aspects of the nature of science as well as learning specific topics in the area.

For Bizzo (2009), "knowing better the subject to be taught in class, how that knowledge was produced, how it was addressed by other people, are equally important tasks" (p.67). Considering the limited opportunities that multi-subject teachers have for delving into scientific knowledge, such materials are very important in training courses, as reference resources for teachers or for direct use with students.

In the specific case of children in the early years of elementary education, Roden (2010) stresses the need for them to be encouraged to seek answers to their "whys?" in a variety of information sources. In addition, they can be challenged to think and discuss whether the answers to their questions require consulting secondary sources or whether possible solutions can be sought through practical investigation activities.

Teachers in training must also be encouraged to analyze different teaching materials and consider whether they ignore any basic aspects of science or transmit any distorted views of it. It is also important to encourage the study of scientific papers with research outcomes and first-hand reports in order to discuss issues related to the nature of scientific knowledge and strategies for mediating such knowledge in the school environment, to the teaching and learning of science by children, etc.

To explore digital information and communication technologies (DICT)

For Ward (2010), the use of information and communication technology in science education should favor, among other skills, students' reasoning, curiosity, observation, the search for trends and patterns, and communication. The author stresses that these tools should also enable the achievement of the goals set for science education in each activity, facilitating the teaching and learning process.

In teacher training and in early elementary education, computers, tablets and smartphones can be important allies, e.g., in having access to different materials and spaces available on the internet, such as simulators, remote laboratories, research repositories, museums and science centers, among others. It is also possible to insert students in knowledge networks, interacting and producing knowledge in partnership with people in distant places.

A cell phone can be used to research information on a plant or animal found during field study, or to access a relief map while exploring local landscape. A cell phone app makes it possible to observe the sky and identify constellations and the position of the stars in real time. With free astronomy software one can simulate sky observation in different parts of the world, under different points of reference (from the earth's surface or from a point in the sky), in the past or in the future. With internet access, it is also possible to take virtual tours in different parts of the world, including natural and built-up spaces, such as museums. DICT thus provides experiences that would not be possible without the help of technology.

In short, the possibilities made available by the use of digital technologies are numerous and dynamic, requiring teachers to pay close attention to new means that can assist in teaching and learning processes, and also to the responsible use of those technologies.

FINAL OBSERVATIONS

For elementary school teachers to contribute to the development of children from the first years of schooling, favoring an adequate understanding of scientific knowledge, undergraduate education courses must rethink their educational strategies and start to incorporate differentiated approaches that explore different aspects of that knowledge and its forms of mediation.

We know that there are many challenges to be faced in courses for teachers of early elementary school years, including little time devoted to addressing different specific content, lack of space and equipment for the development of practical activities, quite often a large number of students per class, night classes, hardly any activities done together with elementary schools, among others. However, we believe that the proposals presented here can be incorporated into initial training curricula as well as continuing education programs, within a Freirean perspective (Freire, 2002, 2005) that explores questioning and the search for answers to different questions that we face in our everyday life.

Despite featuring under separate topics, all the themes listed in this text are closely related and interconnected. In our view, the history and philosophy of science, diversified practices such as experimentation in an investigative approach, field study, the STSE approach, different sources of reference and DICT can be explored in order to contribute significantly to the training of teachers in the area of science and to an efficient practice with the contents of this area.

Teacher training for the early years of elementary education should essentially emphasizes the importance of teaching science from childhood, explaining clearly concepts related to science teaching and learning, and exploring concepts and possibilities of theoretical and methodological approaches that can be used in educational practice with children.

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PART II

Experience reports and researches on science teaching for children

Chapter 6

Brazil

Science, technology, and society education and the scientific and technological literacy: contributions to citizen formation in the early years

Leonir Lorenzetti

In this chapter, we analyze the contributions of science, technology, and society (STS) education and scientific and technological literacy (STL) to citizen formation. The understanding that science and technology have a mutual influence relationship with society is needed for citizens to acknowledge the world around them, such as the concepts and the nature of science and technology, by enabling connections with their daily lives and the knowledge experienced in different contexts. The development of an STS education that expands the levels of scientific and technological literacy in the early years of individuals is essential in the contemporary world.

Keywords: Science Education, Early Years, Citizen Formation

INTRODUCTION

The approach of science, technology, and society (STS) education and scientific and technological literacy (STL) for citizen formation has been a subject of debate and research at all levels of education in Brazil. The discussions in this chapter are the outcome of my personal experiences, such as my work as a teacher in the basic education and as a professor in the higher education — in both undergraduate and postgraduate programs — as well as finished and ongoing researches on the topics.

Science education in the early years[51] of elementary school in Brazil was incorporated as a compulsory subject by Law n. 5691/1971, which reformulated

[51] The early years comprise the first stage of elementary school, encompassing students from the 1st to the 5th grade.

the organizational structure of basic education in elementary school and high school.

Currently in Brazil, the Law n. 9394/1996 establishes the guidelines and foundations of national education: education is a right for all citizens and a duty of the State. School education consists of basic and higher education. Basic education is divided into a) Kindergarten, attending children aged 0 to 5 years; b) Elementary school, subdivided in the early years (1st to 5th grade), attending children aged 6 to 10 years, and final years (6th to 9th grade), comprising teenagers aged 11 to 14 years; and c) High school (1st to 3rd grade of high school), comprising teenagers aged 15 to 17 years.

Garvão and Slongo (2019) present a historical analysis of science education in Brazil in the early years, identifying five periods: i) 1960s: absence of science education in childhood; ii) 1970s: inauguration of science education in the early years; iii) 1980s: changes in science education in childhood; iv) 1990s: first curriculum proposal for science education in the early years at a national level; and v) 2000s: science education in elementary school with a nine-year duration and proposal of a new curriculum.

The curriculum of municipal and state public schools should offer, on average, two hours per week of science education. However, effectively, in the first three years of elementary school, teachers prioritize Portuguese and Mathematics since these subjects are considered essential in enabling students to read, write, and understand basic mathematical operations.

Therefore, the prospect of a significant contribution of other curricular components to the cognitive processes involved in reading, writing, and mental operations is not taken into account. Nevertheless, I have argued that science education can develop a set of cognitive skills that contribute to students' literacy process in their first language, as well as to citizenship formation.

Most teachers working in the early years have a degree in pedagogy and are responsible for teaching all the subjects of the school curriculum. During their undergraduate program, these teachers attend disciplines with reduced hours focused on teaching methodologies in science, which results in a huge conceptual gap in science content. Hence, those teachers lack the conceptual expertise and feel insecure to include such subjects in their teaching practices, even though students are curious and interested in learning more about science and technology in the early years.

Aware of this situation, state and municipal departments of education have been developing actions towards the permanent training of their teachers, seeking to present and discuss didactic and methodological guidelines that can fill the deficiencies of their initial training while combining teaching actions and the current curriculum guidelines. Among the training topics, we can emphasize science, technology, and society education; scientific and technological literacy; science education by investigation, experimentation, critical environmental education, digital communication, and information technologies; didactic resources, among others. In this chapter, we highlight the contributions of STS education and STL for the students' formation.

SCIENTIFIC AND TECHNOLOGICAL LITERACY

Scientific and technological literacy can be considered as one of the main research trends on science education in Brazil. It is pointed as a learning and teaching goal since it is the expansion of knowledge regarding science and technology (ST) along with citizen formation. The development of STL takes place in both formal and non-formal contexts in a procedural and continuous manner. This study aims to stimulate discussions, problem-solving, and critical positionings in matters related to science and technology, based on the premise that by increasing the level of STL, the populations' participation in matters involving science and technology will also increase (Lorenzetti, 2001).

Reading and writing about science should be closely related to the process of understanding the development of scientific and technological literacy. Therefore, educational activities should allow moments of analysis, reflection, and criticism, as well as the incorporation of this knowledge into the students' lives, who begin to identify and analyze the meanings that the topics reveal. This enables the application of scientific knowledge in the multiple contexts in which these individuals are inserted. That is, scientific and technological literacy in school requires a critical and transformative education guided by constructivist assumptions.

> Thus, science education should not be restricted to the simple memorization of scientific facts and concepts. The teaching of science will promote science literacy if it includes the ability to decode symbols, facts, and concepts; the ability to detain/acquire meaning; the competence to interpret sequences of ideas or scientific events. It will also achieve its objective when establishing relationships with other kinds of knowledge, connecting their prior understanding, changing them, and, above all, reflecting on the meaning of what the student is learning, drawing conclusions, thinking, and, ultimately, taking a position towards a subject (Lorenzetti, 2021, pp. 48-49).

These skills should be taught in school, and their practice should be oriented to daily life: reading newspapers, magazines, novels and technical books, advertisements, labels, medical prescriptions, among others. Scientific reading should go from a simple newspaper note to understanding a medicine leaflet. When students comprehend the scientific concepts applied in their daily lives, they also expand their culture.

By impacting work and social and family relationships in different ways, science and technology take part in ordinary life, which highlights how important it is to understand ST. As a result of science education, individuals use scientific knowledge in their daily lives and discuss its social implications. We must also consider that the level of scientific and technological literacy of the population is reflected in political decisions made in a democratic society. According to Hazen and Trefil (1995, pp. 11-12), “today, being able to understand such debates is as important as knowing how to read and write. Therefore, one must be literate in science”. Thus, the higher the level of scientific literacy of a population, the greater the stimulus to an informed and intelligent participation in political issues involving ST.

People can be considered literate in science “when they can understand the news with scientific content, when they can comprehend the context of intelligible articles about genetic engineering or the ozone hole – in short, when they can handle information from the scientific field in the same way as they deal with any other subject” (Hazen & Trefil, 1995, p. 12).

> The average citizen does not need to have the capabilities that are required from scientists. There is no need to know how to calculate the trajectory of an artillery shell or establish the sequence of a DNA strand to understand newspaper news; just as there is no reason to know how to design an airplane to make an air trip. But that does not change the fact that you live in a world where planes exist, and that your world is different because of them. [...] Therefore, it is essential to have the basic knowledge to understand how such changes may occur and what will be the consequences for you and for the generations to come. The ability to comprehend the new scientific and technological advances in a context that allows participating in the debates waged in all the nations of the world is a necessity (Hazen & Trefil, 1995, p.13).

Discussions and decision-making concerning science and technology do not require mastery of science in its utmost details, but it does require knowing how to apply knowledge in daily life. That is, the most important aspect is to know how *to use* science instead of knowing how to do science. Scientific literacy does not require detailed and specialized knowledge, which is reserved for technicians. Instead, it requires enough foundation to understand scientific knowledge and its influences on society.

Therefore, an education aimed at the scientific and technological literacy of students should not be based on the mere formation of future scientists. The STL should enable an understanding of the world that encompasses the discussion and comprehension of scientific and technological phenomena that permeate life (Cachapuz et al., 2005). Moreover, STL allows a greater probability of making positive and rational decisions, since it provides the ability to identify and understand the world in which an individual is inserted, in addition of acting as a transforming agent in society.

Someone who is literate in science and technology may have several behaviors and attitudes as scientifically educated, contributing to their objectiveness, open-mindedness, and willingness. In addition, they can understand, discuss, and take a position on various common issues since they have a general understanding of basic natural phenomena. Such knowledge can prepare capable people, as they will be able to interpret information regarding science and technology present in the media and in their own contexts. Cachapuz et al. (2005) argue that educators should be concerned with contributing to the formation of citizens who are aware of the severity and global character of contemporary problems, such as ecosystem degradation, deforestation, public health issues, depletion of essential natural resources, among others. This can create more conscious students, preparing them to make more appropriate decisions.

Fourez (1994) defines the three main goals of STL as: i) autonomy of the individual (personal component); ii) communication with others (cultural, social, ethical, and theoretical component); and iii) environmental management (economic component). Therefore, communication necessarily involves individuals arguing, debating, engaging in discussions, and standing a position in a given situation.

Schools (through activities that involve curricular components of science in elementary school, in addition to the teaching of chemistry, physics, and biology in high school), non-formal spaces, and sources of communication and information are considered as promoting sources of citizens' participation in scientific and technological knowledge. However, schools will be the source that systematizes productive knowledge for scientific and technological literacy. Bybee (1995, p.32) states that "teachers must implement classroom practices that are consistent with policies, programs, and goals to achieve scientific literacy for all students. [They must] improve practices at the center of the classroom in the most individual, unique, and fundamental aspect of educational science: the act of teaching students."

Scientific and technological literacy can be promoted and expanded through various non-formal sources, such as museums, television programs, magazines and newspapers, the internet, among others. However, "newspapers, magazines, and television cannot be expected to fulfill the function of the most specialized means of scientific literacy" (Cazelli, 1992, p.55). The essence of learning is related to the teacher, the one who stimulates, provokes, problematizes, enriches, systematizes, expands, and gives life to several processes that result in student learning.

Therefore, the faculty is responsible for developing strategies that facilitate the understanding and application of basic scientific concepts in daily situations, developing habits of a scientifically educated person in students. The activities are integrated into the curriculum and reviewed throughout each year of scientific instruction. The development of such activities should enable students to identify and correlate the scientific contents with their reality, guided in a way that contextualization, interdisciplinarity, problematization, dialogicity, and decision-making are evidenced.

In Brazil, there is a consolidated production of dissertations and theses that discuss STL in the early years of elementary school, among which the research of Lorenzetti (2000), Sasseron (2008), and Pizarro (2014) stand out. Lorenzetti's pioneering dissertation (2000) presents the foundations of STL in the early years of elementary school and proposes the use of the three pedagogical moments (Delizoicov, Angotti & Pernambuco, 2002) as structures for its promotion. For Lorenzetti (2000, p.78), scientific literacy can be understood as:

> the process by which the language of natural sciences acquires meanings, constituting itself as a way for the individual to expand his universe of knowledge, his culture as a citizen in the society. These acquired knowledges will be fundamental for acting in society, helping in making decisions that involve scientific knowledge.

The author considers that STL is a lifelong process, developed in schools and in non-formal spaces, and its promotion uses different means. Lorenzetti and Delizoicov (2001, p.9) point to:

> The systemic use of children's literature, music, theater, and educational videos reinforcing the need for teachers who can, through appropriate choices, start working on the meaning of scientific concepts conveyed by the discourse in these means of communication; didactically explore articles and other sections of the journal *Ciência Hoje das Crianças*, linking them with hands-on classes, visits to museums, zoos, factories, water treatment plants, and other government agencies; organization and participation in field trips and science fairs; use of computers and of the internet in the school's environment.

Sasseron (2008) discusses the promotion of scientific literacy in the early years through the teaching of science by inquiry, proposing indicators to verify whether students are being scientifically literate. The indicators are widely used at all levels of education, significantly contributing to the consolidation of the theme in the area and presenting two dimensions: structuring and epistemological. In the structuring dimension, the indicators are: a) information ranking; b) information organization; c) information classification; d) logical reasoning; e) proportional reasoning; f) hypothesis raising; and g) hypothesis testing. The epistemological dimension presents the following indicators: a) justification; b) forecast; and c) explanation.

