EDUCATION FOR SUSTAINABLE DEVELOPMENT: CONTRIBUTIONS TO A SCIENCE CURRICULUM FOR PRIMARY EDUCATION

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Abstract

The Declaration of the Decade of Education for Sustainable Development gives an important role to education in helping solve the situation of planetary emergency that humanity faces. In Education for Sustainable Development (ESD), Scientific Literacy (SL) was established as one of the contributions that stimulates the understanding of current issues and problems, so that responsible decisions, although justified in the present time, will not undermine the future. Therefore, education in science should also be directed towards the promotion of SL since early school years. It is not easy to define what a scientific literate is. It is also difficult to say how the formal teaching and learning of science in the first school years can help develop skills that will allow justified actions without compromising the future, in a democratic society characterized by the prevalence of scientific and technological developments occurring in a vertiginous pace, with implications for personal life, society and even the planet.

Despite its diversity, the design of programme (as a part of curriculum) proposed to promote SL includes the intention to develop and disseminate the practical teaching and learning of science, ground-breaking and suitable for contemporary demands. These programmes share some questions that can be systematized as follows: i) learn what? ii) how? iii) what are the challenges to teachers?

Considering this issue we state a view of SL set out in a programme design framed by the principles of ESD and the guidelines Science / Technology / Society (STS). The programme contains theoretical reference elements organized into four distinct levels: dimensions, components, parameters and indicators. They are organized from broader and more general (dimensions) to narrower and more specific levels (indicators). In each dimension there are different components that allow its characterization. Each component is clarified through its development into several parameters and the latter are specified through the definition of several indicators.

We selected three dimensions: ESD, SL, and STS. The selection of these dimensions resulted from: i) recognizing the importance of directing the teaching and learning process towards an ESD perspective from early school years; ii) the importance attached to SL in achieving that purpose; iii) the conviction that STS orientation programmes can shape of a more adequate vision of science and scientific activity, as well as an involvement based in the discussion of scientific and technological problems with critical thinking, sense of responsibility and solidarity. We chose to establish a hierarchy for these dimensions: ESD being the most comprehensive (our primary goal), followed by SL (as a means to achieve our goal) and finally STS. We defined three components for the ESD dimension: environmental, social and economic issues; for the SL dimension we also established three components: scientific knowledge, skills and attitudes, and for STS we established two components: guidelines for science teaching in contexts and the implications of the interconnections between science and technology in society and vice-versa. In each component there are several parameters and the indicators defined for each parameter are as objective as possible. All distinct levels (dimensions, components, parameters and indicators) will be presented in tables and justified.

Keywords: Education for Sustainable Development (ESD), Scientific Literacy (SL), Science /Technology / Society (STS), Programme Design.

1 INTRODUCTION

The Declaration of the Decade of Education for Sustainable Development (2005 – 2014) gives an important role to education in helping solve the situation of planetary emergency that humanity faces. In Education for Sustainable Development (ESD), Scientific Literacy (SL) was established as one of the contributions that stimulate the understanding of current issues and problems, so that responsible

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decisions, justified in the present time, will not undermine the future. Therefore education in science should also be directed towards the promotion of SL from early school years

Considering this issue we state a view of SL set out in a programme (as a part of curriculum) design framed by the principles of ESD and the guidelines Science / Technology / Society (STS). The programme contains theoretical reference elements organized into four distinct levels: dimensions, components, parameters and indicators. They are organized from broader and more general (dimensions) to narrower and more specific levels (indicators). In each dimension there are different components that allow its characterization. Each component is clarified through its development into several parameters and the latter are specified through the definition of several indicators.

We chose to establish a hierarchy for these dimensions, ESD being the most comprehensive, followed by SL and, finally, STS. Our goal is to start teaching science with ESD referentials in early school years. That was the reason why the ESD dimension was considered to be the most comprehensive, thus becoming the structuring axis directing the learning of science during the mentioned school level. SL and STS dimensions were defined in a later stage and they were intentionally articulated, both among themselves and in relation to the ESD dimension (responsible for integrating and globalizing the organization of re-conceptualizations concerning different scientific, attitudinal and valorizing knowledge).