Sasseron (2008) emphasizes that the teacher who proposes scientific literacy needs to be attentive to its "structuring axes". The author points out that these axes are capable of providing sufficient and necessary bases that must be considered when preparing and planning classes aimed at scientific literacy. The first axis is defined as the "basic understanding of fundamental scientific terms, knowledge, and concepts"; the second refers to the "understanding of the nature of science and the ethical and political factors surrounding its practice"; finally, the third axis "comprises the understanding of the existing relationships between science, technology, society, and the environment".

Marques and Marandino (2018, p.7) also understand scientific literacy as a process that takes place inside and outside school, and it also implies:

> i) the promotion of dialogues and approaches between the experiential culture of individuals and the scientific culture;
>
> ii) the appropriation of knowledge related to scientific terms and concepts, the nature of science, the relations between science, technology, and society;
>
> iii) the promotion of necessary conditions for critical readings of reality, participation in public debates, responsible decision-making, social intervention in an emancipatory and social inclusion perspective; as well as that scientific literacy should promote not only the appropriation of knowledge, but also the construction of what [Paulo] Freire calls epistemological consciousness, increasing social participation.

Pizarro (2014) analyzes the scientific literacy in the early years of elementary school, emphasizing teachers' knowledge and professional learning and the potential formative requirements produced in large-scale evaluation systems.

From the analysis, the author identified a set of indicators that can characterize scientific literacy by understanding “scientific actions as something inseparable from the active and conscious social being” (Pizarro, 2014, p.92), which are: a) articulating ideas; b) investigating; c) arguing; d) reading in science; e) writing in science; e) problematizing; f) creating; and g) acting.

> Articulating ideas, investigating, and arguing are procedures increasingly valued in the early years in several subjects, but students are still very dependent on the teaching action to demonstrate dexterity in these actions, since it seems to be “new” (kept the proper temporal proportions) to listen to what the student has to say and give credit to what he says in education practices.
>
> Reading and writing in science classes seems a trivial thing, but for small children it is not. It is an arduous service of reflection and action at the same time, and sometimes it is even costly for those who are not fully literate.
>
> And proposing new ideas and acting in society are also necessary exercises since early ages for individuals. It seems that they are inherent to other actions, but they must take their significant place in the formation of future citizens, given the directions that society and science have taken (Pizarro, 2014, pp.93-94).

In this sense, Pizarro and Lopes Junior (2015, p.113) recognize

> scientific literacy as a process that imposes commitments to science teaching proposals that goes beyond the contact with scientific notions and concepts, enabling the understanding of science’s public dimension from the point of information access but, in particular, promoting repertoires of discussions, reflections, and critical positions concerning the themes that involve the work of science, its products, their uses, and the human, social, and environmental aspects that circumscribe such works, their products, and their uses.

These studies are considered as references since they present the theoretical and methodological foundations as well as the indicators to assess whether students are being scientifically literate.

SCIENCE, TECHNOLOGY, AND SOCIETY EDUCATION

STS education in the teaching of natural sciences aims to provide a relevant scientific, technological, and humanistic education by motivating citizen-oriented participation of students in decisions involving ST issues and in discussions on the nature of science and technology to overcome naive and/or reductionist views (Auler & Delizoicov, 2001; Cachapuz et al., 2004).

The field of studies on interactions between science, technology, and society presents itself as a possibility for overcoming weaknesses in the training of science teachers. In general, the disciplinary treatment of specific contents, the dissemination of naive conceptions about ST, and the distance from pedagogical training are discussed. In addition to this, the number of researches carried out in Brazil that associate STS education with the training of science teachers is significant (Krasilchik, 1987; Auler, 2002; Cachapuz et al., 2005; Carvalho & Gil-Pérez, 2011; Correa & Bazzo, 2017).

Currently, STS education can be defined as a well-consolidated field of work, with an interdisciplinary character, and organized around criticisms of traditional ST images. According to Palacios et al. (2003, p.125):

> STS studies seek to understand the social dimension of science and technology from the point of view of its social background, as well as its social and environmental consequences, that is, regarding the social, political, or economic factors that modulate scientific-technological change and regarding the ethical, environmental, or cultural repercussions of this change.

Therefore, the curriculum proposal for STS education would correspond to an integration between scientific, technological, and social education, in which the scientific and technological contents are studied together with the discussion of their historical, ethical, political, and socioeconomic aspects (López & Cerezo, 1996).

STS studies are directed to three fields of activity: research, public policies, and education. In the research field, there is space for studies that employ a more contextualized and social approach in ST areas. In the public policies field, there is a demand for the democratic participation of citizens in ST matters. Finally, in the education field, studies promote a citizen education so that students can carry out different readings of the world and understand the relationship between science, technology, and society (Cerezo, 2002).

Therefore, STS education aims to: emphasize discussions on the social dimension of ST, rejecting the treatment of scientific and technological production as pure and neutral; criticize the idea of technology as an applied and neutral science; and encourage public participation in decision-making (Cerezo, 2002).

It can also be stated that STS education aims to promote: a) interdisciplinarity in science education, integrating it with economic, ethical, social, and political aspects; b) the engagement of students and researchers in the examination of issues related to the real world from the scientific-critical point of view; and c) the formation of critical thinking in science, technology, and society.

Bybee (1997) proposes that STS education should contribute to the citizenship and scientific literacy of students. In addition, it can also contribute to the formation of attitudes and values, as it considers:

> [...] the formation of attitudes and values in opposition to the memoiristic teaching of pseudo preparation for the entrance exams; the thematic approach in opposition to the extensive science programs unrelated to the daily life of the student; the teaching that leads to students' participation in opposition to passive teaching, imposed with no space for their own voices and aspirations. Finally, a curricular renovation of STS implies changes in the concepts of education and science teaching roles (Santos & Mortimer, 2002, p. 127).

Santos and Mortimer (2002) argue that, in addition to aiming the insertion of STS education in curricula and teaching programs, it is urgent to think about how to implement such practices in the initial and continuing training of teachers, since referring to the STS assumptions of the curriculum guidelines may not be enough for teachers to work in this perspective (Strieder et al., 2016).

The field of continuing education has been growing in recent years due to the patterns resulting from the interaction of formal education institutions and public macropolitics, aiming to meet a formative demand of teachers (Nascimento, 2000). In this regard, we must consider that teachers are constantly involved in the processes of continuing education, contributing with reflections on their practices and, consequently, leading to an improvement in teaching (Cachapuz et al., 2005).

> [...] the national research on STS has been concerned with building academic results based on teaching in classrooms and in situations of non-formal spaces, as well as with the theoretical elaboration of an autonomous thinking considering European and North American researches (Abreu et al., 2013, p.24).

Bazzo (1998) emphasizes the importance of discussing ST in formal education for citizen formation, which can make one able to understand, belong, and act in the world, freeing himself from the passive, servile, and profitable perspective of labor. For Bazzo (1998), it is not about turning students into sociologists nor philosophers of ST, but rather that STS education:

> [...] must make young people creative and critical about the achievements of science and technology that they themselves have helped to create in numerous situations; it must help them think about the aspirations of their peers and of all citizens; it must make them careful about their health — *heavily dependent nowadays on many technological results* — and, above all, it must lead them to think about the results and consequences of scientific-technological artifacts in a collective process. Most importantly, education should point towards critical thinking about the richness of cultural values as well as the moral and spiritual dimensions of life. [Education] needs to be taken to all young people with such assumptions, regardless of their knowledge background, gender, belief, race, or color (Bazzo, 1998, p.28).

In this sense, we consider it essential to provide tools for teachers who work in the early years by bringing them closer to the discussions about STS education and proposing interventions in the school context. For this, it will be necessary to discuss the concepts of science, technology, and society and propose interventions that can contribute to the STS education's goals.

González et al. (1996) highlight the urgency of disseminating a social image of science and technology, placing them as transitory and filled with controversies. The authors argue that teaching based on STS education should combine all phases of formal education in order to overcome the technocratic vision of the methods and goals of teaching natural sciences.

> As we mentioned earlier, the main goals of academic research and public policy inspired by STS are, on the one hand, the contextualization (demystification) of science and technology and, on the other, the promotion of public participation opposed to the technocratic approach of institutional management. In this sense, one way of understanding STS education is comparable to an application of previous points presented in the educational sphere, which, on the one hand, implies changes in the content of science and technology teaching and, on the other, changes in methodology and attitudes of social groups involved in the process. At last, these changes aim to merge two famous cultures, humanistic and scientific-technological, traditionally separated by an abyss of incomprehension and contempt (González et al., 1996, p. 47).

Solomon (1993) also highlights the characteristics of STS education, emphasizing the environmental issues and their relations with social and economic aspects:

> Special STS features within science education include: an understanding of the environmental threats, including global ones, to the quality of life; the economic and industrial aspects of technology; some understanding of the fallible nature of science; discussions of personal opinion and values, as well as democratic action; a multi-cultural dimension [...]. (Solomon, 1993, p.19).

In order for these assumptions to be incorporated into the school context, it is necessary to consider the curriculum and teacher training. Santos and Mortimer (2002, p.3) argue that a curriculum focusing on STS should have the following requirements:

> (i) *science* as a human activity that attempts to control the environment and ourselves, which is closely related to technology and social issues; (ii) *society* that seeks to develop a sophisticated operational vision of how decisions about social problems related to science and technology are made by the general public and also by scientists; (iii) *student* as someone prepared to make intelligent decisions and able to understand the scientific basis of technology and the practical basis of decision-making; and (iv) *teacher* as the one who develops knowledge and commitment to the complex interrelationships between science, technology, and decision-making.

The study by Domiciano and Lorenzetti (2020) points out that the following elements need to be highlighted in the promotion of critical STS education[52]: a) contextualization; b) problematization; c) interdisciplinarity; d) dialogicity; e) nature of science and nature of technology; f) decision-making; g) humanization; and h) habit of participation.

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[52] Critical STS education involves the understanding of the interactions between scientific, technological, and social fields in an interdisciplinary and contextualized critical way.

Regarding research involving STS education in the early years, there are also relevant studies in Brazil, such as Ferst (2016), Fabri (2017), and Maestrelli (2018).

Ferst (2016) analyzed how the STS relationship occurs in epistemological, ethical, and ontological dimensions in the initial teacher training in pedagogy degrees considering their reflexive tendency.

The author argues that STS education:

> in the educational context, has become an important and decisive point to discuss ST in a critical, innovative, and contextualized perspective with the social, ethical, political, economic, cultural, and environmental problems that underlie such issues. In this context, it is considered that teacher trainings should emphasize more this study and give more importance to it in their curriculum, since it is understood that the focus of STS teaching should permeate all disciplines of this course, instead of being isolated initiatives of certain professors (Ferst, 2016, p.145).

Ferst (2016) also points out that in the pedagogical project of the pedagogy program at the State University of Roraima *(Universidade Estadual de Roraima)*, the focus of her study, and also in statements of interviewed professors there are small isolated initiatives of teachers working in an STS approach. However, a lack of knowledge about the issue was strongly perceived by most of the interviewed teachers.

Regarding the epistemological aspect, the author emphasizes that the curriculum organization must be rethought in order to reverse the image of a traditional way of teaching, based on memories and speeches, and centered on the positivist view of science. Ferst (2016) argues that ethics must permeate and guide discussions, raising the ones that involve STS, and respectfully leads to attitudes that can form ethical citizens who are responsible for their decisions. In the ontological aspect, the author highlights teachers as the centerpiece of the process, assuming the possibility of a critical, ethical, and reflexive way of teaching due to their own formation.

Through a university's extension project, Fabri (2017) analyzed the contributions of a continuing education (CE) course in the science domain with an STS focus for teachers working in the early years. Fabri (2017) used methods to initiate reflections and discussions that could promote scientific and technological literacy, demystification of its neutral, salvatory, and determinant aspect, and theoretical and practical deepening in the areas of physics, chemistry, and biology, with an emphasis on the STS approach.

> Such deepenings are the primary point of CE, as teachers will not be able to work if they have not developed the concept already. The conceptual aspect is fundamental, and teachers must realize that it is taking place throughout their profession. Teachers must establish their concept so that in the future they can contribute to the education of their own students (Fabri, 2017, p.183).

Fabri (2017) also argues that

> It is necessary that teachers understand the STS approach as an attitude, a posture, and an epistemological choice that will guide their teaching practice, creating the habit of critical thinking in their students. This epistemological choice must be clear so that the student realizes that there are contradictory situations in work and multidimensions involved in the issue, which require a critical positioning (Fabri, 2017, p. 184).

Maestrelli (2018) analyzed how the science, technology, society and environment (STSE) approach[53] can contribute to the development of knowledge, values, attitudes, and skills in science classes when developed with a didactic sequence with students of the 4th grade of elementary school. The author uses the expression "STSE" to approach environmental themes, such as "water", from

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[53] In Brazil, some studies have used the expression STSE (Science, Technology, Society and Environment) to emphasize the importance of environmental issues, maintaining the same assumptions of STS education.

a sustainable society perspective. The didactic sequence was structured based on the three pedagogical moments[54] and composed of six meetings.

She argues that:

> in addition to scientific knowledge, the teacher must teach values, attitudes, and skills, which can only be developed through an intentional, adequate, and conscious pedagogical action, as the curriculum is understood, from the perspective of a critical education, as the process that integrates these elements (Maestrelli, 2018, p.144).

She emphasizes that the STSE approach represents a viable way of expanding mechanisms for student participation and enhances the decision-making process, basic elements of citizen formation.

FINAL CONSIDERATIONS

We assume in our research that STS education promotes the understanding of the interrelationships between scientific and technological education with society. We address historical, ethical, political, and economical aspects that permeate the presented and questioned social themes, and that emerge from the students' contexts. The STS education can also be considered as a curriculum renovation that requires a broad and critical understanding of the nature of ST, as well as the citizens' role in it.

In addition to promoting the engagement of students and teachers in the subjects that involve ST, STS education aims at the formation of critical thinking

[54] The three pedagogical moments proposed by Delizoicov, Angotti, and Pernambuco (2002) are presented in the following stages: initial questioning, knowledge organization, and knowledge application. The three pedagogical moments propose the establishment of a dialogical dynamic between teacher and students in the classroom, aiming at the construction and reconstruction of knowledge.

students by expanding their levels of scientific and technological literacy, thus contributing to their citizen formation.

We agree with Marques and Reis (2015), who state that education can be defined as a process of socialization, in which each individual is prepared to take an active place in society through the development of skills that promote their empowerment by allowing productive participation in civic life. By being participatory, affective, problem-solving, located, multicultural, dialogic, democratic, investigative, interdisciplinary, and activist, the empowerment education allows students to become capable workers, critical citizens, thus social critics and agents of change. In this sense, "it is urgent to train citizens capable of facing different problems that permeate today's societies, many of which are highly controversial, representing threats to the well-being of individuals, societies, and environments" (Marques & Reis, 2015, p.3).

Therefore, we must advance in the understanding of theoretical and methodological assumptions of STS education, as well as the promotion of scientific and technological literacy in both formal and non-formal contexts.

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Chapter 7

Colombia

The role of modelling in natural science classes with blind children in primary education

Diana Castro-Castillo & Rosa N. Tuay-Sigua

Throughout science didactics history, different strategies and models have been implemented in order to enable and improve the teaching of this discipline across all academic levels. As an effect of such strategies, it has been possible to study and identify the global diversity and inclusion panorama with respect to education. This chapter presents the observations and conclusions when implementing a model-based strategy in different primary schools focused on children with sight-disabilities in Bogotá, Colombia.

Keywords: Modeling, Natural Sciences, Blind children

INTRODUCTION

In recent years we have reflected on the role of didactics and especially on the way students access the different objects of study of the natural sciences from the sensory capacities they possess, in order to provide an inclusive education that promotes the construction of school scientific knowledge in all children and young people. In this way, different strategies have been developed to favor the teaching and learning processes in the field, among them, modeling, which aims to represent a phenomenon that is part of the natural world so that classroom participants can describe, establish explanations and predict a behavior, understand the world, from the use of models, scale representations, montages, among others.

However, in the design of these models, it has been observed that the visual experience prevails so that the subject can make an image and thus approach the phenomenon, which leads to question what happens to the student who lacks the sense of sight and what actions should be taken to link it to the activities that are carried out in the classes of natural sciences under this methodology. Therefore, this chapter aims to present a research exercise carried out with five children blind from birth whose ages are between 10 and 12 years old, who participate in an inclusive classroom when approaching the study of the solar system, taking as teaching strategies the question and the use of scale models. In this order, the way in which modelling is conceived in the school context, science education in contexts of inclusion, the methodology of research and analysis of the results in particular, the representations that children can externalize from the classroom work carried out are presented.

MODELLING IN NATURAL SCIENCE CLASSES FROM A DIDACTIC PERSPECTIVE

When talking about modelling from a school setting, it is necessary to recognize the importance of the model and scientific representation, because they are necessary elements in the production of knowledge. The model is considered a strategy through which situations of reality are represented in order to "observe", to make "perceptible" to the senses the behavior of certain variables and the relationships between them in order to give explanations or make an image of a phenomenon of the natural world, which requires for its understanding a certain degree of abstraction taking into account that there is no direct relationship with it. For Tuay (2011) the models form entities under which a representation is made, therefore, they become built systems that aim to systematize, organize and facilitate knowledge and intervene in reality by consciously deforming it.

In this order, the model is directly related to the representation, in our case, the scientific one, which can occur in various ways (of physical, conceptual, mathematical order, etc.) in order to simulate phenomena or processes. Representation is a mental process that occurs through images and symbols and that allows to establish relationships between theories and the context in which the subject is immersed, which makes it possible cognitively to establish knowledge, thus achieving "externalize", "evoke" some characteristic features of the configuration it makes to build its own "reality" (Tuay, 2005).

In natural science classes, a strategy for addressing phenomena is made from modelling; where different ways of approaching students to school scientific knowledge are provided, establishing a set of conceptual and empirical structures that provide specific elements for the understanding of a phenomenon (Tuay & Céspedes, 2017). For Bravo and Izquierdo-Aymerich (2009) teachers use pragmatically appropriate scientific models from a didactic transposition, the models lead to a representation that "allows thinking, speaking and acting with rigor and depth on the system being studied" (p.45), likewise, they recognize that the "model" does not necessarily have to be highly elaborated, you can make use of models, images, analogies, among others, the important thing is that it evokes in those who use them, skills to describe, explain, predict and their use is not reduced to a single reproduction of the phenomenon.

Modelling involves elaborating simplified and partial representations of objects and phenomena to be able to describe, predict and explain aspects that interest us about them (Couso, 2020), it also aims to publicize scientific ideas or theories that have been validated by a certain community, making use of different resources, which allow establishing a mental representation of the object of study. That is why modelling is considered an interpretive description of a phenomenon, which, in didactic terms, leads students to access it from concrete, abstract or theoretical entities.

In the case of the present study, scale and analog models were used. The scale model is used as a prototype to establish characteristics of objects and predict their behavior, in this order a scale design of the solar system was made. For Tuay (2012) "scale models represent their target system by the displacement of an idealized image and the physical abstraction of some of its characteristics and their relationships" (p.11). In this order, for sighted and blind students, modelling becomes a way of accessing information that cannot be "tangible" to the senses or that requires a certain degree of abstraction and, therefore, a way of accessing it is through the representation that can be made of the phenomenon or the process studied.

On the other hand, an analog model was used, which reflects the structure of relationships and certain fundamental properties. An analogy is established between the real system and the model, where a detailed study of reality is carried out taking this model as a tool (Tuay, 2012). In its essence, analogy is another form of representation that can not only be expressed through narrative but through sensitive experiences (in our case, privileging touch) that allow evoking characteristics of objects or phenomena in which various properties are compared or related, thus helping the subject, to have a proximity to reality. With the use of the analog model, it was sought that the students recognized some of the characteristics of the movement of the earth to establish the day and night establishing.

SCIENCE EDUCATION IN COLOMBIA IN CONTEXTS OF INCLUSION WITH BLIND STUDENTS.

Science education in the Colombian context, for the primary level, is mobilized from a set of public policy documents issued by the Ministry of National Education (MEN), which establish a set of reflections on the way science is assumed, what should be taught in educational contexts and what are the competencies that students should achieve in natural science classes, among other aspects. However, in studies carried out by Castro and Tuay (2021) it can be seen that, in the guidelines, basic standards of competence and basic learning rights of the natural sciences (published by the MEN) are presented from the generality and that it is necessary to make didactic and pedagogical precisions that allow all students to participate recognizing their sensory capacities.

The educational institutions of the city of Bogotá, Colombia, trying to materialize the ideals of inclusive education, have established a set of strategies that allow linking students with functional diversity to the classrooms, which include, the adaptation of the infrastructure, provision of materials and specialized personnel, to provide the necessary support in communicative terms, pedagogical, social, for the integral development of children and young people in the recognition of difference. In that order, students participate in the classrooms, with visual, auditory, cognitive functional diversity, etc., who require attention strategies in which their sensory condition is recognized for the teaching and learning processes of the different disciplines.

Starting from the idea that each diversity requires a form of attention and a particular analysis of what the objects of study imply, in this case, the natural sciences for blind students, Castro and Tuay (2021) establish that for the teaching and learning processes of this discipline, the auditory and tactile experience must be privileged in the development of experiences, because they are the main sources of information collection that will allow the child to get an image of the world around him. Another set of elements that must be present are the detailed description of situations, verbal or physical representations, collaborative work.

On the other hand, the didactic material is an indispensable tool in the teaching process, therefore, it is required to adapt or design relief material that allows the student to establish a representation of the object of study. The use of the model becomes a disengagement so that the child can approach, interpret, know different elements of the natural world and thus access the construction of school scientific knowledge.

METHODOLOGY

The qualitative research presented in this chapter aimed to identify how children blind from birth approach the study of the solar system and how the use of modelling influences the construction of school scientific knowledge for this population. The initial hypotheses that were established focus on the idea that to make use of modelling in the teaching processes of the natural sciences requires a certain degree of abstraction on the part of children that allows them to organize their ideas, imagine situations, draw conclusions that lead them to understand the phenomenon, despite the fact that there is no sensitive experience with the phenomenon addressed. Likewise, that the approach from the model must be accompanied by the detailed narrative and activities in which different experiences are involved to give meaning later to the modeling used as a didactic strategy to study different thematic axes in the natural sciences.

The work with the students was organized in four moments and the solar system model was taken as the central axis to provide a representation of the general aspects that allow explaining day and night, which are explained in Table 1.

Table 1

Moments of the work done with the students

Moment	Objective	Activities
Moment 1: **Recognizing Initial Representations of Blind Children**	Identify the initial representations that the blind child has about the solar system, based on the phenomenon of day and night .	Ask a set of questions that allow the student to evoke their knowledge about aspects related to the solar system, in particular, the phenomenon of day and night.
Moment 2: **How does the earth move around the sun?**	Represent the movement of translation and rotation of the earth around the sun making use of its own body.	To make known the relationship of the earth and the sun, from two scale-sized spheres. Simulate the movements of the earth around the sun (translation and rotation).

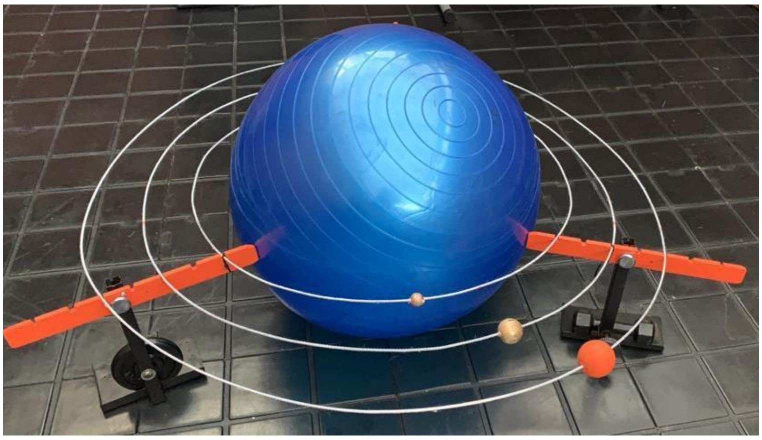
Moment 3: **Let's know the model of the solar system**	Establish a dynamic that allows the student to recognize the different elements that make up the solar system through haptic exploration.	Perform an exploration of the solar system model. Make use of narrative to explain the phenomenon using analogy.
Moment 4: **Let's represent the learned**	Have students externalize some of the understandings achieved through the creation of their own solar system model.	Realization of the solar system with plasticine.

The first moment was aimed at knowing the initial representations that the blind child has about the phenomenon under study, considering that sensitive experiences are limited, especially "visible ones", to characterize aspects of this phenomenon. For this, initially a set of generating questions was asked, How do you know it is day or night? What do you know about the sun? What do you know about the earth? That constitute key axes of the understanding of the phenomenon.

Subsequently, in the second moment an activity based on analogy was proposed, making use of the blind child's own body, displacements were made to identify the movements made by the earth around the sun (rotation – translation), additionally exercises were carried out that prioritized the haptic experience to recognize the proposed model of the solar system. In the third moment, the student explored a model proposed in Figure 1, which was built maintaining the relationship of the size of the sun and some planets, leading him to recognize, through touch, each of the elements that compose it: Sun, orbit and planet.

Figure 1

Designed solar system model



A set of spheres of different sizes was also used to scale (in relation to the current model of the solar system), which allow comparing the size of the sun, the earth and the other planets. The sun was represented with a pilates ball of 0.6 meters in diameter and the earth with a small sphere of $6x10^{-3}$ meters in diameter, the other elements are listed in Table 2.

Table 2

Size of the spheres to represent the planet

Planet	Sphere diameter (m)
Mercury	$3x10^{-3}$
Mars	$4x10^{-3}$
Earth	$6x10^{-3}$
Venus	$3x10^{-3}$
Uranus	$2,5x10^{-2}$
Neptune	$2,5x10^{-2}$
Saturn	$6x10^{-2}$
Jupiter	$7x10^{-2}$

From the narrative, explanations were made about the solar system, characteristics of the planets, location and distances referring to the sun. In the fourth moment, as a synthesis activity, the student was asked to express his understandings by reproducing in plasticine and making a verbal description of the aspects worked on in the exploration that focused interest on the modeling of the solar system.

ANALYSIS OF THE RESULTS

Taking into account the four moments, it was sought to recognize the role of modelling in the construction of scientific knowledge with blind children in primary education. In this way, the analysis will be made taking into account each of the proposed activities.

In the first moment, the children were asked about the way they identify that it is day or night, for this they resort to activities they perform in these periods of time or terms that are used by close people to define them. It can be established that the first approximation that children have about the phenomenon is influenced by social aspects, that is, they make descriptions from the association of words that are used by seers to define them, "there is light" "darkness" (because it was consulted and they do not have any type of visual residue) and situations or habits that they have acquired and that depend on the dynamics of their own families, attending to schedules, time to get up, presentation of television programs. It is also observed that there are other elements in their explanations that lead to a sensitive experience, concluding that the representation about day and night is associated with the haptic experience they can have with the sun. Some of the answers to the question How do you know it's day or night? are listed below:

[By the light, I know it's day and by the darkness I know it's night] [I know it's daytime because I feel the sun or because of the hour, for example, when I go out I feel the sun, or when I'm in the house I ask the time] [If they didn't tell me the time I wouldn't know or for example, I know sometimes because my dad gets up or I know it's night because I'm going to sleep] (Excerpted from student stories)

Talking about the sun with children involves them evoking experiences related to the "heat" at first. Then it can be identified in his speeches that the subject has been addressed in different contexts and other adjectives are used to characterize it "big", "round", "it is a star". Representations that have been built particularly with the work that is done in the school and the dialogue with relatives who explain some topics of their interest.

[The sun throws rays that can burn one], [The sun is big, round]

[I think it's a star, no more.] [The sun is very hot, because it is a warming star]

Despite the fact that planet earth is the place where one lives, students express greater difficulty when giving their opinion on the matter. The descriptions they make are based on the knowledge they have of nature and is based on spatial egocentrism (Malagón, 2020), that is, the relationship that their own body has with elements of the environment in which they operate. On the other hand, a relevant element is evidenced in their explanations and that is to enunciate the place or the territory they occupy on the earth, in this case, they indicate that they live in Bogotá.

[Planet earth is very cool because it is on earth. It is the planet where we live, I live in Bogotá] [On earth there are animals, trees and people]

In the second moment, from the narrative the movements that the earth makes around the sun were explained. Taking as a reference a flexible ball that represented the sun, displacements were made that involved "rotating" on its own axis and around the sun (as if it were a type of dance). Students are receptive to the activity, assuming their own body as the earth, allows them to appropriate the terms translation and rotation. It became necessary to delve into these two words and exemplify in various ways the terms to enlarge the image that the child can make through experience. This type of proposal motivates students and involves them directly in the representation that can be made of the phenomenon.

The third moment took the children to explore the assembly made and each of the parts that compose it, sun, poses and orbits. Students are interested in participating in the activity and ask questions that help with the tactile exploration they make of the different elements that compose it. They are curious to know more and conceive the model as a game in which they can relate different variables. The detailed description is a fundamental aspect to dynamize the montage that is used to bring students closer to the phenomenon, since exploration is nourished not only by haptic experience, but by the analogies and examples that are used to lead the other to understand the scientific theory that is being addressed in that degree of schooling.