We now present the conceptual principles that justify the importance of building a science programme suitable for early school years and we also present the analysis categories, arranged according to tables, which sustain the latter construction of the programme, meant to be innovative and adequate for the current planetary emergency situation.

2 GUIDELINES FOR A PROGRAMME PROPOSAL OF SCIENCE EDUCATION IN EARLY SCHOOL YEARS, WITH ESD REFERENTIALS

According to UNESCO [1] guidelines, ESD must detain a high quality, be holistic and oriented by democratic values and principles, aiming for the promotion of a responsible citizenship, aware of the planetary emergency situation we currently face, respecting our limits of the planet and taking responsibility for all living beings. In that sense, it must consider the complexity of interactions established between the environment, society and economy, which are essential to sustainability [2].
Several problems connected to the teaching of science can explain the lack of interest for this area and the selection of different academic and professional trajectories, as well as poor student results, state that the European Union "should invest significantly in research and development in assessment in science education. The aim should be to develop items and methods that assess the skills, knowledge and competencies expected of a scientifically literate citizen" [3] (p. 9). The European Comission [4], mentions the unsettling decrease interest of youth towards sciences, with serious repercussions in european development and progress: "Europe's longer term capacity to innovate and the quality of its research will also decline. Furthermore, among the population in general, the acquisition of skills that are becoming essential in all walks of life, in a society increasingly dependent on the use of knowledge, is also under increasing threat" (p.2). Attaining such goals implies a need for change in several domains: curricular, evaluation, resources, initial and ongoing teacher training. We selected the programme because we consider it to be fundamental as a basal structure in the process of teaching and learning. Multiple as they may be, all proposals for a programme conception oriented towards the promotion of sustainability include the development of SL and the intention of developing ground-breaking practices for the teaching and learning of sciences, addressing current demands. Additionally, several studies have revealed that, from an early age, children are predisposed to learn science.

3 DESIGNING AN EDUCATION FOR A SUSTAINABLE DEVELOPMENT PROGRAMME

The analysis categories are arranged in tables and sustaining the subsequent construction of a programme both innovative and suitable for the current planetary emergency situation, derived from a construction - selection inductive process which led us to the operational concept. This concept was empirically built, based on the scientific knowledge developed by science didactics experts. The construction of the operational concept therefore began with the pursuit of the main ideas to retain, in other words, the different directions analysis will assume. These main ideas, or previous theoretical referents, established the broader and more comprehensive analysis categories we called dimensions. After the analysis dimensions were found (initial categories), we defined the components for each analysis dimension and we clarified the parameters for each component in each analysis dimension (intermediate categories). Finally, each parameter was clarified in the analysis indicators (final categories). All distinct levels (dimensions, components, parameters and indicators), presented in the tables were validated by experts in education.

3.1 The education for a sustainable development dimension

The dimension ESD, being the most comprehensive (our primary goal), is considered at all times: in content selection (multi, trans and inter disciplinary); in context selection for emerging concepts; in classroom strategy/activity selection; in scientific and technological comprehension of problems and their impact in the social, environmental, economic and ethical order; in developing certain skills, aptitudes and values (respect, cooperation, solidarity); in reinforcing democratic values and processes of participation (questioning, debating ideas, managing conflicts, voting, dialoging, reaching consensus). “Environment”, “Society” and “Economy” were the components we selected to clarify our understanding of the ESD dimension. Each component was subsequently defined based on the definition of parameters representing ESD relevant and problematic contexts in early school years, and each parameter was clarified in indicators (tables 1, 2 and 3).

Dimension 1 - Education for Sustainable Development (ESD)		
Components	**Parameters**	**Indicators**
1.1 Environmental	**1.1.1 Human activity on the planet** Promotes the understanding behind the need to (re)consider attitudes, behaviors and values concerning the Earth, bearing in mind the finite nature of its resources and space.	**A** Recognizing the improvement of life conditions: agriculture, medicine, basic sanitation **B** Identifying problems related to anthropic pressure resulting from demographic growth and asymmetrical population distribution **C** Identifying inadequate actions performed by human beings on a daily basis that impact renewable and non-renewable resources **D** Valuing the significance of control measures in agricultural and industrial activity and in the destruction of toxic materials/residues **E** Valuing measures for the preservation of terrestrial, aerial and landscape heritage **F** Recognizing the increase of greenhouse effect gases, the ozone layer degradation, climatic changes and global warming **G** Valuing natural energy resources as a way of minimizing the depletion of fossil resources, the production of acid rain and the degradation of soils **H** Identifying environmental degradation resulting from war and weaponry **I** Getting involved in the search for solutions regarding real local, regional and global environmental issues
	1.1.2 Biodiversity, natural and landscape heritage Increases the knowledge that ecosystems and their interdependencies sustain all life on earth.	**A** Identifying the causes and the effects of species extinction **B** Identifying interactions and interdependences between ecosystems **C** Recognizing correlations between demographic growth and the loss of species **D** Recognizing correlations between deforestation and the loss of species. **E** Recognizing correlations between diseases and the loss of species **F** Recognizing that human survival depends on animals and plants **G** Valuing international conventions and agreements regarding the protection of wild fauna and flora and the war against international trade of threatened species **H** Valuing the significance of potable water reduction: causes and consequences **I** Identifying the benefits and drawbacks concerning genetic manipulation of food **J** Valuing natural and landscape heritage as a contribution for the equilibrium of ecosystems

Table 1. ESD dimension – Environmental component: parameters and indicators

Dimension 1 - Education for Sustainable Development (ESD)		
Components	**Parameters**	**Indicators**
1.2 Economic	**1.2.1 Economic growth and the situation of planetary emergency** Increases the understanding of correlations established between the prosperity of a small number of countries, the extreme poverty of other countries and the situation of planetary emergency.	**A** Recognizing the improvement of human life conditions on the planet, stemming from economic growth **B** Recognizing the consequences in the life of some populations conditions stemming from discrepancies between countries on a global scale **C** Identifying the causes and consequences of excessive economic resource exploitation **D** Valuing the creation and implementation of control measures for economic growth sustainability **E** Valuing the development of scientific and technological investigation focused on sustainability

Table 2. ESD dimension – Economic component: parameters and indicators

Dimension 1 - Education for Sustainable Development (ESD)		
Components	**Parameters**	**Indicators**
1.3 Social	**1.3.1 Individual and collective responsibility** Highlights the compromises assumed by each and every one in concrete actions (informed and substantiated), according to a logic of collective and shared responsibility in the promotion of sustainability.	**A** Valuing demographic stabilization **B** Valuing equity and a culture of peace **C** Recognizing the significance of creating biodiversity preservation mechanisms **D** Valuing education in the performance of a responsible citizenship **E** Recognizing the significance of individual actions for collective goals.
	1.3.2 Respect for difference Values the equality of different cultures and races, refusing all forms of racism and all ethnic, social, local and international barriers.	**A** Valuing the equality of rights between genders **B** Valuing respect for cultural differences **C** Valuing the decrease of intolerance, imposition and intercultural conflicts **D** Recognizing the significance of fighting cultural homogeny and its consequences **E** Recognizing the increase of demographic pressure, identity loss, racism and xenophobia in migratory flows **F** Promoting intra- and inter-generational solidarity and the respect for difference