> *((approaches the assembly of the solar system, begins to touch it)) [Oops! so cool, this is the earth, they turn and this how is it?] [What we are exploring is a model of the solar system] [It is composed of the sun and planets. The sun is in the center.] ((Touch the ball that represents the sun, the wires)) [What are wires?] [These wires are what is called in the solar system, the orbits and let's observe that there are some planets closer to the sun, here we have a planet, here we have another planet] ((guiding your hand so you can recognize the elements)) [This planet let's assume is Jupiter, another one that is closer to earth. Look at what happens to the planets, they revolve around the sun] ((moving each of the elements that make up the system))*

The fourth moment sought that the students capture through plasticine some of the understandings reached through the proposed activities. It is noteworthy that in exercise children take several aspects when reproducing their own model. In each of them the existence of shape and size prevails, and the presence of the earth, the sun, and a planet, maintaining in some cases the distances between them.

Each of the models developed by the students is explained below. In Figure 2a, the student represents the orbits and on the right side the sun "enveloping the earth" (red and yellow plasticine). In this case, the intention to capture the elements is evident, but not a relationship between the orbits, the planets and the sun. In Figure 2b another model is observed, there the student locates the sun, different planets and orbits, trying to highlight characteristics such as the rings of saturn, in which an order in the location of the planets does not prevail, nor in the shape of the orbit, but verbalizes that each of them corresponds to one. In Figure 2c it is observed that the elements of the solar system are presented separately and no relationship is established between them. However, in the dialogue with the student, they verbalize that all eight plans are separated, recognizing more elements of the system, which are not located when performing the exercise with the plasticine.

Figure 2d shows the shapes and sizes explored with the scale model. An attempt is made to locate the sun in the center and in the first orbits a continuity is observed which is lost in those that are farther from the sun (it is assumed by the difficulty of joining the wool). Additionally, it is observed that it represents details such as two planets in which it tries to change its structure by placing more plasticine around it.

Figure 2e depicts an orbit and within it the sun, and the planets. It becomes evident that for the student it is important to emphasize that all planets have a different size just like the sun. In this case, the names of all the planets are verbalized, but it places the planet Saturn (with its rings) as the farthest from the sun.

By making the general analysis of the models made by the five children it can be established that in these representations deepen the discussions on the way the systems are assumed, and in this particular case, whether they are open or closed, an aspect that should be reviewed in greater depth because they are related to cosmological aspects. This is evidenced, in the case of images, 2a and 2c, that the systems are open, but in the structure given to the 2b and 2e systems, it is closed, figure 2d would be a mixed case that deserve to be reviewed.

Figure 2

Model of the solar system captured by the students

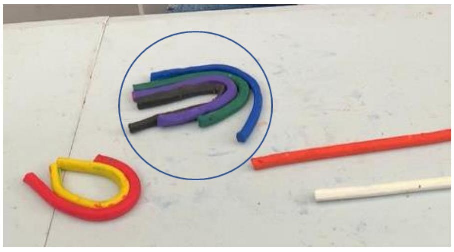


Figure 2a. Final construction of the E1 solar system

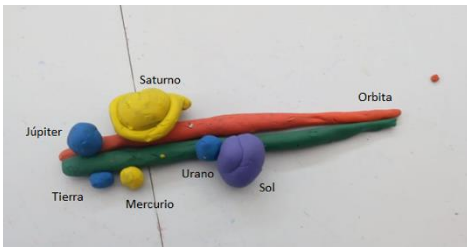


Figure 2b. Final construction of the E2 solar system

Figure 2c. Final construction of the E3 solar system

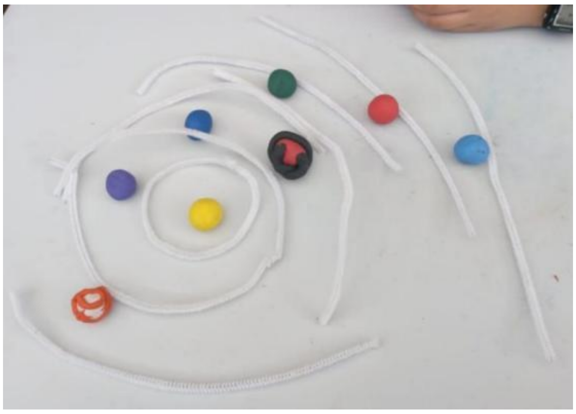


Figure 2d. Final construction of the E4 solar system

Figure 2e. Final construction of the E5 solar system

CONCLUSIONS

The work carried out allows us to see that modelling becomes an indispensable resource for the teaching of science in communities with visual functional diversity in primary education, taking into account that other sensory channels (touch and hearing) that allow the child to approach the phenomenon under study should be privileged. In the didactic transposition that is carried out, not only the intention to carry out the model must be made explicit, but also the characteristics of the population for which it is directed, in this way, students will be able to attribute a meaning and meaning to the experiences that are carried out within the classroom.

The exercise of asking about the way blind students have been explored, the subject matter under study allows to identify the initial representations aspect makes it possible to guide the classroom processes that lead to the understanding of scientific theories with situations that live in everyday life, getting children to establish their own knowledge structures.

In the development of the research it became evident that it is very useful to use the blind child's own body in the modeling strategy to lead them to live the experience in a different way, in the case of the simulation of the movements that the earth can perform, it favored that the students recognized certain elements when exploring the scale model used to represent the solar system.

With the study the hypotheses raised are reaffirmed, it is completely necessary to make use of concrete material so that the blind child can make an image of the different objects of study of the natural sciences, however, this alone, can not be used as a didactic resource, must be accompanied by the narrative and in particular detailed descriptions that allow him to question and inquire about the variables immersed and in this way, attribute characteristics, establish relationships and externalize the way he has organized his own experience.

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Chapter 8

Argentina

Students' views of science and of scientists "outside the laboratory": a proposal to incorporate the nature of science in primary education

Jhon Deivi Acosta-Paz, Alejandro P. Pujalte & Agustín Adúriz-Bravo

Critical thinking on science as an activity and on the scientists who perform it is one of the most significant educational topics that can be addressed in science teaching from the first years of basic education. In this chapter we present some results around the so-called "images of science and of scientists" that a group of fourth-year primary school students hold in relation to "field work" (that is, scientific work outside the classic laboratory environment). A survey on those images was carried out as part of a didactical sequence that we designed adapting materials from an existing workshop. In the sequence, instruments for data collection were applied before and after an instructional intervention around what is known as nature of science. Results obtained at the pre-instructional phase show that students' initial images conform to results reported in the literature, in which such images are conceptualised as "distorted views" that do not adjust to currently valid knowledge from the philosophy of science. Post-instructional results, on the other hand, indicate favourable changes in the ways students perceive people, activities and knowledge in science developed in natural environments. Identifying, categorising and intervening these images aims at building conceptions of the nature of science that contribute to overcoming obstacles classically identified in science learning.

Keywords: Nature of science, Images of science and of scientists, Distorted views, Primary education, Didactical sequence, Pre/post study

INTRODUCTION

Didactics of science (science education) as an established academic discipline has been able to define some important research topics on which scholars have been researching for more than four decades now (Adúriz-Bravo, 2021). The bulk of results obtained constitute relevant input for the transformation of the ways in which science is taught in the different educational levels. One of the most consolidated lines of didactical research regards the study and transformation of the so-called "images of science and of scientists" that K-12 students, and even those at the tertiary and university levels, have; the same has been done for prospective and in-service science teachers (Shibeci, 1986; Pujalte et al., 2014). This research line has gained momentum thanks to the fact that critically characterising the kind of science that is taught and learned in the classrooms is an essential requirement for any well-founded didactical proposal (Newton & Newton, 1998; Adúriz-Bravo et al., 2013).

Recent consensus around the idea that science education is an essential element of the culture of our times (Adúriz-Bravo & Pujalte, 2020) has made it urgent that the general population achieves solid scientific and technological literacy. This is truer than ever in times of the COVID-19 pandemic, in which specialists in the field of education have verified serious limitations in the scientific foundations of people's discourse and action during this severe social and health crisis.

Knowing the images of science and of scientists that circulate in the classrooms allows systematically characterising one of the most relevant factors that directly influence the quality of science education implemented (Calado & Bogner, 2013). It has been said that such images or views are very often "distorted" (Fernández et al., 2002; Calado & Bogner, 2013) with respect to knowledge from recent philosophy of science and, at the same time, from current curriculum prescriptions. They then work as genuine obstacles –in the didactical sense of the term (see Escrivà-Colomar & Rivero-García, 2017)– for students to have access to a quality scientific education enabling them to deal, on the basis of consistent arguments, with questions, issues and problems related to natural phenomena and to our action upon them.

These distorted views on the nature of science circulating in the classrooms should not be understood as autonomous conceptions, independent from other pieces of knowledge. On the contrary, it is safe to assume, given its homogeneity and persistence (Gallego Torres, 2007), that we are in face of a social problem that requires thorough intervention in order to identify and classify them, ascertain their possible causes, and propose ways to address them. The treatment of these views should be undertaken from a holistic epistemological perspective directed towards meaningful science learning in its different dimensions (similarly to what has been done with the so-called "misconceptions" of students in the different scientific domains: Osborne & Freyberg, 1985).

In this chapter we present some results of the implementation of a didactical sequence adapted from a previous workshop (described in Pujalte et al., 2011; Pujalte et al., 2018) originally aimed at identifying the images of science and of scientists in secondary school biology teachers. The workshop that served as a starting point for the piece of research that we report here is part of a battery of didactical interventions designed by our research group GEHyD at the Universidad de Buenos Aires (Argentina) in order to work intensively on the conceptions about the nature of science that circulate in the educational system (see Adúriz-Bravo, 2005a, 2005b; Adúriz-Bravo & Ariza, 2013).

We implemented our didactical sequence in a class with students in the fourth year of primary school, that is, girls and boys between 10 and 11 years of age. In previous publications (Adúriz-Bravo et al., 2006; Pujalte et al., 2011; Pujalte et al., 2012; Adúriz-Bravo et al., 2013; Pujalte et al., 2016; Pujalte et al., 2018) we reported similar interventions, also based on the original workshop, in K-12 classrooms and in pre- and in-service teacher education.

We assume in this chapter that girls and boys are capable of rigorously expressing their conceptions about science, understood as an activity and as a product. We further assume that they have acquired their "folk" or "naïve" views on science through their social experiences inside and outside school, their exposure to mass media (TV shows, cartoons, films, etc.), their use of social networks, among other ways.

We took these two hypotheses into account when designing our didactical sequence, as follows. In the first place, we acknowledged the need to elicit students' views as genuinely as possible; accordingly, we took maximum care in the design of the demands and instructions that we presented to the participating girls and boys. In the second place, we tried to put the elicited views in dialogue with historical and current social images of science and of scientists, contextualising them so as to make them accessible to the targeted audience.

Results reported in this chapter show very favourable changes in the images of science and of scientists in the group of primary school students with which we worked. Such changes (or learning gains), as it will be discussed, are here attributed to the inclusion of an explicit reflection (Khishfe & Abd-El-Khalick, 2002) on the nature of science in the didactical unit that we implemented.

THEORETICAL FRAMEWORK

As it was stated in the previous section, science teaching in the different educational levels centrally requires considering the enormous diversity of conceptions of the participants, be they scientific or meta-scientific (Osborne & Freyberg, 1985; Pozo et al., 1992). It is on the basis of a careful diagnosis of those conceptions that contextualised didactical sequences can be designed; these need to include strategies to problematise and enrich the conceptions through dense social interaction in the classroom. Students' images of science and of scientists ("imprinted" in them in the many years of their "history of science" in their social milieu by relatives and friends, media, fiction, popularisation, networks and even formal education) are here seen as misconceptions, but in this case of a meta-scientific nature, that is, they concern knowledge about science. It is therefore pertinent to contemplate, in didactical sequences, the existence of specific spaces to intentionally elicit them and to critically intervene on them.

For more than three decades now, research in the line around the so-called nature of science (abbreviated in the literature as "NOS") is well established (see Mohan & Kelly, 2020). However, most publications in this line still revolve around a detailed "naturalistic" characterisation of students' and teachers' conceptions, with a much smaller number of publications devoted to the evaluation of didactical proposals, sequences and materials aimed at teaching what science is.

A number of empirical studies have shown that, just as with students, the vast majority of science teachers usually adhere to conceptions about the nature of science that are "inappropriate" in terms of curriculum prescription (Halai, 2010). As we have mentioned, the specialised literature suggests to consider such conceptions as epistemologically distorted (Isabel Fernández and her colleagues [2002] called them "deformed" in Spanish). In order to characterise such conceptions, we can say that the dominant image of science in the educational system is markedly empiro-inductivist: it considers the activity of scientists as ahistorical, individualistic, value-neutral, detached from interests, ideologies and contexts, and therefore objective, infallible and seeking absolute truth. At the same time, science is seen as an elitist and exclusionary endeavour, essentially performed by white males, founded on a hard scientific rationality centred on the use of the infamous "scientific method" (Adúriz-Bravo, 2008; Yacoubian & Hansson, 2020).

The analytic literature to which we resort for our study (e.g. Fernández et al., 2002; Gil-Pérez & Vilches, 2005; Gallego Torres, 2007) allows identifying seven very recurrent distorted views on the scientific activity. Table 1 organises the main characteristics of each of those views and therefore works as fundamental input for the analysis of the data collected before and after implementing our didactical sequence (which will be briefly addressed in the methodology section).

Table 1

Seven distorted views of science (adapted from Fernández et al., 2002) that serve as analytic categories in our study.

View of science	Core features
Empiricist and a-theoretical	The role of neutral observation and experimentation (not contaminated by a priori ideas), and even of pure chance, is highlighted, forgetting the essential function of hypotheses and the processes of construction of global and coherent bodies of knowledge.
Rigid (algorithmic, precise, infallible)	The "scientific method" is presented as a set of steps to follow mechanically. Scientific operations that suppose quantitative treatment, rigorous control, manipulation, etc., are highlighted, disregarding (or even rejecting) elements that entail invention or creativity.
Non-problematic and ahistorical (dogmatic)	Knowledge is considered in its final form, which does not show what the problems that generated its construction were or what its evolution has been. Difficulties and limitations of scientific knowledge are hidden and the plurality of perspectives is not discussed.
Exclusively analytic	The need for an analytic segmentation of the reality under study is overemphasised; the limited and simplified nature of models is obscured. Efforts to unify and construct coherent bodies of knowledge are disregarded.
Of cumulative development	Scientific development appears as the result of linear, purely cumulative growth, ignoring crises and "remodelling" processes. Complex processes that do not conform to simplified "patterns" of scientific change are not considered.
Decontextualised, socially neutral	The complex relationships between science, technology and society are ignored or very superficially considered. A simplistic exaltation of science as the motor of progress dominates the epistemological rhetoric.
Individualistic and elitist	Scientific knowledge appears as the work of isolated individuals; the role of collective work and of lively exchange between groups is ignored. In particular, it is implied that results obtained by a single scientist or a single team are enough to verify or falsify a hypothesis (or even an entire theory).

Parallel to the diagnosis of these distorted views of science, views on the scientists have been studied. Discouraging results were also consistently found. It is widely reported that when students face the question of how they imagine people working in science or are asked to draw them in their work environment on a typical day, the results tend to be very similar – and worrying from an epistemological point of view. In the vast majority of cases, girls and boys draw male scientists, with glasses and lab coats, often bald or with wild hair, working alone in a place that almost always shares characteristics with the school laboratory (Chambers, 1983; Adúriz-Bravo et al., 2013). Research carried out along this line reveals a recurrence of these clichés across different educational levels and in different cultures and social backgrounds.