Table 3. ESD dimension – Social component: parameters and indicators

3.2 The science literacy dimension

The different SL conceptualization proposals (an evolutional concept, considering it depends of social and economic contexts in each particular period of time) suggest several implications for the formal teaching and learning of science, concerning the knowledge and skills to create active participation in democratic societies, where the increase of scientific and technological developments, as well as their consequences, requires informed interventions that will not compromise the future. It is not easy to identify a particular set of knowledge and skills that allows us to proclaim that a certain individual possessing is scientifically knowledgeable. The question "what does holding SL mean?" involves such a high number of factors (considering the complexity of the concept itself) that it is practically impossible to give a complete answer. The SL concept is, therefore, extremely broad, is historically held, and still holds, several meanings. By defining this dimension we intend to designate the set of (re)conceptualizations we consider students should have when concluding the early school years, in order to develop widely varied skills, aptitudes, attitudes and values that will allow them to live and adequately intervene in a democratic society, characterized by the prevalence of scientific and technological developments, and to adapt themselves to its vertiginous development rhythm, to the implications in their lives, in society and in the planet. This learning should also allow them to continue their studies in science and stimulate them to continue their learning process all throughout their lives.

Despite the debate and controversy concerning what really is evaluated with the PISA tests, their results assume great relevance in our days, and the issues they evaluate are consistent with the goals of science programmes developed for early school years and promoting SL. In this study we assume the definition of PISA of SL: "the capacity to use scientific knowledge, to identify questions and to draw evidence - based conclusions in order to understand and help make decisions about the natural world and human interactions with it" [5]. The evaluation performed by these PISA tests falls upon: "Knowledge", "Skills" and "Attitudes", perceived as [5]: i) "Knowledge – understanding the natural world based in scientific knowledge, including both the knowledge of the natural world and the knowledge concerning science itself"; ii) "Skills – includes identifying scientific questions, scientifically explaining phenomena and drawing conclusions based on data"; iii) "Attitudes – reveal interest in science, support scientific investigation and show motivation to act responsibly when dealing with, for instance, natural resources and the environment." Therefore, "Scientific knowledge", "Skills" and "Attitudes" were the components we selected to clarify our understanding of the SL dimension. The parameters and indicators of each component were defined after the science programmes analysis for the countries with the best PISA marks (generically the same for 2000, 2003, 2006 and 2009 cycles) and whose language was accessible for the authors was carried out (Finland, Australia, Canada, New Zealand, Ireland, England and Scotland). The components, parameters and indicators in this dimension (tables 4, 5 and 6) represent the set of (re)conceptualizations a student should have developed when concluding the early school years The selection of analysis categories we mentioned also considered the interconnections with "ESD" and "STS" dimensions. "STS" dimension is considered as a teaching orientation, so is always present in referred interconnections.

Dimension 2 - Scientific Literacy (SL)		
Components	**Parameters**	**Indicators**
2.1 Scientific Knowledge	**2.1.1 Planet Earth** Potentiates useful and functional (re)conceptualizations concerning the shape, structure, position, resources of the Earth and atmosphere, in different daily contexts and in a planetary scale.	**A** Understanding the structure and shape of the Earth **B** Establishing the distinction between stars and planets **C** Understanding the solar system **D** Orienting oneself on Earth using cardinal points and stars **E** Identifying sources of natural and artificial light **F** Understanding the formation of shades **G** Understanding the formation of lunar phases **H** Describing the succession of days and nights **I** Understanding the seasons of the year **J** Establishing the distinction between renewable and non-renewable resources **K** Recognizing the existence of air **L** Recognizing the existence of the ozone layer **M** Describing the carbon cycle **N** Describing the greenhouse effect **O** Describing earthquake and volcano formation
	2.1.2 Diversity of living being on Earth Potentiates (re)conceptualizations concerning the diversity of living beings that can be both useful and functional for the preservation of species.	**A** Understanding the constitution and functioning of the human body. **B** Describing changes that occur with growth and age **C** Identifying different living beings **D** Understanding common vital processes in different beings **E** Describing healthy habits and lifestyles **F** Recognizing types of genetic manipulation **G** Understanding reproduction mechanisms in living beings and sexual education **H** Describing the food chain **I** Identifying interdependencies between species **J** Describing the reasons that justify the importance of species preservation
	2.1.3 Diversity of materials on Earth Potentiates (re)conceptualizations concerning the diversity of materials, their proprieties and the transformations they go through (naturally or by human action), with or without energy involvement. Enables the understanding of how science and technology contribute to improve the quality of life.	**A** Knowing materials with different origins **B** Describing different types of energy **C** Identifying physical and chemical properties of materials: heat and electric current conductivity and solubility **D** Recognizing magnetic properties in materials **E** Recognizing the importance of light and heat for living beings **F** Building simple battery-ran electrical circuits **G** Recognizing changes in the physical state and their reversibility **H** Describing the water cycle **I** Identifying float factors for materials, in water and other liquids **J** Recognizing the benefits of the IS unit usage and measuring different quantities