Frequently, enquiry performed through the request of drawings is completed with a short survey that asks the population under study to explain some characteristics of scientists through the formulation of a written or oral text to accompany and complement the drawings (see Reis & Galvão, 2006; Adúriz-Bravo et al., 2013). Descriptions and narratives obtained in this way are also often highly consistent: the stereotypical scientist is absent-minded, absorbed in his work, with scarce social life, studying things only he can understand, with no family or friends, having no other interests or motivations.

All these stereotypical traits enumerated here, and many others, correspond to a socially established, distorted view on people who do science. We consider that this stereotyped image reflected in the drawings and short texts is an epiphenomenon (or emergence) of a particular image of science, in the sense that those who draw "personify" in the scientist their own conceptions about the scientific activity (see Mohan & Kelly, 2020). That is, we find a strong correlation between the seven distorted views in Table 1 and the most common traits of the "drawn scientist" (see Matthews, 1996) in students. Of course, and as it was anticipated in the case of the images of science, these distorted views of scientists are not only present in this population, but also in active teachers and in student-teachers.

Meta-analyses help us see that, although this heavily stereotyped image is formed quite early, as schooling advances, its characteristic features become more and more strongly accentuated. This correlates to a corresponding disinterest and aversion towards science subjects in teenagers and young people, with their consequent estrangement from participation in science (Steele, 1997).

Based on the theoretical considerations and the empirical findings available in the literature previously reviewed, our research group has been designing a number of didactical sequences that seek to mobilise misconceptions and acquaint science students and teachers with more adequate models of the nature of science, in order to contribute to high quality science education. In the case of primary school, our intention is to promote, from early ages, epistemologically more sophisticated views of science and of scientists, less biased and more inclusive and democratic (Adúriz-Bravo & Pujalte, 2020).

METHODS

The original instructional workshop that was adapted for the piece of research reported in this chapter is, as stated, part of a battery of didactical instruments designed by our research group GEHyD to teach the nature of science to different populations. That workshop has been previously used in a variety of contexts, within qualitative research aimed at diagnosing pre-instructional (folk) images of science and of scientists and identifying possible "gains" in those images caused by explicit NOS teaching (see Pujalte et al., 2018).

A series of adaptations were made to that workshop in order to apply it within ordinary lessons of the school subject Natural Sciences included in the 4th year of Argentinian primary education (students aged 10 to 11). The adapted sequence was implemented in a course with 45 students (23 boys and 22 girls) in a private, Catholic school in the city of Buenos Aires. This implementation constituted part of a major innovation project ("Aula Viva": "Living Classroom"), designed, executed and evaluated by the first author of this chapter as a strategy to teach the science programme traversed by the nature of science.

During this implementation, the canonical activity of drawing a person who works in science (Chambers, 1983) was applied twice: (1) at the beginning of the didactical sequence, to characterise students' conceptions around the figure of a scientist (and, as said, to indirectly know their views on science as an activity), and then (2), at the end of the sequence, with the intention of recognising possible changes in these conceptions after the theoretically-founded didactical intervention. Elaboration of the drawings was supported –as suggested by the research literature– by other instruments of data collection that allowed capturing students' discourse on science and on scientists.

The classroom proposal whose results are examined in this chapter belongs to one of the research foci of GEHyD, devoted to analysing socially installed images of the scientist who performs their activity in environments outside the laboratory, with the nuances that this introduces in standard research approaches (Pujalte et al., 2018).

A first approach to this topic –on the basis of available results coming from international research (see, for example, Apffel, 2006; Subramaniam et al., 2018)– leads us to assume that the predominant image will be that of the typical solitary scientist, now dressed to resist inclement weather, equipped with tools that will help them "unravel" the mysteries of nature or portray it with pictorial precision. The stereotypical field scientist, we would expect, is someone relying on the power of their (his) meticulous observation, a key asset to "discover the truth" under the rocks, amid the vegetation or in the depths of the sea.

From an epistemological point of view, the stereotype of the field scientist will presuppose, on the one hand, the existence of certain "truths" that are out there waiting to be discovered and, on the other, the adoption of a method requiring meticulous and diligent observers, who share some characteristics with explorers or adventurers. In this folk depiction, the most typical activities would be "inquiry, data collection and interpretation, [and] hands on real life experience" (Apffel, 2006, p. 12).

Considering the average attention span of 10/11-year-olders, our didactical sequence amounted to a total of 8 hours distributed in eight classes of 1 hour each. Four of these classes were devoted to "peri-instructional" activities (2 pre-instructional hours of diagnosis at the beginning of the sequence and 2 post-instructional hours of assessment at the end). The other four classes in between correspond to instruction itself (lessons about scientists and their contributions), which will not be discussed in this chapter. These were designed, as said, under the standard directions of explicit and reflective NOS teaching (Khishfe & Abd-El-Khalick, 2002); during instruction, an important number of circulating images of science and of scientists were collected, classified and critically examined.

Table 2 describes the four activities carried out in the didactical sequence before and after the NOS intervention itself. As indicated, each of these activities lasts 1 hour.

Table 2

Description of the pre- and post-instructional activities carried out during the sequence. They correspond to the first and last 2 hours of a total of 8.

Activity	Description	Instructions
Before teaching		
1. Survey of the folk images among students (individual work).	Participating students must mobilise their NOS images, evoked when asked to draw and describe a "field scientist" (i.e., a person who performs their scientific activity outside the laboratory).	a. How do you imagine people who develop their scientific activity in contact with nature? Represent them by means of a drawing. b. Write five words that for you characterise this kind of scientist. c. Write five words that for you characterise this kind of activity.
2. Systematisation of the most frequent images (group work).	Participating students must identify coincidences, differences and relations between all the participants' productions. First in small groups and then in plenary.	The following axes are explored for systematisation: a. Does the drawing show one person or several? b. Gender of the person(s). c. What specific activity is being developed? d. In what context?

		e. What does he/she seem to be doing? With what tools? f. What are the most frequent words to characterise the activity? g. What are the most frequent words to characterise the person/s?
After teaching		
3. Critical contrast of representations (individual and group work).	Participating students examine and compare their own representations with those of their classmates and those of other students (15- to 17-year-olders who attend the secondary level in the same school).	a. What similarities and differences exist between the different pre-instructional representations? b. What similarities and differences exist between those representations and what was observed during the lessons? c. In small groups, construct an argumentation text stating possible causes for your pre-instructional representations. d. Modify or redraw your initial drawing of a scientist based on what you have been thinking, reading and discussing.
4. Meta-scientific reflection (individual work).	Participating students get involved in a process of individual reflection at a meta-theoretical level, on the nature and aims of these instructional activities and the extent of their learning processes.	a. To what extent do you agree or disagree with the different images of a scientist to which you have been exposed during the lessons? Justify. b. How can you explain the differences and similarities between your initial and final drawings? c. What key ideas about scientists do you now think are the most important to communicate to other girls and boys of your age? d. What did you know about this topic and what do you know now? What else would you like to learn?

With regard to the interpretation of data obtained in the application of this sequence, one of the previous pieces of research of the group GEHyD (Pujalte et al., 2018), which had been carried out with secondary school students, was an indispensable contribution when making analyses and typologies and assessing students' progress.

RESULTS AND DISCUSSION

Considering our methodological design, the presentation of results is divided into two subsections, which respectively correspond to the pre- and post-instructional activities. Initial representations of the field scientist obtained from the students who participated in our didactical intervention are markedly homogeneous, and in all respects compatible with the results reported in the literature of educational research (including those obtained by us with high school students and science teachers in previous enquiries). After the intervention designed and executed to tackle with these pre-instructional representations, changes are evident (and methodologically significant). We can consider the new images, enriched by NOS teaching, as "reformed" views, much more consistent with recent philosophy of science and much more adequate to curriculum prescriptions.

Results before NOS lessons

We systematise the most salient characteristics of the initial productions of the participating students by means of the guiding questions that served us to structure the discussions within the NOS sequence. The first question regards the number of people drawn: we check if the drawings show one or more persons. In practically all cases, a single scientist is drawn. Then we ask about the gender of the drawn scientists: they result males in the overwhelming majority (with only one exception in 45 drawings).

This special case of the draw-a-scientist task (Chambers, 1983) was asking students about field scientists. Nevertheless, the drawings represent laboratory work, experimentation of various types, operation with tools and instruments, and manufacture of objects (see Figure 1). When students draw a background for the scientific activity, school-lab-like settings predominate; in a few cases, they include a desk with a computer. Scientists are represented in attitude of observing, manipulating, intervening or building, but the drawings result extremely generic.

Figure 1

Selection of drawings of scientists produced by the students in our study before explicit NOS instruction.

Another question is about the most frequent words that this group of students uses to characterise the activity of their drawn scientists. We find, in decreasing order of frequency: discovery, responsibility, rewarding, innovation, new, true, natural, everyday ("cotidiana" in Spanish), valuable, verifiable. Regarding the terms used to describe the scientists, the following are the most frequent: observant (in Spanish, "observador": paying close attention to details), curious, boring, indefatigable/persistent, elderly, shabby/messy ("desprolijo", which applies either to the scientist himself or to his actions).

In the pre-instructional phase, findings show that, despite what we though were clear instructions around the task of representing a field scientist, it is extremely difficult for students to recognise science as an activity that can be carried out outside the laboratory. It should be noted that the teacher researcher, faced with a first, small sample of "negative" results, decided to clarify and expand the instructions during execution; however, all the results we are reporting here remained almost identical: in the drawings, there are no indications of the nature of the "fields" in which scientists can work.

In their folk representations, the participating girls and boys attribute scientific activity to lonely, elderly men, who almost always wear white lab coats but are usually careful with their personal appearance (and this is contradictory with mentions to the term "messy" or "shabby" in their written descriptions). Most of the drawings present amiable scientists, satisfied with their work and the results obtained from it. (Note the exception depicted in the first drawing in Figure 1, where a Doctor-Frankenstein-esque "evil scientist" sniggers at the sight of his monstrous creation).

In turn, the words used to characterise the scientific activity show that students have profound admiration and respect for people who do science; girls and boys adhere to a romanticised view (see Miedema, 2022) considering that scientific research requires high levels of commitment, dedication, perseverance, organisation and detail.

Results after NOS lessons

The instruction itself, which we will not describe here, but which follows previous GEHyD proposals (see Adúriz-Bravo et al., 2013), takes the distorted images analysed in the last subsection as a "baseline", and intends to have positive impact on them through explicit and reflective teaching of key elements of the nature of science (see Khishfe & Abd-El-Khalick, 2002). The 4-hour didactical sequence that we designed and implemented (distributed in four classes of 1 hour each) aimed at generating in students a view of science and of scientists that is more solidly founded on the philosophy of science.

Results obtained in the post-instructional draw-a-scientist task are here presented and analysed seeking to recognise gains in students' representations probably caused by student-student, student-teacher and student-materials interaction fostered by the sequence. As it can be seen in the selection in Figure 2.1., students' drawings now show much greater gender parity in scientists. In a few cases, there is more than one person depicted, working collaboratively. The activities drawn, on the other hand, are more varied (in addition to observation and experimentation, there is sampling, data recording, communication of findings, etc.), and are portrayed in greater detail (Figure 2.2.).

The context of the scientific activity has moved from the laboratory to the field, and not to a generic field or with few details, but to an interesting variety of natural settings (in the drawings of Figures 2.1. to 2.3. readers can see, among others: a glacier, a volcano, an archaeological excavation, a forest, a cave, and the bottom of the sea).

Figure 2

Selection of drawings of scientists made by the students participating in our study after NOS instruction.

2.1. *Examples of gender parity*

2.2. *Examples of varied scientific activities*

2.3. *More examples of various scientific settings ("fields"), with the use of technological devices.*

As regards the words used by the participating students to describe the scientific activity, changes are not so extensive. The original list remains, and only the terms "exploration" (with very high frequency) and "teamwork" are added; this constitutes an epistemologically productive addition in order to continue working on the nature of science.

Regarding the list of the most frequent terms to characterise scientists, those with negative connotations (boring, messy) disappear. The idea that they are intelligent, observant, curious, creative and patient is reinforced, showing that the romanticised stereotype is very entrenched in the general population. Students add new traits that we can relate to the interaction of their drawn scientists with other people outside their environment: they are described as kind and friendly.

After instruction, it is seen that girls and boys represent women assuming a leading role in the elaboration of science; the portrayed scientists are also younger than in pre-instructional representations. Scientists are shown enjoying their work and developing a wide variety of activities in an important diversity of contexts. The conception of science as an individual activity is still strongly maintained, although some exceptions begin to emerge.

When we search for scientific work outside the laboratory in the drawings, this second series, as opposed to the first one, shows a representation of a wide range of field activities, which we can relate to a variety of techno-scientific disciplines. We carried out a triangulated interpretation of the activities represented in the students' drawings; this interpretation was validated with data obtained from the recorded interactions between them and with the teacher in lesson 8 (meta-scientific reflection). Table 3 reviews the frequency of appearance of the disciplines that we have attributed to each post-instructional drawing.

Table 3

Disciplines in which the diverse techno-scientific activities carried out by the scientists represented in the post-instructional drawings could be included.

Discipline group		**Frequency** (over a total of 45 drawings)
1	Botany and zoology (sometimes conflated with agronomy and veterinary medicine).	16
2	Palaeontology, archaeology, anthropology.	14
3	Astronomy, meteorology, geology, oceanography, speleology.	8
4	Natural interpretation, observation and drawing, photography and video recording, collection of specimens, taxonomy, museology, conservation, ornithology, bird-watching.	4
5	Analysis, experimentation, sampling, data collection in the field.	3

One last interesting element in students' post-instructional representations is the use of technological devices by scientists during fieldwork.

A notable example of this, which appears in 5 drawings (3 of them included in Figure 2.3.), is the presence of drones controlled by scientists, which fly over the fields under research. This may be evidence of a conception of science in relation to the technology of its time, far away from the frequent strongly timeless representations, featuring the typical glass jars of alchemists.

In summary, analysis of post-instructional drawings allows us to identify a very positive, significant change in the images of science and of scientists in the students participating in our study, especially with regard to gender equity and to the variety of scientific activities. Teamwork, which is a desirable trait in a more epistemologically robust conception of science, still does not appear with the frequency that we would expect. However, this may be an "artefact" caused by the wording of the instructions provided to students, which will have to be revised.

CONCLUSIONS

Traditional science teaching in primary schools generally reduces itself to the presentation of a series of typified curriculum contents (solar system, seed germination, solutions, photosynthesis, acidity, human muscles, etc.), with their corresponding classroom activities (searching information, writing reports, designing posters, performing small experiences with home materials or in the school laboratory, constructing scale-models, making simple calculations, memorising specific vocabulary, etc.). However, such an approach to school science is rarely accompanied by a careful examination of "what this thing called science is", according Alan Chalmers's (1976) famous expression.

The lack of inclusion of meta-scientific reflection implies that students' folk views on the nature of science are seldom problematised in the classroom. Accordingly, the social images of science and of scientists that girls and boys bring from outside school (supported, for example, on TV programmes, YouTube videos, cartoons and videogames that they consume) remain unquestioned; they may even be reinforced by textbooks and materials that still focus on a supposed "scientific method" and present a strongly positivistic view of the scientific activity (see Adúriz-Bravo, 2008). The overall result is, as it is confirmed once again in this study, that students' conceptions about science as an activity and as a product and about the people who participate in it remain strongly distorted with respect to: (1) recent developments in the history and philosophy of science, and (2) current curricula prescribing science education for all, or citizen science education (Adúriz-Bravo & Pujalte, 2020).

In front of the pessimistic diagnoses reported in the literature of didactics of science, we adhere to the idea that carefully designed educational interventions around the nature of science are extremely necessary, and all the more effective the earlier they are implemented. Explicit and reflective teaching of the nature of science is especially pertinent in the first years of primary school, when girls and boys are for the first time formally acquainted with science. And, in this respect, there are many different methodological approaches to be taken into account.

For instance, a comprehensive, well-referenced work (Bodzin & Gehringer, 2001) studied the effect of including the presentation of real scientists (in person or through digital technologies) in the didactical sequences intended to teach science to primary school students. With a methodological design similar to ours, these authors used pre- and post-tests and were able to reveal significant changes in the most recurrent aspects of the stereotype of scientist. These authors' report is fully consistent with the post-instructional results discussed in this chapter.

In turn, in one of our previous studies (Adúriz-Bravo & Izquierdo-Aymerich, 2009), we designed, implemented and evaluated a didactical sequence on the epistemological topics of methods, gender and values that revolved around the figure of Maria Skłodowska-Curie. In that sequence, classroom work on NOS was structured around a commercial film on the life and achievements of the scientist: "Les palmes de Monsieur Schutz"[55]. Students were invited to debate and argue around some selected episodes of the film with the aid of some key epistemological ideas, and positive post-instructional effects were found.

The main aim of the present study has been to provide some more evidence in favour of the realisation that there can be palpable improvements in the images of science and of scientists among students after a simple and inexpensive, but carefully designed, classroom intervention. The task remains to research into the persistence of such improvements in front of the strong external influence of the all-pervading distorted views.

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[55] See: https://en.wikipedia.org/wiki/Les_Palmes_de_M._Schutz

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Chapter 9

Portugal

Innovative learning environments: a study in science teacher education

Bento Cavadas, Marisa Correia & Elisabete Linhares

The scope of this study is on innovative learning environments (ILE) on preservice teachers' science education. The ILE are a movement with increasing importance on many levels of education, including in higher education. This work presents the impact of the ILE CreativeLab_Sci&Math in science teacher education, which is in continuous development since 2016. Thirty-one preservice teachers (PST) participated in this study. The ILE influence in how the future preschool, primary or elementary preservice teachers learn science, its impact on the usage of open educational resources for science education is addressed in this study. The analysis of the data collected by interviews and surveys showed that the preservice teachers appreciate the natural light, temperature, large space, comfort, diversity of resources and the layout of the CreativeLab_Sci&Math spaces. Some preservice teachers also mentioned that the ILE facilitated their understanding of science content knowledge and the collaboration among them, and between their teachers. Findings revealed that a significative diversity of open educational resources, namely apps, simulators, interactive boards, robots, tablets, and other digital devices were reported as being frequently used in science education classes. This approach had also an impact on the education of preservice teachers who, by experiencing active teaching methodologies in their formation, could be more capacitated to include these experiences into their future professional practice. The ILE was also an ecosystem that promoted the co-creation of online educational resources for science teaching between the professors and the preservice teachers, many of them open educational resources. These resources are often shared in open educational platforms with other educators, such as Casa das Ciências®. Concluding, the ILE CreativeLab_Sci&Math caused a significant and positive impact on the science education of the preservice teachers.

Keywords: Innovative learning environment, Open educational resources, Preservice teachers, Science education

INTRODUCTION

Initial teacher education in Portugal is currently organized in two sequential moments. The future kindergarten, primary and elementary school teachers firstly must conclude a three-year degree program, with a total of six semesters, named "Basic Education", in a higher education teacher training institution. In this program, the preservice teachers (PSTs) engage in classroom practice across various contexts (kindergarten, primary and elementary school). Secondly, they must successfully conclude a Master' degree program, specialized in kindergarten, primary or elementary education. Some Masters' degree programs aggregate the teacher training for two of the previous educational levels. In the initial and in the Master' degree programs, the PSTs receive a broad training in science, usually in biology, geology, chemistry and physics.

The authors of this study are science teachers in a Portuguese teacher training institution and they have a considerable experience in science education of PSTs. A few years ago, in 2016, they collaboratively created a project entitled "CreativeLab_Sci&Math" (CLab) whose goal was to promote innovation in science and mathematics teacher education. For that aim, the teachers transformed traditional learning environments into innovative learning environments (ILEs). Concretely, they changed two classic laboratories of the teacher training institution into ILEs. At this exploratory study, the impact of these ILEs on PSTs science learning and open educational resources (OER) creation is going to be presented.

THEORETICAL FRAMEWORK

Innovative Learning Environments in Higher Education

Figueiroa and Monteiro (2018) characterize an ILE as "a workspace thought out and designed for the development of active, student-centred learning, in which technology can assume a determining role in enriching the space" (p.7). The ILEs movement was further developed in Europe by the Future Classroom Lab, a European Schoolnet initiative whose aim was to develop an inspirational, fully equipped, reconfigurable, teaching and learning environment, challenging visitors to rethink the role of pedagogy, technology, and design in their classrooms. This movement has influenced the Educational System in Portugal, and many primary, elementary, and high schools created their own ILEs, supported by the Educational Resources and Technologies Team of the Portuguese Ministry of Education (Portuguese Ministry of Education/General-Directorate of Education, n.d.).

Change in pedagogical practices is associated with innovation and ILEs provide unique opportunities to accelerate the generation and diffusion of innovation (Osborne, 2016). For that aim, the ILEs should also comply with seven learning principles (OECD, 2017, pp.22-26):

- Learning principle one: the learning environment recognises the learners as its core participants, encourages their active engagement and develops in them an understanding of their own activity as learners.
- Learning principle two: the learning environment is founded on the social nature of learning and actively encourages well-organised co-operative learning.
- Learning principle three: the learning professionals within the learning environment are highly attuned to the learners' motivations and the key role of emotions in achievement.
- Learning principle four: the learning environment is acutely sensitive to the individual differences among the learners in it, including their prior knowledge.
- Learning principle five: the learning environment devises programmes that demand hard work and challenge from all without excessive overload.

- Learning principle six: the learning environment operates with clarity of expectations and deploys assessment strategies consistent with these expectations; there is strong emphasis on formative feedback to support learning.
- Learning principle seven: the learning environment strongly promotes "horizontal connectedness" across areas of knowledge and subjects as well as to the community and the wider world.

While learning environment is an expression used to refer to the social, psychological, or conceptual environment were learning occurs, learning space refers to the physical environment or space were learning occurs (Cleveland & Fisher, 2014). Borba et al. (2020) study stresses the importance of the physical space as a factor that influences the students' engagement and connection between students and teachers in active learning approaches. Furthermore, an ILE is intrinsically associated with technology. Brooks (2011) study suggest that space matters and technologically enhanced learning environments have a positive and significant impact on student learning.

The evaluation of the impact of learning environments and learning spaces on higher education students has followed different approaches. One is the evaluation of the impact of classroom attributes on student satisfaction and performance. This approach was followed by Yang et al. (2013). The authors concluded that students' perceptions are focused on spatial attributes, mainly visibility, room layout and furniture, as well as ambient attributes, specifically air quality and temperature. Some of these findings are similar to those reported by Clinton and Wilson (2019) about students' perceptions of ILEs features. Students valued the furniture, specifically the round tables and the whiteboard space, appreciated the visibility because it allowed them to see their peers during collaborative learning, and the ample space of the ILE. However, the inadequate size of the tables for group work and the uncomfortable seats were criticized by the students (Clinton & Wilson, 2019). The findings of Yang et al. (2013) also indicate that students' perceptions could be influenced by seating locations and other factors, such as classroom size. These findings express the potential value of design, management, and maintenance of higher education classrooms (Yang et al., 2013).

OER in Teacher Education

OER are frequently defined as "digitized materials offered freely and openly for educators, students and self-learners to use and reuse for teaching, learning and research" (OECD, 2007, p.10); and can be produced in different ways - text, video, audio, or computer-based multimedia (UNESCO, 2011). The purpose of using OER is to enhance learning (OECD, 2007) in ways "that enable students to take greater control of their own learning – engaging more with core resources in their own time and at their own pace" (UNESCO, 2011, p.19). Besides boosting learning, according to Machado et al. (2016), incorporating OER is a key element to educational innovation.

For teachers and students to take advantage of the benefits of OER, they must develop the capacity to use and produce it (Machado et al., 2016), therefore, it is essential to make OER a part of initial teacher training curriculum (Misra, 2014). COVID-19 pandemic crisis demonstrated the importance of creating an OER repository in teacher education, to develop didactic, pedagogical, and digital skills so that teachers are able to redesign teaching to meet new challenges of our society, such as the emergency situation we have been experiencing (Bozkurt et al., 2020). Moreover, many educators are unfamiliar with these openly available resources; and teaching is a profession in which educators share resources to benefit their students. Therefore, "exposure to OER enhanced the teacher candidates' learning experience and made the class learning resources more accessible and individualized to their needs (…). Incorporating OER within teacher preparation coursework not only benefits the teacher candidates in the classes but also potentially benefits the future students these candidates will teach". (Van Hallen & Katz, 2020, p.211)

RESEARCH METHODOLOGY

Research Design

The research design used was an exploratory study (Fraenkel et al., 2012). The aim of the study is to identify the impact of two ILE spaces, named CreativeLab_Sci&Math1 (CLab_1) and CreativeLab_Sci&Math2 (CLab_2), on PSTs interest in learning science and their perceptions about environmental and physical attributes of the ILEs, after experiencing science learning activities in those spaces. Furthermore, this study presents the PSTs' perception about the collaboration with their teachers, with the aim to create science OER in the CLab environment; and the development of their pedagogical knowledge.

The CreativeLab_Sci&Math features

The CLab comprises two spaces CLab_1 and CLab_2. One has laboratorial equipment and educational resources dedicated for biology and geology classes (Figure 1) and the other one to physics and chemistry classes.

Each space is organized in four main areas. The first one is the teacher area and includes a white board, a laboratorial table and projection equipment. The second one has mobile chairs faced to the board and is used by the students for presentations and to discuss information presented by the teacher. The third area has three large and fixed laboratory tables, used mainly for laboratorial or other practical activities. The last area, constituted by small tables and cosy puff cushions, is located at the bottom of the space and is adapted for discussion and collaboration.

Figure 1

CLab_1, an ILE dedicated for biology and geology classes. In the pictures is visible area 1, with ICT and the teacher space, area 2, where students are usually seated, and area 3, a working area for laboratorial or other practical tasks.

Starting from traditional laboratories, the space of this classrooms was continuously transformed into an ILE, since 2016. Table 1 presents the specifications of those spaces, using Yang et al. (2013) criteria.

Table 1

Specifications of the CLab spaces.

Criteria	CLab_1	CLab_2
Layout	Organized in four working areas: first area for teacher presentation; a second area with mobile seats for students; a third area with three large and fixed tables for laboratorial or other practical work; a discussion area with comfortable seats.	Organized in four working areas: first area for teacher presentation; a second area with mobile seats for students; a third area with three large and fixed tables for laboratorial or other practical work; a discussion area with comfortable seats.
Dimension (Width*depth* height)	25m*8m*3m	25m*8m*3m
Capacity	Medium occupancy (25 – 45)	Medium occupancy (25 – 45)
Lighting	Natural light	Natural light
Windows	Large windows along two walls	Large windows along the major wall
Temperature	Two air-conditioning	Two air-conditioning
Ventilation	Mechanical and natural ventilation	Mechanical and natural ventilation
Furniture	First and third areas have low flexibility Second and fourth areas have high flexibility	First and third areas have low flexibility Second and fourth areas have high flexibility
Technology	Projector; Laptop; Promethean ACTIVPanel®; Laboratory equipment for biology and geology classes	Projector; Laptop; Promethean ACTIVPanel®; Laboratory equipment for physics and chemistry classes

Participants

The participants in this study were PSTs that have in common having carried out activities in the CLab spaces, attending classes delivered with the support of OER or producing OER in collaboration with their teachers.

A total of n=31 PSTs participated in this study. Twenty-five of them were attending the second year of their initial teacher education program, and six PSTs were enrolled in the first year of their Master' education program.

Data Collection

Data collection instruments included a questionnaire applied to PSTs who were attending the second year of their program, concerning their perceptions about the ILE. These PSTs attended physics and chemics classes in CLab2, in the first year, and biology classes in CLab1, in the second year of their program. The questionnaire was applied at the end of the biology classes of the second year.

The six PSTs enrolled in a master's degree program were engaged in a focus-group interview. Open-ended questions included in a semi-structured interview protocol focused on preservice teacher vision about: (a) the ILE attributes; (b) the impact of ILE attributes on their interest in learning science; (c) the impact of ILE attributes on the development of pedagogical knowledge, specifically on their ability to create OER for science teaching.

Data Analysis

Each PST was anonymized using a number (PST1 to PST31). Through a post-categorization of participants' responses, a qualitative analysis of these data was done using a coding process (Fraenkel et al., 2012). Participants' sentences were the unit of analysis. From the coding process, four main categories emerged: "Environmental attributes", "Physical attributes", "Impact on PSTs performance" and "Pedagogical impact". Subcategories of each main category were also extracted for a more in-depth analysis of students' qualitative answers. The subcategories were quantified. Excerpts from text-based responses were used to further support the analysis whenever necessary.

RESULTS

CreativeLab_Sci&Math spaces and attributes

Table 2 presents the PSTs perceptions about the CLab spaces.

Table 2

Categorisation of PSTs perceptions about the CLab spaces.

Categories	Subcategories	Frequency (n= 25)
Environmental attributes	Global positive appreciation	10
	Natural light	2
	Adequate temperature	2
	Colour	1
Physical attributes	ILE Layout	7
	Large space	4
	Comfort	2
Impact on PSTs performance	Facilitates learning	8
	Implement laboratorial activities with security	1
	Furniture	2
Pedagogical impact	Diversity of resources	10
	Interaction between students and teacher	2

Results show that 40% of the PSTs have a global positive appreciation of the environmental attributes of the CLab spaces. For instance, PST12 considered that "it is a good, dynamic and welcoming workspace". Some of the features appreciated by the PSTs were the natural light, temperature and color, such as in this example: "The CreativeLab_Sci&Math (…) has a lot of natural light and a good environmental temperature (PST9)". Another student mentioned that it is a "colorful and pleasant space "(PST 16).