Table 4. SL dimension - Scientific knowledge component: parameters and indicators

<table>
<tr><th colspan="3">Dimension 2 - Scientific Literacy (SL)</th></tr>
<tr><th>Components</th><th>Parameters</th><th>Indicators</th></tr>
<tr><td rowspan="2">2.2 Skills</td><td>2.2.1 Scientific and technological knowledge and its impact on Earth

Increases the understanding of relationships established between the development of scientific and technological knowledge and the differences observed in the modern lifestyles society, encouraging respect towards the planet, the others, and following an ethic of shared responsibility.</td><td>A Understanding environmental consequences stemming from the transformation of materials
B Describing factors that lead to the depletion of resources
C Recognizing the importance of saving energy
D Describing environmental impacts resulting from lifestyles
E Recognizing different types of air and water contamination
F Identifying human actions that impact the Earth
G Measuring one’s ecological footprint
H Describing the Earths activity over itself: erosion, earthquakes and hurricanes, in some cases resulting from human activity
I Valuing natural and cultural heritage
J Recognizing each and everyone’s responsibility in preserving the planet</td></tr>
<tr><td>2.2.2 Scientific and technological knowledge and its impact on living beings.

Increases the understanding of the implications behind the development of scientific and technological knowledge for issues that are currently relevant and concern the life of different species; attaches responsibility to each (and every) individual and its own construction through life.</td><td>A Understanding the impact of demographical growth
B Recognizing the consequences of an asymmetrical demographic distribution
C Describing factors of human dependency from nature
D Recognizing the importance of health promoting behaviors
E Identifying access discrepancies to education, health and food
F Recognizing the impact of environmental problems in health
G Describing problems concerning the extinction of species
H Recognizing the importance of adopting suitable behaviors, involving others</td></tr>
</table>

Table 5. SL dimension – Skills component: parameters and indicators

Dimension 2 - Scientific Literacy (SL)		
Components	**Parameters**	**Indicators**
2.3 Attitudes	**2.3.1 Nature of science** Potentiates (re)constructions regarding the nature of science and scientific work.	**A** Recognizing that scientific knowledge is built in expert communities subjected to multiple factors (affective, cultural, economic, political...) **B** Recognizing scientific work as a product of methodological pluralism, human inference, imagination and creativity **C** Recognizing that both scientific knowledge construction and problem identification/recognition/formulation are oriented by previous knowledge **D** Recognizing that scientific knowledge is subject to change **E** Recognizing the utility of scientific knowledge **F** Describing the scientist in a humanized frame **G** Recognizing limits for scientific knowledge validity
	2.3.2 History of science and technology Promotes the comprehension of the evolution of science and technology, drawing attention to its utility and to historical details that render it interesting and special.	**A** Recognizing science and technology as different forms of knowledge when compared to others **B** Describing evolutionary aspects of scientific and technological knowledge **C** Describing the history of specific scientific content constructions and technological developments **D** Recognizing interactions between science and technology and human needs that led to scientific and technological knowledge (re)constructions **E** Knowing bibliographical data concerning certain scientists