About the physical attributes, two PSTs mentioned that the space provides the necessary comfort for their science work. For instance, PST4 mentioned "It's a well-structured environment. By having elevated work surfaces, we can perform the tasks with more comfort and space". Some students (n=4) appreciated the size of the space, such as PST21: “It's a large space where you can do a lot of practical activities”. The CLab layout was valued by seven PST, as exemplified by the PST25 words: “The CreativeLab_Sci&Math is a room with several spaces that favours the implementation of different phases of the lesson. It's a very dynamic space that allows us to do different activities without having to go to another space".

Concerning the impact on PSTs performance, many PSTs (n=8) considered that the CLab facilitates their learning. The participant quoted below, for example, mentioned:

> It's an environment that facilitates learning in a laboratory, which I find quite interesting because by conducting experiments we understand the subject better and learning occurs in a more dynamic way (PST 15).

However, the furniture, namely the chairs (see area 2, in Figure 1), were criticized by two students because “were quite small and difficult taking notes of the class” (PST24). One student appreciated the security of the space, saying that is "a space in which we can safely conduct experiments" (PST5).

Regarding the pedagogical impact, two PSTs valued the “good interaction between the students and the teacher” favored by the CLab. Another aspect pointed out by several PSTs (n=10) was the variety of the resources in the CLab: “In CreativeLab_Sci&Math are available several innovative resources that allow a better understanding of contents” (PST2).

The second group of preservice teachers’ participants in the study (PST26-31) answered similar questions, during the focus-group interview. They all emphasized that CLab physical and environmental attributes provided the best learning experience. The acoustic quality of the spaces was pointed out as the least satisfactory attribute, especially in the moments when a teacher is presenting something on the board. On the other hand, the fact that the space was large allows easier group work, as they were able to listen to their colleagues better. Visibility, similarly, was one of the least satisfactory attributes. For instance, PSTs referred that some shelves reduce the visibility of seats from the back of the room to the board. Lastly, the third attribute not so satisfying for PSTs was related to software, particularly due to the Wi-Fi signal that sometimes is weak causing problems to download or upload documents.

Other CLab attributes (temperature, air quality, artificial lighting, daylight, furniture, room layout and hardware) were highly satisfactory for these participants. One PST referred several times as a strong point of the space its flexibility and the fact that facilitates mobility:

> the diversity of spaces also brings us some comfort not all of us feel good in the same places. For example, our group like to be on the benches by the window (…). So, it's really a matter of taste, it also turns out to be very beneficial for those who are studying and sometimes doing prolonged experiments to be able to be in a pleasant place, so the issue of disposition was great in terms of circulation. (PST31)

CreativeLab_Sci&Math impact on science learning and on production of OER

Most PSTs interviewed agreed that CLab ILEs enhance interest and learning in science. For one PST this is related to group work:

> the search for knowledge in the field of science is done in groups, with sharing; and if the space is not suitable for that, if we have a normal classroom (…) full of tables and chairs, sharing is not possible, because we need to be seated and to get up, you have to get everyone in the queue up. Therefore, a suitable space, well equipped ends up encouraging us, because we have material to experiment. (PST31)

Another PST has a different opinion on the subject. For PST29 the space itself does not influence her interest in science contents: "because I was already interested" even "in traditional laboratories". Yet, this student stressed that what really had an impact on her interest was working collaboratively in CLab ILEs. This idea, that the space is inseparable from the pedagogy that takes place there, is shared by all participants. For example, PST28 referred:

> we wish this [CLab] were the classrooms of the future because we could really motivate our students and we also feel motivated, there was no division between subjects, between content areas; (…) to be able to have this dynamic, connection and circulation of both students and teachers, as well as learning groups, therefore, for me it also makes perfect sense. (PST28)

PSTs believe that CLab ILEs facilitate teaching strategies promoting active learning; and give some examples of collaborative and interdisciplinary inquiry-based learning activities. The learning activities performed and/or developed in ILEs that PSTs described during the interview integrate science contents with other area (Mathematics, Language, History, etc.) in a technology enriched context. According to the PSTs, "room layout and different working areas facilitate the adoption of an interdisciplinary approach" (PST29).

This notion is also reinforced when PSTs were asked about the potential of ILEs for the development of their pedagogical knowledge. For PST31 "learning by example" has always been a priority in CLab otherwise "it would be useless to talk about interdisciplinarity if we don't see it happen". About this, PST29 added the importance of the presence of teachers of different content domains (e.g., Science and Mathematics):

> I don't remember other classes like that, in which there was more than one teacher in class (…), as happened in these laboratories. Without a doubt that it also contributed for us to learn new strategies, how to work with our colleagues in the future, how to work with children because teachers often worked with us as if we were the children, putting ourselves in the role of the student was also very important for us to have a different perspective. (PST29)

Moreover, PSTs discussed the importance OER production in these ILEs to develop their pedagogical knowledge and envision their future as teachers. PSTs' voices highlighted the common idea that CLab ILEs positively influence their pedagogical knowledge by supporting the production of OER. In fact, those spaces created the perfect opportunity, "given the different disposition, to talk to each other, to have new ideas and to be able to create these resources" (PST29). Regarding the design of OER, PST26 underlined the importance

> at the beginning of the process (…), to put ourselves in the child's shoes, 'will they understand it this way? what will be their interests?'. In other words, it's crucial to explain or build a resource thinking about the child, not only about what we intend to teach. It's all about putting the child in the central role. (PST26)

Several PSTs revealed no to be familiar with OER. For example, one PST referred that: "before attending classes in these spaces, I hardly knew any resources and I think it was an advantage for me to have explored several resources to later use them with children" (PST27). Another PST focused that "in today's society, with so many technological advances, it is essential for us to create resources and also be able to apply them in practice" (PST30). In addition to this, PSTs analysed the impact of the publication in online repositories (e.g., Casa das Ciências®) of the OER, with peer-review, and the fact that some of those resources have received awards. On this subject, PSTs acknowledged that it provided recognition and knowledge transferable to pedagogical practice. For instance, PST31 described being challenged by a teacher to publish an OER in Casa das Ciências®: "the fact that we have produced something that can be applied and shared with colleagues and teacher, this validates our work (…) and also we feel valued for what we produce". This PST considered that this experience made her more confident to develop pedagogical practice: "I know I can implement something because I have the ability to produce something that others have also explored and/or applied" (PST31). PST26 added that been awarded motivated her even more to continue developing OER.

Discussion

The findings presented in the previous sections suggest a global positive perception of the preservice teachers concerning the ILE CLab environmental and physical attributes, impact on their performance and pedagogical impact.

Concerning the environmental attributes, the natural light, temperature, and colours used in the space seems to have created a comfortable environment that predisposed students to do their tasks with a positive attitude. This is according to the ILE learning principle three (OECD, 2017) since the learning environment is highly attuned to the learners' motivations and the key role of emotions in achievement. Another favourable aspect is the fact that the CLab facilities are large. Each lab dimensions are 25m*8m*3m. This large working area allowed the organization of the ILE in different spaces that were quite appreciated by the students. They moved easily from space to space when necessary to do their tasks. The space also allowed collaborative work and an easy interaction between the teachers and the students, an aspect that was quite appreciated by some students. This feature is according to the ILE learning principle two (OECD, 2017), that stresses the social nature of learning and actively encourages well-organised co-operative learning in the learning environments. Borba et al. (2020) study also pointed out that an adequate physical space promotes collaboration. We think this collaborative work and interaction is favourable for science learning and can contribute to develop the PST 21st century learning skills, such as collaboration and communication. These are skills very important in scientific inquiry, but also in teachers work.

Many PSTs mentioned that the CLab features, and activities implemented in those spaces facilitated their learning. In fact, many activities implemented in the CLab were focused on the active participation of the students, structured in hands-on or inquiry digital activities, in which PSTs had to collaborate and use their critical thinking to solve it. However, some students complained about the furniture, namely the uncomfortable seats, a problem also reported in other studies (Clinton & Wilson, 2019; Yang et al., 2013). In fact, this is not a minor problem because students can spend most of their time inside the ILE seated, and therefore adequate seats and supports to take notes could improve a lot their comfort and positive perception of the ILE. Therefore, we agree with Yang et al. (2013) about the value of management, maintenance, and design of higher education classrooms.

Another aspect that deserves discussion are the resources available in the CLab and their impact on students' science learning. In fact, the CLab spaces have many laboratorial materials, but also technology, such as interactive boards, robots, and drones. These resources allowed the implementation of different science educational activities, that we believe were engaging for the PSTs and promoted the development of their science content knowledge. These results are similar to those reported by Brooks (2011), which suggests that technologically enhanced learning environments have a positive impact on student learning.

Regarding the production of OER, PSTs recognized CLab ILEs favoured this process and the development of their pedagogical knowledge. Furthermore, creating OER contribute to a deeper understanding of its benefits.

CONCLUSION

This study stresses that the ILE CreativeLab_Sci&Math prompted favourable PSTs' perceptions of the ILE environmental and physical features impact on their learning. PSTs also noticed pedagogical impacts, such as more resources available, and the fact that the ILE provided opportunities for students' collaboration, and a good interaction between students-teachers. Therefore, although taking in consideration that this is an exploratory study, we suggest that the transformation of classical laboratories into ILE could have a positive impact on students' science learning. Besides, we share Misra' (2014) point of view that nowadays it is an imperative to capacitate future teachers to maximize the benefits of OER in order to improve the learning process and, above all, to help their futures students to reach the highest potential. Overall, the study results demonstrated that ILEs contribute to the production of innovative OER, and reinforce Van Hallen and Katz (2020) recommendations to include OER in teacher training.

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Chapter 10

Spain

Learning communities in experiment-based science teaching: a case study

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Ever more schools are becoming Learning Communities that involve people from the immediate environment and carry out successful educational actions such as interactive groups. In this context, the intention of this research was to study how experimental science activities are worked with and whether they follow the guidelines of Science Didactics research. For this, a qualitative study was carried out in which a sample of 57 pupils from the CEIP Adriano del Valle infant and primary school (Sevilla, Spain) was observed when carrying out experimental activities while forming interactive groups. The data acquisition instruments were an observation grid and a field notebook. The data showed that the teaching which takes place in this school is very teacher centered. The teacher sets and carries out the experiment together with the group of volunteers from the community. Together with other aspects that are Far from the guidelines formulated in the research literature, no encouragement is given to the pupils to ask questions, form hypotheses, or search for possible answers. This study can be the starting point to foster a change in experiment-based science teaching through interactive groups.

Keywords: Learning Community, Experimental Activities in Science, Primary Education.

INTRODUCTION

Research in science teaching currently has many open lines. Nevertheless, there is a clear consensus about the need to face the difficulties that exist when proposing alternative proposals to the traditional way of teaching science (Rivero et al., 2017), as well as the failure these proposals generate.

The vast majority of primary Nature Sciences classes continue to be taught in a traditional and de-contextualized way (Godoy, Segura, & Di Mauro, 2014). Pupils learn that science is something that is hard and only within the reach of a few, and that it is normally too technical to be applicable to the real problems of everyday life.

For many years, numerous researchers have highlighted the failure of the traditional model of science teaching to help achieve learning at school. This model is too focused on de-contextualized conceptual content for the pupils to meaningfully process the information they get in Nature Sciences classes (De Las Heras & Jiménez, 2011). In this sense, the Didactics of Experimental Sciences is doing good work in deciphering how sciences are taught and learnt in class (García-Carmona, Cruz-Guzmán, & Criado, 2014).

Thus, there stands out the importance that Didactics gives to curiosity since it is understood to be the motor of learning. It suggests a scientific education that begins with pupils' curiosity about natural phenomena that they can perceive and inquire into by themselves in their immediate environment, and then moves towards educational approaches that are closer to the usual practice of science (Cañal et al., 2016).

The pupils' ideas also acquire great importance. Thus, it is essential that the teacher is interested in what their pupils think (Cope & Spendlow, 2015), that they know the child, and that they start from that prior knowledge (Del Pozo Asensio, 2017).

These prior ideas of pupils are defined by Jiménez Vicioso (2006) as a body of knowledge in a much broader sense than mere academic concepts, encompassing such aspects as their intuitions, life experiences, non-formal knowledge, etc.

From all of the above, it can be deduced that the starting point of any teaching and learning proposal must be to make the pupils' ideas about the subject explicit, since for them these are the most rational explanations (Cañal et al., 2016).

It is also important to refer to the approach to the teaching and learning process through inquiry in class. Numerous authors stress that the inquiry approach in class develops significant learning in pupils, increases the pleasure of learning, encourages motivation and curiosity, emphasizes the leading role of the pupil, and fosters a far more participatory classroom (Crujeiras-Pérez & Cambeiro, 2018; Cañal, Pozuelos & Travé, 2005).

But, in addition, one of the main recommendations made by Science Didactics is that experimental activities or experiences be included in the inquiries or research carried out in Primary Education classes. It is in these classrooms where more importance should be given to experiments than to master classes in which countless conceptual contents are expounded (Del Pozo Asensio, 2017).

These experimental activities or experiences that we are talking about have become an invaluable resource endorsed by the entire international community (Pérez Miguel, 2017). In addition, these types of activities guarantee the acquisition of conceptual content through doing experiments (Rudolph et al., 2016), albeit in a much more relaxed and participatory environment.

In summary, the lines of research enunciated by the Didactics of Experimental Sciences emphasize prior ideas, searches or inquiries done in school, and experimental activities, among other issues. In this sense, it is claimed that "it is very important that the classroom becomes a community in which most of the learning takes place through inquiry" (Friedl, 2000, p.13). In addition, these inquiries form the perfect framework for classes to be taught in which science content is addressed experimentally (Rudolph, Maturano, Soliveres & Perinez, 2016). Thus, the pupils will be able to enjoy a contextualized, investigative, experimental science that has real use (Valcárcel et al., 1990).

But in addition, it has been seen that this can be complemented with the participation of people from the immediate environment so as to come closer to science. In this sense, there are many schools that have decided to change their educational practices and place them within the framework of the communicative conception, with dialogue and interaction becoming key elements in learning. With this change, these schools intend to "open democratic spaces based on the participation of everyone; ultimately, they seek citizens' social inclusion" (Folgueiras, 2011, p.252).

By making this change, schools become a Learning Community in which the intention is for everyone in the environment to participate actively, and all the spaces and resources are reorganized so that this can put into practice (Flecha & García, 2007). More and more schools are deciding to open up to their communities and allow everyone's active participation in the pupils' teaching and learning processes from their immediate environment, taking advantage of all the knowledge and skills that individuals may have (Molina, 2015).

One of the most widespread practices in Learning Communities is that of the so-called Interactive Groups. This is a flexible way of organizing educational work in class to promote the pupils' maximum instrumental learning, working in solidarity and through dialogue of equals between the members of the group (Álvarez-Álvarez, 2016). This structuring of the classroom into interactive groups, with one volunteer per group, implies a dynamic of solving tasks through interaction and dialogue between all the members of the group (Peirats & López, 2013). Furthermore, numerous studies highlight the fact that these groups promote such values as cooperation, solidarity, empathy, and pacifism (Chocarro del Luis & Mollà, 2017).

The Interactive Groups which are defined in the following are successful educational actions that are carried out in Learning Communities: Four or five heterogeneous groups are established in class with a maximum of four or five male and female pupils, and one volunteer. Previously, the tutor has prepared the four or five different tasks that each group will be carrying out. The pupils rotate from group to group, so that, at the end of the session, everyone has completed the four or five proposed tasks. The same time is established for each of these tasks, with the tutor being the one who indicates the moment to change (Odina, Buitago & Alcalde, 2009, p.43).

These interactive groups usually last fifteen minutes, so that, in an hour of class, each group has carried out four activities while interacting with their classmates and with the four volunteers (Valls-Carol et al., 2014). In addition, this system is carried out every two weeks and is applicable to all the subjects taught at school (Odina et al., 2009).

The volunteers must be responsible for fostering equal interactions and dialogue between the members of the group. Although many may lack a high level of education, they can all enrich the interactions that take place in class (Álvarez-Álvarez, 2017).

Finally, it is important to highlight the fact that in the Interactive Groups the pupils understand that the whole group must progress and that knowledge can not be built individually. That is why numerous studies carried out point to Interactive Groups as being a very effective and inclusive form of grouping (Odina et al., 2009; Álvarez-Álvarez, 2017; Ordóñez-Sierra & Rodríguez-Gallego, 2016).

Given the above, the intention of the present research was to study the case of a school where the two issues converge, i.e., it is a school described as a Learning Community where science is worked on in interactive groups. The objective was to describe this situation and to show whether the premises dictated by science education research are being followed.

METHODS

Statement of the problem and objectives

This research arose from posing the following research problem:

How will the teaching and learning process of Science be approached in a Learning Community?

From this problem, the general objective of the investigation was established:

- Determine how Science is worked on in a school which is constituted as a Learning Community.
- Likewise, the following specific objectives were detailed:
- Determine what method is followed in the Sciences teaching and learning process.
- Identify the experimental activities carried out in the classes.
- Assess whether these experimental activities are in line with what Didactics of the Experimental Sciences research dictates.

Description of the research

In order to determine how the teaching of Experimental Sciences is approached in a school that is constituted as a Learning Community, a qualitative investigation (Rodríguez, Gil & García, 1996) was carried out whose information collection technique was mainly direct observation in the classes of the CEIP (infant and primary school) Adriano del Valle (Sevilla). This school was selected because it is constituted as a Learning Community, and because it usually stands out for introducing innovations in its classrooms.

Participant sample

The study took as referent the population of pupils enrolled in the Primary Education stage, specifically 57 pupils. From each class, a single, randomly selected, interactive group was observed.

Data acquisition instruments

The data acquisition instruments were an observation grid and a field notebook.

Observation grid: Observation was the main source of data acquisition. In this case, we are specifically referring to formal observation since it involved planning, the design of an instrument, and a certain time spent in the classrooms from first to sixth of Primary Education (Reis, 2011).

An observation grid was prepared consisting of 7 broad categories (Ideas, School Inquiry Phases, Objectives, Contents, Participation, Resources, Work Method). These were then divided into a total of 30 items to observe. Lastly, a column was added with the title "Examples of evidence" which allowed annotations to be collected regarding any of the items. This instrument was complemented with the incorporation of identification data of each class and each interactive group in particular.

The observations were carried out over two weeks, resulting in 27 observation records. These were subjected to a frequency analysis based on their dichotomous responses (Yes/No).

Field notebook: During the first week of the research, an observation was carried out with the specific objective of determining the type of method used in the classroom. This involved analysing the teacher's role, the pupils' role, the resources used, the type of activities, and the evaluation. Also added were all the observations that the researcher considered pertinent to elucidate the proposed objective.

RESULTS AND DISCUSSION

The results of the study and their discussion will be presented on the basis of the specific research objectives set out.

Determine what method is followed in the Sciences teaching and learning process

The data collected in the field notebook of all the courses in which the observation was carried out made it possible to verify that the Nature Sciences classes continue to use the traditional method. The same pattern is repeated from first to sixth of Primary Education – the teacher reads or explains the point from the book that corresponds to the day in question, and immediately afterwards the pupils carry out the activities found on the same pages. From this, the passive role of the pupils and the leading role of the teacher can be deduced. Likewise, the main resource used is the textbook, with pencil and paper activities that mainly consist of writing out completely one of the paragraphs that have been read or explained. The evaluation is finalist, consisting of repeating in an exam the theoretical content that had been worked on in the class. In accordance with García (2000), all these aspects come together for the method used in the Science classes of this school to be considered eminently traditional. This is not in line with current scientific evidence, which also indicates that the traditional model of science teaching is not really getting pupils to learn (García-Carmona et al., 2014).

Identify the experimental activities carried out in the classes

With respect to the experimental activities that are carried out in the interactive groups, it should be noted that they do not arise to respond to or work on the content, but rather have nothing to do with what is being worked on at that moment in class. Moreover, they are activities that had been chosen previously by the management team, and that are given to the teachers pre-prepared and with clear instructions on how to carry them out with the interactive groups. In addition, it was observed that neither do they have a classroom inquiry perspective (Cañal et al., 2016) nor involve true experimentation (Claxton, 2001).

The community volunteers are those who actually carry out the experimental activities in each interactive group. Although it is true that it is necessary to give the people of the community the opportunity to participate in the teaching and learning processes (Aubert et al., 2008), there are also numerous studies which insist that the person who teaches science must, among many other things, know how to teach science (Crujeiras-Pérez & Cambeiro, 2018; Cañal et al., 2013; Rivero et al., 2017; Jiménez Vicioso, 2003). The volunteers do not meet this requirement. Therefore, many of the discrepancies that will occur between how science is worked on in this school and how it should be worked on according to Didactics are rooted in the fact that, although these people are willing to help, they do not have enough science teaching background for anything truly rich to be created in these learning opportunities.

The experiments are conceived of as recreational activities that are only carried out during the seven days of one week. Also, in fact they will never be done again because they require an environment that is difficult to control. In this sense, it is true that these experimental activities can lead to a certain lack of order (Pujol, 2013). But it is also unquestionable that there has to be a break with the idea that, in order to learn, pupils need to arrange themselves in rows, where individual work is prioritized and where silence prevails above all else (Jiménez Vicioso, 2006).

In addition to this, the pupils only observe the experimental activity. After watching it, they form groups to respond to a prototype worksheet. Of all the questions on the worksheet, only those referring to the name of the experiment, the materials, and the steps to follow are answered. This is so because each interactive group only has 15 minutes to watch the activity and fill in the worksheet before rotating to the next experiment. They therefore ignore the two most fundamental questions included in the worksheet, namely: what happens and why it happens. These are the most important questions because it is in them that the ideas that pupils have regarding scientific phenomena appear explicitly (Rivero et al., 2017).

Assess whether these experimental activities are in line with what Didactics of the Experimental Sciences research dictates

To respond to this objective, the results extracted from the observation grid will be presented. Table 1 lists the percentages of positive or negative response to each of the items by category. (The total number of observations of all the groups observed was 27.)

Table 1

Percentage of responses to the items in the observation grid (taking into account that the total number of observations was 27).

Categories and Items		Response %	
		Yes	**No**
Ideas	1. The pupils' prior ideas are taken into account as the base	26	74
	2. They are taken into account before the experimental activity		
	3. They are taken into account during the experimental activity		
	4. They are taken into account at the end of the experimental activity		
School inquiry phases	5. Questions are raised that are of interest to the pupils in relation to their immediate context	11	89
	6. An exposition of the initial knowledge about the problem is produced	15	85
	7. The formulation of hypotheses and/or inquiry questions is encouraged	4	96
	8. Discussion and agreement on the inquiry design takes place	0	100
	9. The development of the inquiry is carried out	0	100
	10. There is significant processing of the information obtained	0	100
	11. Conclusions are drawn	0	100
	12. Initial hypotheses are accepted or rejected	0	100
	13. New questions are raised in relation to the experimental activity carried out	30	70
	14. The results achieved are communicated	0	100
Objectives	15. Learning objectives are defined	0	100
	16. The activities are appropriate for the proposed objectives	96	4
	17. The pupils are aware of the objectives of the inquiry	11	89
Content	18. Conceptual content is worked on	100	0
	19. Procedural content is worked on	0	100
	20. Attitudinal content is worked on	0	100

Participation	21. The teacher designs the experimental activity	100	0
	22. The pupils design the experimental activity	0	100
	23. The teacher performs the experimental activity	100	0
	24. The pupils perform the experimental activity	0	100
Resources	25. Technologies are integrated into the experimental activity	0	100
	26. Resources are optimized	74	26
	27. These are everyday materials for the pupils	0	100
Method of working	28. The experimental activities are related to what is worked on in class	0	100
	29. The experimental activities are one-off and isolated in time	100	0
	30. A relation is made between what has been worked on and past learning	4	96

As can be seen, if one stops at the analysis of prior ideas, in 74% of the cases these are not taken into account compared to 26% in which they are. These results are not coherent with the importance that Didactics gives to pupils' prior ideas (Solís et al., 2016). For this reason, it is necessary that, in future educational practices, this situation is reversed so as to start from prior knowledge (Del Pozo Asensio, 2017).

Also, it is shown that, despite how important it is to work from the immediate environment (Cañal et al., 2016), this was rarely done (only in 11% of the cases). Neither is the approach of hypotheses and inquiry questions encouraged (only in 4% of the cases). This is very far from what La Cueva (2000) proposes. Moreover, despite the recommendations of science education researchers (Jiménez Vicioso, 2006; Cañal et al., 2016; Rivero et al., 2017), no type of inquiry takes place, and the phases of the classroom inquiry model are not taken into account. Nonetheless, in 30% of the situations observed, new questions are posed after the experimental activity.

With respect to the objectives, although these are set for each activity, there are no specific objectives for the pupils' learning since the experimental activities are designed without being immersed in any school inquiry process such as is suggested by some authors (Cañal et al., 2016).

With respect to the content, we can see that, while work is done on an infinity of conceptual contents, there is rarely any on procedures and attitudes. This is contrary to what is outlined in the literature as being of most importance, which is to give priority to the experiments (Del Pozo Asensio, 2017). In particular, too many conceptual contents do not guarantee more significant learning (De Las Heras & Jiménez, 2011), the best way for children to learn science is by doing procedural science (CAA, 2015), and what pupils learn experimentally is hard for them to forget (Sbarbati, 2015). This, among other things, is due to the fact that, although the pupils are carrying out an experimental activity, they only observe without actively participating in it. The teacher is the one who designs the experimental activity in 100% of the cases and, in the same way, is the one who executes it on all occasions. This empirical reality again conflicts with the importance given to the fact that the pupils themselves must agree on an inquiry design and carry out the corresponding experimental activities, as argued by many authors (Valcárcel et al., 1990; Jiménez Vicioso, 2006; Godoy et al., 2014; Cañal et al., 2016; Rivero et al., 2017) as well as set out in the Primary Education curriculum (CAA, 2015).

With regard to discussing the resources category, one observes that in 100% of the times ICTs are not used, even though they are available. This is relevant in that the curriculum (CAA, 2015) also includes them when scientific activities are to be carried out, affirming that the pupils' learning process is much enriched when they are used. In addition, Didactics research also adds that these ICTs can be used to include numerous scientific procedures which could not be worked on otherwise.

With respect to resource optimization, 74% of the cases tried to make all the materials employed be reusable. Much effort is being put into this since we find ourselves in a vulnerable socioeconomic context in which resource optimization cannot be ignored (Aubert et al., 2008). Indeed, in 100% of the situations, the materials were everyday items and within the pupils' reach, requiring no major financial outlay. This is important since it helps to contextualize science (De Las Heras & Jiménez, 2011; Cañal et al., 2016). Neither does it make experimentation in class dependent on the families' economic level (Aubert et al., 2008).

With respect to the method of working, in 100% of the cases, the experimental activities have no relation with what is worked on daily in class. Likewise, in 96% of the cases the experimental activity is unrelated to previous learning. In addition, the experiments are conceived of as something playful which are only carried out during one week in the year. This prevents them from serving to strengthen the acquisition of conceptual content (Rudolph et al., 2016) and from making learning be more meaningful (Cañal et al., 2016).

CONCLUSIONS

Similarly to how the results have been presented taking the research objectives as a framework, the conclusions will also be presented along the same lines.

With respect to the specific objective that referred to determining what method is followed in science teaching and learning in the school studied, we were able to conclude that it continues to be traditional throughout the Primary Education stage. This is despite the recommendations of numerous authors who insist that ineffective patterns that fail to produce the expected effect should not continue to be reproduced (Aubert et al., 2009; Vázquez-Bernal et al., 2007), and that it is necessary to look for alternatives to traditional teaching (Rivero et al., 2017). As was noted above, these Nature Sciences classes are based on reading or the teacher's explanation, and subsequently completing a series of activities that consist in copying literally a series of fragments of the text that has been read or explained.

With regard to the specific objective of identifying the experimental activities that are carried out in the classes, the conclusion was that these were conveyed to the teachers already prepared and with clear instructions on how to carry them out with the interactive groups. This implies that these experimental activities are done in isolation. and that they are not framed within the widely defended perspective of classroom inquiry (Cañal et al., 2016). Neither do they involve true experimentation (Claxton, 2001).

In relation to assessing whether the experimental activities are in line with the reference framework of Science Didactics, it was found that they do not follow the indications set forth in the scientific literature since the pupils' ideas are usually not taken into account. Not all the phases of a school inquiry are carried out, the teacher or volunteer does the design of the experiment and its execution, and the volunteer has no training in Science Didactics. All these results are unrelated to the facts that prior ideas are of great interest (Solís et al., 2016) and should be regarded as the starting point of any proposal (Cañal et al., 2016), that it is necessary for the pupils to agree on the experimental design and for them to carry it out (Rivero et al., 2017), and that teaching science requires a person to guide the process, a guide who must know science and have notions about how to teach it (Crujeiras-Pérez & Cambeiro, 2018; Cañal et al., 2013; Jiménez Vicioso, 2003).

In addition, it has been shown that the experimental activities are not framed from an investigative perspective, but are relegated to one-off game-type activities, without any connection with previous learning or with what is already being worked on in class.

Nonetheless, despite these results and taking into account the limitations that any research investigation presents, the present study is novel in that it combines Learning Communities with the teaching of Nature Sciences since there have been no antecedents on this topic in the scientific literature.

Therefore, a new line of research has been opened that may have a major trajectory in the future, seeking, on the one hand, the contextualization of science teaching by integrating people from the immediate environment and, on the other, to implement their training within the framework presented by Science Didactics research, with the idea of achieving an improvement in pupils' scientific literacy.

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