Table 6. SL dimension – Attitude component: parameters and indicators

3.3 The Science /Technology/Society dimension

We can globally describe the world in which we live by the interconnections established between the broad range of scientific and technological knowledge, mainly developed from the latter half of the 20th century onwards, and all political, economic, social and environmental changes these interconnections imply. Guiding the education of science with a humanistic, global and less fragmented point of view, and also by potentially preparing students for a better comprehension of the World and the interconnections of scientific and technological knowledge in society has become an asset for the teaching and learning of science [6]. STS guidelines for science teaching reflect the dialog between different scientific fields, namely between natural sciences and social and human sciences, as they highlight the social significance of the knowledge set forth by science and technology which, at the same time, provides a better understanding of the natural world and represents an essential instrument for its transformation [7]. Studies carried out in different countries in order to understand the impact of STS guidelines in teaching revealed a general attitude improvement from the students regarding science, and showed that the comprehension of scientific ideas development is equivalent to the one observed in traditional approaches [8]. In the STS dimension we designate two components: “guidelines for science teaching in contexts” and “the implications of the interconnections between science and technology in society and vice-versa”. All the parameters, components and indicators representing guidelines for science education are shown in Tables 7 and 8.

Dimension 3 - Science/Technology/Society (STS)		
Components	**Parameters**	**Indicators**
3.1 Guidelines for science teaching in contexts	**3.1.1 Context approaches** Highlights the analysis of key-issues: familiar to the students; socially relevant; technological; ethical; environmental; in emerging problematic situations; leading to participation of students in problem solving tasks; opened and increasing one's conceptual, processual and attitudinal knowledge; with access to methodological pluralism.	**A** Valuing scientific and technological knowledge in the global understanding of the world **B** Recognizing the importance of different scientific and technological knowledge intersections in understanding the multiple dimensions that constitute each problem **C** Identifying and formulating problems **D** Selecting scientific and technological knowledge when solving problems **E** Approaching different problem solving strategies **F** Promoting team work, cooperation and mutual help **G** Developing practical, laboratorial, experimental and investigational activities **H** Promoting oral and written communication **I** Accessing different sources of information **J** Reflecting about publicity and scientific divulgation papers **K**. Reflecting about the future implications of today's actions **L** Recognizing individual and collective responsibility in the preservation of our planet

Table 7. STS dimension - Guidelines for science teaching in contexts component: parameters and indicators

Dimension 3 - Science/Technology/Society (STS)		
Components	**Parameters**	**Indicators**
3.2 The implications of the interconnections between science and technology in society and vice-versa	**3.2.1 Science and technology in current life and reciprocally** Potentiates the knowledge of how the interconnections between science and technology influence changes in life conditions of people, the planet and in each other, reciprocally.	**A** Identifying reciprocate (re)constructions of science and technology **B** Understanding the history behind the construction of scientific concepts and technological developments **C** Recognizing humans needs fulfilled or created by science and technology **D** Recognizing that the scientific and technological developments depend on economical, political and cultural factors. **E** Identifying asymmetric life conditions amongst countries arising from discrepancies in scientific and technological developments **F** Recognizing the influence of society in science and technology, and reciprocally **G** Identifying problems where science and technology can play a solving role

Table 8. STS dimension - The implications of the interconnections between science and technology in society and vice-versa component: parameters and indicators

4 FINAL REMARKS

Considering the current situation, all across the globe, educational perspectives in general and science education in particular are oriented to the development of SL in primary education, envisioning the ESD. Programmes with ESD referentials, developing a ground-breaking SL oriented practice, support science knowledge (re)constructions, with an ever-increasing meaning, through the interpretation and reinterpretation of phenomena, based in models and theories, organizing interconnected conceptual structures that enable action in daily scenarios, articulating science education with values, ethical reflection and sense of responsibility, that can assure the sustainability of our planet.

The categories described, structuring the design of a science programme, were defined individually. Notwithstanding, they exist as a result of multiple interrelations, intentional joints, aimed at making the construction of the programme. So, there are several interconnections established between the mentioned levels of analysis, and some of them can assume priority over the others in certain moments, depending on the opportunity they represent.

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